PURIFICATION OF LABORATORY CHEMICALS

Fourth Edition

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Preface to the Fourth Edition

THE AIMS of the first three editions, to provide purification procedures of commercially available chemicals and biochemicals from published literature data, are continued in this fourth edition. Since the third edition in 1988 the number of new chemicals and biochemicals which have been added to most chemical and biochemical catalogues have increased enormously. Accordingly there is a need to increase the number of entries with more recent useful reagents and chemical and biochemical intermediates. With this in mind, together with the need to reorganise and update general purification procedures, particularly in the area of biological macromolecules, as well as the time lapse since the previous publication, this fourth edition of **Purification of Laboratory Chemicals** has been produced. Chapter 1 has been reorganised with some updating, and by using a smaller font it was kept to a reasonable number of pages. Chapters 2 and 5 were similarly altered and have been combined into one chapter. Eight hundred and three hundred and fifty entries have been added to Chapters 3 (25% increase) and 4 (44% increase) respectively, and four hundred entries (310% increase) were added to Chapter 5 (Chapter 6 in the Third Edition), making a total of 5700 entries; all resulting in an increase from 391 to 529 pages, i.e. by *ca* 35%.

Many references to the original literature have been included remembering that some of the best references happened to be in the older literature. Every effort has been made to provide the best references but this may not have been achieved in all cases. Standard abbreviations, listed on page 1, have been used throughout this edition to optimise space, except where no space advantage was achieved, in which cases the complete words have been written down to improve the flow of the sentences.

With the increasing facilities for information exchange, chemical, biochemical and equipment suppliers are making their catalogue information available on the Internet , e.g. Aldrich-Fluka-Sigma catalogue information is available on the World Wide Web by using the address http://www.sigma.sial.com, and GIBCO BRL catalogue information from http://www.lifetech.com, as well as on CD-ROMS which are regularly updated. Facility for enquiring about, ordering and paying for items is available *via* the Internet. CAS on-line can be accessed on the Internet, and CAS data is available now on CD-ROM. Also biosafety bill boards can similarly be obtained by sending SUBSCRIBE SAFETY John Doe at the address "listserv@uvmvm.uvm.edu", SUSCRIBE BIOSAFETY at the address "listserv@mitvma.mit.edu", and SUBSCRIBE RADSAF at the address "listserv@romulus.ehs.uiuc.edu"; and the Occupational, Health and Safety information (Australia) is available at the address "http://www.worksafe.gov.au/~wsa1". Sigma-Aldrich provide Material Safety data sheets on CD-ROMs.

It is with much sadness that Dr Douglas D. Perrin was unable to participate in the preparation of the present edition due to illness. His contributions towards the previous editions have been substantial, and his drive and tenacity have been greatly missed.

The Third Edition was prepared on an IBM-PC and the previous IBM files were converted into Macintosh files. These have now been reformatted on a Macintosh LC575 computer and all further data to complete the Fourth Edition were added to these files. The text was printed with a Hewlett-Packard 4MV -600dpi Laser Jet printer which gives a clearer resolution.

I thank my wife Dr Pauline M. Armarego, also an organic chemist, for the arduous and painstaking task of entering the new data into the respective files, and for the numerous hours of proofreading as well as the corrections of typographic errors in the files. I should be grateful to my readers for any comments, suggestions, amendments and criticisms which could, perhaps, be inserted in the second printing of this edition.

W.L.F. Armarego
30 June 1996

Preface to the First Edition

WE BELIEVE that a need exists for a book to help the chemist or biochemist who wishes to purify the reagents she or he uses. This need is emphasised by the previous lack of any satisfactory central source of references dealing with individual substances. Such a lack must undoubtedly have been a great deterrent to many busy research workers who have been left to decide whether to purify at all, to improvise possible methods, or to take a chance on finding, somewhere in the chemical literature, methods used by some previous investigators.

Although commercially available laboratory chemicals are usually satisfactory, as supplied, for most purposes m scientific and technological work, it is also true that for many applications further purification is essential.

With this thought in mind, the present volume sets out, firstly, to tabulate methods, taken from the literature, for purifying some thousands of individual commercially available chemicals. To help in applying this information, two chapters describe the more common processes currently used for purification in chemical laboratories and give fuller details of new methods which appear likely to find increasing application for the same purpose. Finally, for dealing with substances not separately listed, a chapter is included setting out the usual methods for purifying specific classes of compounds.

To keep this book to a convenient size, and bearing in mind that its most likely users will be laboratory-trained, we have omitted manipulative details with which they can be assumed to be familiar, and also detailed theoretical discussion. Both are readily available elsewhere, for example in Vogel's very useful book **Practical Organic Chemistry** (Longmans, London, 3rd ed., 1956), or Fieser's **Experiments in Organic Chemistry** (Heath, Boston, 3rd ed, 1957).

For the same reason, only limited mention is made of the kinds of impurities likely to be present, and of the tests for detecting them. In many cases, this information can be obtained readily from existing monographs.

By its nature, the present treatment is not exhaustive, nor do we claim that any of the methods taken from the literature are the best possible. Nevertheless, we feel that the information contained in this book is likely to be helpful to a wide range of laboratory workers, including physical and inorganic chemists, research students, biochemists, and biologists. We hope that it will also be of use, although perhaps to only a limited extent, to experienced organic chemists.

We are grateful to Professor A. Albert and Dr D.J. Brown for helpful comments on the manuscript.

D.D.P., W.L.F.A. & D.R.P.
1966

Preface to the Second Edition

SINCE the publication of the first edition of this book there have been major advances in purification procedures. Sensitive methods have been developed for the detection and elimination of progessively lower levels of impurities. Increasingly stringent requirements for reagent purity have gone hand-in-hand with developments in semiconductor technology, in the preparation of special alloys and in the isolation of highly biologically active substances. The need to eliminate trace impurities at the micro- and nanogram levels has placed greater emphasis on ultra purification technique. To meet these demands the range of purities of laboratory chemicals has become correspondingly extended. Purification of individual chemicals thus depends more and more critically on the answers to two questions -Purification from what, and to what permissible level of contamination. Where these questions can be specifically answered, suitable methods of purification can usually be devised.

Several periodicals devoted to ultra purification and separations have been started. These include "Progress in Separation and Purification" Ed. (vol. I) E.S. Perry, Wiley-Interscience, New York, vols. 1-4, 1968-1971, and **Separation and Purification Methods** Ed. E S.Perry and C.J.van Oss, Marcel Dekker, New York, vol. 1-, 1973-. Nevertheless, there still remains a broad area in which a general improvement in the level of purity of many compounds can be achieved by applying more or less conventional procedures. The need for a convenient source of information on methods of purifying available laboratory chemicals was indicated by the continuing demand for copies of this book even though it had been out of print for several years.

We have sought to revise and update this volume, deleting sections that have become more familiar or less important, and incorporating more topical material. The number of compounds in Chapters 3 and 1 have been increased appreciably. Also,

We take this opportunity to thank users of the first edition who pointed out errors and omissions, or otherwise suggested improvements or additional material that should be included. We are indebted to Mrs S.Schenk who emerged from retirement to type this manuscript.

D.D.P., W.L.F.A. & D.R.P.
1980

Preface to the Third Edition

THE CONTINUING demand for this monograph and the publisher's request that we prepare a new edition, are an indication that **Purification of Laboratory Chemicals** fills a gap in many chemists' reference libraries and laboratory shelves. The present volume is an updated edition which contains significantly more detail than the previous editions, as well as an increase in the number of individual entries and a new chapter.

Additions have been made to Chapters 1 and 2 in order to include more recent developments in techniques (e.g. Schlenk-type, *cf* p. 10), and chromatographic methods and materials. Chapter 3 still remains the core of the book, and lists in alphabetical order relevant information on *ca* 4000 organic compounds. Chapter 4 gives a smaller listing of *ca* 750 inorganic and metal-organic substances, and makes a total increase of ca 13% of individual entries in these two chapters. Some additions have also been made to Chapter 5.

We are currently witnessing a major development in the use of physical methods for purifying large molecules and macromolecules, especially of biological origin. Considerable developments in molecular biology are apparent in techniques for the isolation and purification of key biochemicals and substances of high molecular weight. In many cases something approaching homogeneity has been achieved, as evidenced by electrophoresis, immunological and other independent criteria. We have consequently included a new section, Chapter 6, where we list upwards of 100 biological substances to illustrate their current methods of purification. In this chapter the details have been kept to a minimum, but the relevant references have been included.

The lists of individual entries in Chapters 3 and 4 range in length from single line entries to *ca* one page or more for solvents such as acetonitrile, benzene, ethanol and methanol. Some entries include information such as likely contaminants and storage conditions. More data referring to physical properties have been inserted for most entries [i.e. melting and boiling points, refractive indexes, densities, specific optical rotations (where applicable) and UV absorption data]. Inclusion of molecular weights should be useful when deciding on the quantities of reagents needed to carry out relevant synthetic reactions, or preparing analytical solutions. The Chemical Abstracts registry numbers have also been inserted for almost all entries, and should assist in the precise identification of the substances.

In the past ten years laboratory workers have become increasingly conscious of safety in the laboratory environment. We have therefore in three places in Chapter 1 (pp. 3 and 33, and bibliography p. 52) stressed more strongly the importance of safety in the laboratory. Also, where possible, in Chapters 3 and 4 we draw attention to the dangers involved with the manipulation of some hazardous substances.

The world wide facilities for retrieving chemical information provided by the Chemical Abstract Service (CAS on-line) have made it a relatively easy matter to obtain CAS registry numbers of substances, and most of the numbers in this monograph were obtained *via* CAS on-line. We should point out that two other available useful files are CSCHEM and CSCORP which provide, respectively, information on chemicals (and chemical products) and addresses and telephone numbers of the main branch offices of chemical suppliers.

The present edition has been produced on an IBM PC and a Laser Jet printer using the **Microsoft Word (4.0)** word-processing program with a set stylesheet. This has allowed the use of a variety of fonts and font sizes which has made the presentation more attractive than in the previous edition. Also, by altering the format and increasing slightly the sizes of the pages, the length of the monograph has been reduced from 568 to 391 pages. The reduction in the number of pages has been achieved in spite of the increase of *ca* 15% of total text.

We extend our gratitude to the readers whose suggestions have helped to improve the monograph, and to those who have told us of their experiences with some of the purifications stated in the previous editions, and in particular with the hazards that they have encountered. We are deeply indebted to Dr M.D. Fenn for the several hours that he has spent on the terminal to provide us with a large number of CAS registry numbers.

This monograph could not have been produced without the expert assistance of Mr David Clarke who has spent many hours to load the necessary fonts in the computer, and for advising one of the authors (W.L.F.A.) on how to use them together with the idiosyncrasies of Microsoft Word.

D.D.P. & W.L.F.A.
1988

CHAPTER 1

COMMON PHYSICAL TECHNIQUES USED IN PURIFICATION

GENERAL REMARKS

Purity is a matter of degree. Other than adventitious contaminants such as dust, paper fibres, wax, cork, etc., that may have been incorporated into the sample during manufacture, all commercially available chemical substances are in some measure impure. Any amounts of unreacted starting material, intermediates, by-products, isomers and related compounds may be present depending on the synthetic or isolation procedures used for preparing the substances. Inorganic reagents may deteriorate because of defective packaging (glued liners affected by sulphuric acid, zinc extracted from white rubber stoppers by ammonia), corrosion or prolonged storage. Organic molecules may undergo changes on storage. In extreme cases the container may be incorrectly labelled or, where compositions are given, they may be misleading or inaccurate for the proposed use. Where any doubt exists it is usual to check for impurities by appropriate spot tests, or by recourse to tables of physical or spectral properties such as the extensive infrared and NMR libraries published by the Aldrich Chemical Co. The important question, then, is not whether a substance is pure but whether a given sample is sufficiently pure for some intended purpose. That is, are the contaminants likely to interfere in the process or measurement that is to be studied. By suitable manipulation it is often possible to reduce levels of impurities to acceptable limits, but absolute purity is an ideal which, no matter how closely approached, can never be attained. A *negative* physical or chemical test indicates only that the amount of an impurity in a substance lies below a certain level; no test can demonstrate that a specified impurity is entirely absent.

When setting out to purify a laboratory chemical, it is desirable that the starting material is of the best grade commercially available. Particularly among organic solvents there is a range of qualities varying from *laboratory chemical* to *spectroscopic*, *chromatographic* and *electronic* grades. Many of these are suitable for use as received. With many of the commoner reagents it is possible to obtain from the current literature some indications of likely impurities, their probable concentrations and methods for detecting them. However, in many cases complete analyses are not given so that significant concentrations of unspecified impurities may be present. See for example *Reagent Chemicals* (American Chemical Society Specifications, 8th edn, 1992), the American Chemical Society for Testing Materials D56-36, D92-46, and national pharmacopoeias. Other useful sources include *Ashford's Dictionary of Industrial Chemicals*, R.D.Ashford, Wavelength Publications Ltd, 1995 and references on pp.44-47 and pp. 61-62. For purification of proteins, see for example R.K.Scopes, *Protein Purification*, Springer-Verlag, New York, 3rd edn, 1994, and for nucleic acids see for example T.A.Brown, *Essential Molecular Biology - A Practical Approach* (2 vols), Oxford University Press 1991.

Abbreviations

To save space the following abbreviations have been generally used in Chapters 3, 4 and 5: abs (absolute), anhyd (anhydrous), aq (aqueous), atm (atmospheric), crystd (crystallised), crystn (crystallisation), crysts (crystallises), dec (decomposes), dil (dilute), distd (distilled), distn (distillation), evap (evaporate), evapd (evaporated), evapn (evaporation), filtd (filtered), h (hour[s]), pet ether (petroleum ether, ligroin), ppte (precipitate), ppted (precipitated), pptn (precipitation), satd (saturated), soln (solution), TLC (thin layer chromatography), HPLC (high pressure liquid chromatography), vac (vacuum), vol (volume). Other abbreviations used occasionally are self evident in meaning.

The following journals are designated by their initials:

Annalen Chem.	*A*	*J.Chem.Soc.Farad.Trans.*	*JCSFT*
Analyt.Biochem	*AB*	*J.Heterocyclic Chem.*	*JHC*
Anal.Chem.	*AC*	*J.Chromatography*	*JC*
Ber.deut.Chem.Ges. or Chem.Ber.	*B*	*J.IndianChem.Soc.*	*JICS*
Biochem.J.	*BJ*	*J.Inorg.Nucl.Chem.*	*JINC*
Biochem.Biophys.Res.Commun.	*BBRC*	*J.Org.Chem.*	*JOC*
Brit.J.Pharmacol.	*BJP*	*J.Phys.Chem.*	*JPC*
Bull.Acad.Sci.USSR	*BASU*	*Monatsh Chemie*	*M*
Helv.Chim.Acta	*HCA*	*Pure Appl.Chem.*	*PAC*
Fed.Eur.Biochem.Soc.Letters	*FEBS LETT*	*Synthesis*	*S*
Ind.Eng.Chem.(Anal.Ed.)	*IECAE*	*Synth.Commun.*	*SC*
J.Am.Chem.Soc.	*JACS*	*Tetrahedron*	*TET*
J.Biol.Chem.	*JBC*	*Tetrahedron Letters*	*TET LETT*
J.Chem.Phys.	*JCP*	*Trans.Faraday Soc.*	*TFS*
J.Chem.Soc.	*JCS*	*Zhur.Org.Khimii*	*ZOK*
J.Chem.Soc.Chem.Commun.	*JCSCC*	*Z.Physik.Chem.*	*ZPC*
J.Chem.Soc.Dalton Trans.	*JCSDT*		

Abbreviations of periodicals not included in this list are written in such a way that the periodical can be readily identified, e.g. *Acta Chem Scand* for Acta Chemica Scandinavica.

Purity of Substances

Solvents and substances that are specified as *pure* for a particular purpose may, in fact, be quite impure for other uses. Absolute ethanol may contain traces of benzene, which makes it unsuitable for ultraviolet spectroscopy, or plasticizers which make it unsuitable for use in solvent extraction.

Irrespective of the grade of material to be purified, it is essential that some criteria exist for assessing the degree of purity of the final product. The more common of these include:

1. Examination of physical properties such as:
   (a) Melting point, freezing point, boiling point, and the freezing curve (i.e. the variation, with time, in the freezing point of a substance that is being slowly and continuously frozen).
   (b) Density.
   (c) Refractive index at a specified temperature and wave-length. The sodium D line at 589.26 nm (weighted mean of D_1 and D_2 lines) is the usual standard of wavelength but results from other wavelengths can often be interpolated from a plot of refractive index versus $1/(\text{wavelength})^2$.
   (d) Absorption spectra (ultraviolet, visible, infrared, and nuclear magnetic resonance).
   (e) Specific conductivity. (This can be used to detect, for example, water, salts, inorganic and organic acids and bases, in non-electrolytes).
   (f) Optical rotation, optical rotatory dispersion and circular dichroism.
   (g) Mass spectroscopy.

2. Empirical analysis, for C, H, N, ash, etc.

3. Chemical tests for particular types of impurities, e.g. for peroxides in aliphatic ethers (with acidified KI), or for water in solvents (quantitatively by the Karl Fischer method).

4. Physical tests for particular types of impurities:
   (a) Emission and atomic absorption spectroscopy for detecting and determining metal ions.
   (b) Chromatography, including paper, thin layer, liquid (high, medium and normal pressure) and vapour phase.
   (c) Electron spin resonance for detecting free radicals.
   (d) X-ray spectroscopy.

(e) Mass spectroscopy.
(f) Fluorimetry.

5. Electrochemical methods (see Chapter 5 for macromolecules).

6. Nuclear methods which include a variety of radioactive elements as in organic reagents, complexes or salts.

A substance is usually taken to be of an acceptable purity when the measured property is unchanged by further treatment (especially if it agrees with a recorded value). In general, at least two different methods, such as recrystallisation and distillation, should be used in order to ensure maximum purification. Crystallisation may be repeated (from the same solvent or better from different solvents) until the substance has a constant melting point or absorption spectrum, and until it distils repeatedly within a narrow, specified temperature range.

With liquids, the refractive index at a specified temperature and wavelength is a sensitive test of purity. Note however that this is sensitive to dissolved gasses such as O_2, N_2 or CO_2. Under favourable conditions, freezing curve studies are sensitive to impurity levels of as little as 0.001 moles per cent. Analogous fusion curve or heat capacity measurements can be up to ten times as sensitive as this. With these exceptions, most of the above methods are rather insensitive, especially if the impurities and the substances in which they occur are chemically similar. In some cases, even an impurity comprising many parts per million of a sample may escape detection.

The common methods of purification, discussed below, comprise distillation (including fractional distillation, distillation under reduced pressure, sublimation and steam distillation), crystallisation, extraction, chromatographic and other methods. In some cases, volatile and other impurities can be removed simply by heating. Impurities can also sometimes be eliminated by the formation of derivatives from which the purified material is regenerated.

Safety in the Chemical Laboratory

Although most of the manipulations involved in purifying laboratory chemicals are inherently safe, care is necessary if hazards are to be avoided in the chemical laboratory. In particular there are dangers inherent in the inhalation of vapours and absorption of liquids and low melting solids through the skin. To the toxicity of solvents must be added the risk of their flammability and the possibility of eye damage. Chemicals, particularly in admixture, may be explosive. Compounds may be carcinogenic or otherwise deleterious to health. Present day chemical catalogues specifically indicate the particular dangerous properties of the individual chemicals they list and these should be consulted whenever the use of commercially available chemicals is contemplated. Radioisotopic labelled compounds pose special problems of human exposure to them and of disposal of laboratory waste. Purchased chemicals are sometimes accompanied by detailed information regarding their toxicity, safety handling procedures and the necessary precautions to be taken. These should be read carefully.

The commonest hazards are:

(1) Explosions due to the presence of peroxides formed by aerial oxidation of ethers and tetrahydrofuran, decahydronaphthalene, acrylonitrile, styrene and related compounds.
(2) Compounds with low flash points (below room temperature). Examples are acetaldehyde, acetone, acetonitrile, benzene, carbon disulphide, cyclohexane, diethyl ether, ethyl acetate and *n*-hexane.
(3) Contact of oxidising agents ($KMnO_4$, $HClO_4$, chromic acid) with organic liquids.
(4) Toxic reactions with tissues.

For detailed discussion, see *Bretherick's Handbook of Reactive Chemical Hazards*, Butterworths, London, 1990, Sax's *Dangerous Properties of Industrial Materials*, 8th edn, van Nostrand Reinhold, NY 1992.

The laboratory should at least be well ventilated and safety glasses should be worn, particularly during distillation and manipulations carried out under reduced pressure or elevated temperatures. With this in mind we have endeavoured to warn users of this book whenever greater than usual care is needed in handling chemicals. As a general rule, however, **all chemicals which users are unfamiliar with should be treated with extreme care and assumed to be highly flammable and toxic.** The safety of others in a

laboratory should always be foremost in mind, with ample warning whenever a potentially hazardous operation is in progress. Also, unwanted solutions or solvents should never be disposed of *via* the laboratory sink. The operator should be aware of the usual means for disposal of chemicals in her/his laboratories and she/he should remove unwanted chemicals accordingly. **Never mix organic liquids for disposal in the same container, and always keep halogenated waste solvents for disposal separate from other liquids.**

Further aspects of safety are detailed on p.29.

Trace Impurities in Solvents

Some of the more obvious sources of contamination of solvents arise from storage in metal drums and plastic containers, and from contact with grease and screw caps. Many solvents contain water. Others have traces of acidic materials such as hydrochloric acid in chloroform. In both cases this leads to corrosion of the drum and contamination of the solvent by traces of metal ions, especially Fe^{3+}. Grease, for example on stopcocks of separating funnels and other apparatus, e.g. greased ground joints, is also likely to contaminate solvents during extractions and chemical manipulation.

A much more general source of contamination that has not received the consideration it merits comes from the use of plastics for tubing and containers. Plasticisers can readily be extracted by organic solvents from PVC and other plastics, so that most solvents, irrespective of their grade (including spectrograde and ultrapure) have been reported to contain 0.1 to 5ppm of plasticizer [de Zeeuw, Jonkman and van Mansvelt *AB* **67** 339 *1975*]. Where large quantities of solvent are used for extraction (particularly of small amounts of compounds), followed by evaporation, this can introduce significant amounts of impurity, even exceeding the weight of the genuine extract and giving rise to spurious peaks in gas chromatography (for example of fatty acid methyl esters, Pascaud, *AB* **18** 570 *1967*). Likely contaminants are di(2-ethylhexyl)phthalate and dibutyl phthalate, but upwards of 20 different phthalic esters are listed as plasticisers as well as adipates, azelates, phosphates, epoxides, polyesters, trimellitates, and various heterocyclic compounds. These plasticisers would enter the solvent during passage through plastic tubing or from storage in containers or from plastic coatings used in cap liners for bottles. Such contamination could arise at any point in the manufacture or distribution of a solvent. The trouble with cap liners is avoidable by using corks wrapped in aluminium foil, although even in this case care should be taken because aluminium foil can dissolve in some liquids e.g. benzylamine and propionic acid.

Solutions in contact with polyvinyl chloride can become contaminated with trace amounts of lead, titanium, tin, zinc, iron, magnesium or cadmium from additives used in the manufacture and moulding of PVC.

N-Phenyl-2-naphthylamine is a contaminant of solvents and biological materials that have been in contact with black rubber or neoprene (in which it is used as an antioxidant). Although it was only an artefact of the separation procedure it has been isolated as an apparent component of vitamin K preparations, extracts of plant lipids, algae, livers, butter, eye tissue and kidney tissue [Brown *Chemistry in Britain* **3** 524 *1967*].

Most of the above impurities can be removed by prior distillation of the solvent, but care should be taken to avoid plastic or black rubber as much as possible.

Cleaning Apparatus

Laboratory glassware and Teflon equipment can be cleaned satisfactorily for most purposes by treating initially with a solution of sodium dichromate in concentrated sulphuric acid, draining, and rinsing copiously with distilled water. Where traces of chromium (adsorbed on the glass) must be avoided, a 1:1 mixture of concentrated sulphuric and nitric acid is a useful alternative. (*Used in a fumehood to remove vapour and with adequate face protection.*) Acid washing is also suitable for polyethylene ware but prolonged contact (some weeks) leads to severe deterioration of the plastic. For much glassware, washing with hot detergent solution, using tap water, followed by rinsing with distilled water and acetone, and heating to 200-300° overnight, is adequate. (Volumetric apparatus should not be heated: after washing it is rinsed with acetone, then hexane, and air-dried. Prior to use, equipment can be rinsed with acetone, then with petroleum ether or hexane, to remove the last traces of contaminants.) Teflon equipment should be soaked, first in acetone, then in petroleum ether or hexane for ten minutes prior to use.

For trace metal analyses, prolonged soaking of equipment in 1M nitric acid may be needed to remove adsorbed metal ions.

Soxhlet thimbles and filter papers may contain traces of lipid-like materials. For manipulations with highly pure materials, as in trace-pesticide analysis, thimbles and filter papers should be thoroughly extracted with hexane before use.
Trace impurities in silica gel for TLC can be removed by heating at 300° for 16h or by Soxhlet extraction for 3h with redistilled chloroform, followed by 4h extraction with redistilled hexane.

Sililation of Glassware and Plasticware
Sililation of apparatus makes it repellant to water and hydrophilic materials. It minimises loss of solute by adsorption onto the walls of the container. The glassware is placed in a desiccator containing dichloromethyl silane (1ml) in a small beaker and evacuated from 5min. The vacuum is turned off and air is introduced into the desiccator which allows the sililating agent to coat the glassware uniformly. The desiccator is then evacuated, closed and set aside for 2h. The glassware is removed from the desiccator and baked at 180° for 2h before use.
Plasticware is treated similarly except that it is rinsed well with water before use instead of baking. Note that dichloromethyl silane is highly **TOXIC** and **VOLATILE**, and the whole operation should be carried out in an efficient fumecupboard.
An alternative procedure used for large apparatus is to rinse it with a 5% solution of dichloromethyl silane in chloroform, then rinse several times with water before baking at 180°/2h (for glass) or drying in air (for plasticware). REPEL-SILANE (a solution of 2% w/v of dichloromethyl silane in 1,1,1-trichloroethane) is available commercially (LKB, Sweden).

DISTILLATION

One of the most widely applicable and most commonly used methods of purification of liquids or low melting solids (especially of organic chemicals) is fractional distillation at atmospheric, or some lower, pressure. Almost without exception, this method can be assumed to be suitable for all organic liquids and most of the low-melting organic solids. For this reason it has been possible in Chapter 3 to omit many procedures for purification of organic chemicals when only a simple fractional distillation is involved - the suitability of such a procedure is implied from the boiling point.
The boiling point of a liquid varies with the atmospheric pressure to which it is exposed. A liquid boils when its vapour pressure is the same as the external pressure on its surface, its normal boiling point being the temperature at which its vapour pressure is equal to that of a standard atmosphere (760mm Hg). Lowering the external pressure lowers the boiling point. For most substances, boiling point and vapour pressure are related by an equation of the form,

$$\log p = A + B/(t + 273),$$

where p is the pressure, t is in °C, and A and B are constants. Hence, if the boiling points at two different pressures are known the boiling point at another pressure can be calculated from a simple plot of log p *versus* $1/(t + 273)$. For organic molecules that are not strongly associated, this equation can be written in the form,

$$\log p = 8.586 - 5.703\ (T + 273)/(t + 273)$$

where T is the boiling point in °C at 760mm Hg. Table 1 gives computed boiling points over a range of pressures. Some examples illustrate its application. Ethyl acetoacetate, **b** 180° (with decomposition) at 760mm Hg has a predicted **b** of 79° at 8mm; the experimental value is 78°. Similarly 2,4-diaminotoluene, **b** 292° at 760mm, has a predicted **b** of 147° at 8mm; the experimental value is 148-150°. For self-associated molecules the predicted **b** are lower than the experimental values. Thus, glycerol, **b** 290° at 760mm, has a predicted **b** of 168° at 8mm: the experimental value is 182°.
For pressures near 760mm, the change in boiling point is given approximately by [Crafts *B* **20** 709 *1887*],

$$\hat{I}t = a(760 - p)(t + 273)$$

where $a = 0.00012$ for most substances, but $a = 0.00010$ for water, alcohols, carboxylic acids and other associated liquids, and $a = 0.00014$ for very low-boiling substances such as nitrogen or ammonia.

When all the impurities are non-volatile, simple distillation is an adequate purification. The observed boiling point remains almost constant and approximately equal to that of the pure material. Usually, however, some of the impurities are appreciably volatile, so that the boiling point progressively rises during the distillation because of the progressive enrichment of the higher-boiling components in the distillation flask. In such cases, separation is effected by fractional distillation using an efficient column.

The principle involved in fractional distillation can be seen by considering a system which approximately obeys *Raoult's law*. (This law states that the vapour pressure of a solution at any given temperature is the sum of the vapour pressures of each substance multiplied by its mole fraction in the solution.) If two substances, A and B, having vapour pressures of 600mm Hg and 360mm Hg, respectively, were mixed in a mole ratio of 2:1, the mixture would have (ideally) a vapour pressure of 520mm Hg and the vapour phase would contain 77% of A and 23% of B. If this phase was now condensed, the new liquid phase would, therefore, be richer in the volatile component A. Similarly, the vapour in equilibrium with this phase is still further enriched in A. Each such liquid-vapour equilibrium constitutes a "theoretical plate". The efficiency of a fractionating column is commonly expressed as the number of such plates to which it corresponds in operation. Alternatively, this information may be given in the form of the height equivalent to a theoretical plate, or HETP.

In most cases, systems deviate to a greater or less extent from Raoult's law, and vapour pressures may be greater or less than those calculated from it. In extreme cases, vapour pressure-composition curves pass through maxima or minima, so that attempts at fractional distillation lead finally to the separation of a constant-boiling (azeotropic) mixture and one (but not both) of the pure species if either of the latter is present in excess.

Techniques

Distillation apparatus consists basically of a distillation flask, usually fitted with a vertical fractionating column (which may be empty or packed with suitable materials such as glass helices or stainless-steel wool) to which is attached a condenser leading to a receiving flask. The bulb of a thermometer projects into the vapour phase just below the region where the condenser joins the column. The distilling flask is heated so that its contents are steadily vaporised by boiling. The vapour passes up into the column where, initially, it condenses and runs back into the flask. The resulting heat transfer gradually warms the column so that there is a progressive movement of the vapour phase-liquid boundary up the column, with increasing enrichment of the more volatile component. Because of this fractionation, the vapour finally passing into the condenser (where it condenses and flows into the receiver) is commonly that of the lowest-boiling components in the system. The conditions apply until all of the low-boiling material has been distilled, whereupon distillation ceases until the column temperature is high enough to permit the next component to distil. This usually results in a temporary fall in the temperature indicated by the thermometer.

The efficiency of a distillation apparatus used for purification of liquids depends on the difference in boiling points of the pure material and its impurities. For example, if two components of an ideal mixture have vapour pressures in the ratio 2:1, it would be necessary to have a still with an efficiency of at least seven plates (giving an enrichment of 2^7 = 128) if the concentration of the higher-boiling component in the distillate was to be reduced to less than 1% of its initial value. For a vapour pressure ratio of 5:1, three plates would achieve as much separation.

In a fractional distillation, it is usual to reject the initial and final fractions, which are likely to be richer in the lower-boiling and higher-boiling impurities. The centre fraction can be further purified by repeated fractional distillation.

To achieve maximum separation by fractional distillation:

1. The column must be flooded initially to wet the packing. For this reason it is customary to operate a still at reflux for some time before beginning the distillation.

2. The reflux ratio should be high (i.e the ratio of drops of liquid which return to the distilling flask and the drops which distil over), so that the distillation proceeds slowly and with minimum disturbance of the equilibria in the column.

3. The hold-up of the column should not exceed one-tenth of the volume of any one component to be separated.

4. Heat loss from the column should be prevented but, if the column is heated to offset this, its temperature must not exceed that of the distillate in the column.

5. Heat input to the still-pot should remain constant.

6. For distillation under reduced pressure there must be careful control of the pressure to avoid flooding or cessation of reflux.

Distillation at Atmospheric Pressure

The distilling flask. To minimise superheating of the liquid (due to the absence of minute air bubbles or other suitable nuclei for forming bubbles of vapour), and to prevent bumping, one or more of the following precautions should be taken:

(a) The flask is heated uniformly over a large part of its surface, either by using an electrical heating mantle or, much better, by partial immersion in a bath somewhat above the boiling point of the liquid to be distilled.

(b) Before heating begins, small pieces of unglazed fireclay or porcelain (porous pot, boiling chips), pumice, carborundum, Teflon, diatomaceous earth, or platinum wire are added to the flask. These act as sources of air bubbles.

(c) The flask may contain glass siphons or boiling tubes. The former are inverted J-shaped tubes, the end of the shorter arm being just above the surface of the liquid. The latter comprise long capillary tubes sealed above the lower end.

(d) A steady slow stream of inert gas(e.g. N_2, Ar or He) is passed through the liquid.

(e) In some cases zinc dust can also be used. It reacts chemically with acidic or strongly alkaline solutions to liberate fine bubbles of hydrogen.

(f) The liquid in the flask is stirred mechanically. This is especially necessary when suspended insoluble material is present.

For simple distillations a Claisen flask (see, for example, Quickfit and Quartz Ltd cataloque of interchangeable laboratory glassware, Kontes Glass Co, Vineland, New Jersey, cat.no TG-15, Normschiff, Wertheim, Germany, Embell Scientific, Murwillumbah, NSW 2484, Australia) is often used. This flask is, essentially, a round-bottomed flask to the neck of which is joined another neck carrying a side arm. This second neck is sometimes extended so as to form a Vigreux column.
For heating baths, see Table 2 (p 33). For distillation apparatus on a semi-micro scale see Quickfit, Kontes and other glassware catalogues (above).

Types of columns and packings. A slow distillation rate is necessary to ensure that equilibrium conditions operate and also that the vapour does not become superheated so that the temperature rises above the boiling point. Efficiency is improved if the column is heat insulated (either by vacuum jacketing or by lagging) and, if necessary, heated to just below the boiling point of the most volatile component (an electrical heating tape is convenient for this purpose.) Efficiency of separation also improves with increase in the heat of vaporisation of the liquids concerned (because fractionation depends on heat equilibration at multiple liquid-gas boundaries). Water and alcohols are more easily purified by distillation for this reason.
Columns used in distillation vary in their shapes and types of packing. Packed columns are intended to give efficient separation by maintaining a large surface of contact between liquid and vapour. Efficiency of separation is further increased by operation under conditions approaching total reflux, i.e. under a high reflux ratio. Better control of reflux ratio is achieved by fitting a total condensation, variable take-off still-head (see, for example, catalogues by Quickfit and Quartz, or Kontes) to the top of the fractionating column. However, great care must be taken to avoid flooding of the column during distillation. The minimum number of theoretical plates for satisfactory separation of two liquids differing in boiling point by $\hat{I}t$ is approximately $(273 + t)/3\hat{I}t$, where t is the average boiling point in °C.

Some of the commonly used columns are:

Bruun column. A type of all-glass bubble-cap column.

Bubble-cap column. A type of plate column in which inverted cups (bubble caps) deflect ascending vapour through reflux liquid lying on each plate. Excess liquid from any plate overflows to the plate lying below it and ultimately returns to the flask. (For further details, see Bruun and Faulconer *Ind Eng Chem (Anal Ed)* **9** 247 *1937*). Like most plate columns, it has a high through-put, but a relatively low number of theoretical plates for a given height.

Dufton column. A plain tube, into which fits closely (preferably ground to fit) a solid glass spiral wound round a central rod. It tends to choke at temperatures above 100° unless it is lagged (Dufton *J Soc Chem Ind* (London) **38** 45T *1919*).

Hempel column. A plain tube (fitted near the top with a side arm) which is almost filled with a suitable packing, which may be of rings or helices.

Oldershaw column. An all-glass perforated-plate column. The plates are sealed into a tube, each plate being equipped with a baffle to direct the flow of reflux liquid, and a raised outlet which maintains a definite liquid level on the plate and also serves as a drain on to the next lower plate [see Oldershaw *Ind Eng Chem (Anal Ed)* **11** 265 *1941*].

Podbielniak column. A plain tube containing "Heli-Grid" Nichrome or Inconel wire packing. This packing provides a number of passage-ways for the reflux liquid, while the capillary spaces ensure very even spreading of the liquid, so that there is a very large area of contact between liquid and vapour while, at the same time, channelling and flooding are minimised. A column 1m high has been stated to have an efficiency of 200-400 theoretical plates (for further details, see Podbielniak *Ind Eng Chem (Anal Ed)* **13** 639 *1941*; Mitchell and O'Gorman *AC* **20** 315 *1948*).

Stedman column. A plain tube containing a series of wire-gauze discs stamped into flat, truncated cones and welded together, alternatively base-to-base and edge-to-edge, with a flat disc across each base. Each cone has a hole, alternately arranged, near its base, vapour and liquid being brought into intimate contact on the gauze surfaces (Stedman *Canad J Research B* **15** 383 *1937*).

Todd column. A column (which may be a Dufton type, fitted with a Monel metal rod and spiral, or a Hempel type, fitted with glass helices) which is surrounded by an open heating jacket so that the temperature can be adjusted to be close to the distillation temperature (Todd *Ind Eng Chem (Anal Ed)* **17** 175 *1945*).

Vigreux column. A glass tube in which have been made a number of pairs of indentations which almost touch each other and which slope slightly downwards. The pairs of indentations are arranged to form a spiral of glass inside the tube.

Widmer column. A Dufton column, modified by enclosing within two concentric tubes the portion containing the glass spiral. Vapour passes up the outer tube and down the inner tube before entering the centre portion. In this way flooding of the column, especially at high temperatures, is greatly reduced (Widmer *HCA* **7** 59 *1924*).

The packing of a column greatly increases the surface of liquid films in contact with the vapour phase, thereby increasing the efficiency of the column, but reducing its capacity (the quantities of vapour and liquid able to flow in opposite directions in a column without causing flooding). Material for packing should be of uniform size, symmetrical shape, and have a unit diameter less than one eighth that of the column. (Rectification efficiency increases sharply as the size of the packing is reduced but so, also, does the hold-up in the column.) It should also be capable of uniform, reproducible packing.

The usual packings are:

(a) **Rings.** These may be hollow glass or porcelain (Raschig rings), of stainless steel gauze (Dixon rings), or hollow rings with a central partition (Lessing rings) which may be of porcelain, aluminium, copper or nickel.

(b) **Helices.** These may be of metal or glass (Fenske rings), the latter being used where resistance to chemical attack is important (e.g. in distilling acids, organic halides, some sulphur compounds, and phenols). Metal single-turn helices are available in aluminium, nickel or stainless steel. Glass helices are less efficient, because they cannot be tamped to ensure uniform packing.

(c) **Balls.** These are usually glass.

(d) **Wire packing.** For use of "Heli-Grid" and "Heli-Pak" packings see references given for Podbielniak column. For Stedman packing, see entry under Stedman column.

Condensers. Some of the more commonly used condensers are:

Air condenser. A glass tube such as the inner part of a Liebig condenser. Used for liquids with boiling points above 90°. Can be of any length.

Allihn condenser. The inner tube of a Liebig condenser is modified by having a series of bulbs to increase the condensing surface. Further modifications of the bubble shapes give the Julian and Allihn-Kronbitter condensers.

Bailey-Walker condenser. A type of all-metal condenser fitting into the neck of extraction apparatus and being supported by the rim. Used for high-boiling liquids.

Coil condenser. An open tube, into which is sealed a glass coil or spiral through which water circulates. The tube is sometimes also surrounded by an outer cooling jacket.

Double surface condenser. A tube in which the vapour is condensed between an outer and inner water-cooled jacket after impinging on the latter. Very useful for liquids boiling below 40°.

Friedrichs condenser. A "cold-finger" type of condenser sealed into a glass jacket open at the bottom and near the top. The cold finger is formed into glass screw threads.

Graham condenser. A type of coil condenser.

Hopkins condenser. A cold-finger type of condenser resembling that of Friedrichs.

Liebig condenser. An inner glass tube surrounded by a glass jacket through which water is circulated.

Othmer condenser. A large-capacity condenser which has two coils of relatively large bore glass tubing inside it, through which the water flows. The two coils join at their top and bottom.

West condenser. A Liebig condenser with a light-walled inner tube and a heavy-walled outer tube, with only a narrow space between them.

Wiley condenser. A condenser resembling the Bailey-Walker type.

VACUUM DISTILLATION

This expression is commonly used to denote a distillation under reduced pressure lower than that of the normal atmosphere. Because the boiling point of a substance depends on the pressure, it is often possible by sufficiently lowering the pressure to distil materials at a temperature low enough to avoid partial or complete decomposition, even if they are unstable when boiled at atmospheric pressure.

Sensitive or high-boiling liquids should invariably be distilled or fractionally distilled under reduced pressure. The apparatus is essentially as described for distillation except that ground joints connecting the different parts of the apparatus should be greased with the appropriate vacuum grease. For low, moderately high, and very high temperatures Apiezon L, M and T, respectively, are very satisfactory. Alternatively, it is often preferable to avoid grease and to use thin Teflon sleeves in the joints. The distilling flask, must be supplied with a capillary bleed (which allows a fine stream of air, nitrogen or argon into the flask), and the receiver should be of the fraction collector type (e.g. a Perkin triangle, see Quickfit and Quartz Ltd interchangeable glassware catalogue, or Kontes Glass Co, Vineland, New Jersey, cat. no. TG-15). When distilling under vacuum it is very important to place a loose packing of glass wool above the liquid to buffer sudden boiling of the liquid. The flask should be not more than two-thirds full of liquid. The vacuum must have attained a steady state before the heat source is applied, and the temperature of the heat source must be raised *very slowly* until boiling is achieved.

If the pump is a filter pump off a high-pressure water supply, its performance will be limited by the temperature of the water because the vapour pressure of water at 10°, 15°, 20° and 25° is 9.2, 12.8, 17.5 and 23.8mm Hg respectively. The pressure can be measured with an ordinary manometer. For vacuums in the range 10^{-2}mm Hg (10μ) to 10mm Hg, rotary mechanical pumps (oil pumps) are used and the pressure can be measured with a Vacustat McLeod type gauge. If still higher vacuums are required, for example for high vacuum sublimations, a mercury diffusion pump is suitable. In principle, this pump resembles an ordinary water pump. It has a single, double or triple jet through which the mercury vapour and condensate pass. Such a pump can provide a vacuum up to 10^{-6} mm Hg. Two pumps can be used in series. For better efficiency these pumps are backed by a mechanical pump. The pressure is measured with a Pirani gauge. Where there is fear of contamination with mercury vapour, the mercury in the pumps can be replaced with vacuum oils, e.g. Apiezon type G or Silicone fluid (Dow Corning no. 702 or 703), which produce a vacuum range of 10^{-4} to 10^{-7}mm Hg depending on pump design and system used. These fluids are resistant to oxidation, are non-corrosive and are non-toxic. The gauge should be as close to the distillation apparatus as possible in order to obtain the distillation pressure as accurately as possible, thus minimising the pressure drop between the gauge and the apparatus.

In all cases, the pump is connected to the still through several traps to remove vapours. These traps may operate by chemical action, for example the use of sodium hydroxide pellets to react with acids, or by condensation, in which case empty tubes cooled in solid carbon dioxide-ethanol or liquid nitrogen (contained in wide-mouthed Dewar flasks) are used.

Special oil or mercury traps are available commercially and a liquid-nitrogen trap is the most satisfactory one to use between these and the apparatus. It has an advantage over liquid air or oxygen in that it is non-explosive if it becomes contaminated with organic matter. Air should not be sucked through the apparatus before starting a distillation or sublimation because this will cause liquid air to condense in the liquid nitrogen trap and a good vacuum cannot be readily achieved. Hence, it is advisable to degas the system for a short period before the trap is immersed into the liquid nitrogen (which is kept in a Dewar flask).

Kügelrohr Distillation. This is more like reverse molecular distillation. The apparatus (Büchi Glasapparat Fabrik, FLAWL, Switzerland) is made up of small glass bulbs (*ca* 4-5cm diameter) which are joined together *via* Quickfit joints at each pole of the bulbs. The liquid (or low melting solid) to be purified is placed in the first bulb of a series of bulbs joined end to end, and the system can be evacuated. The first bulb is heated in a movable furnace at a high temperature whereby most of the material distils into the second bulb (which is outside of the furnace). The furnace is then moved to the second bulb and the furnace temperature is reduced by *ca* 5° whereby the liquid in the second bulb distils into the third bulb (at this stage the first bulb is now out of the back of the furnace and the third and subsequent bulbs are outside the front of the furnace). The furnace temperature is lowered by a further *ca* 5° and moved to the third bulb when lower boiling material will distil into the fourth bulb. The process is continued until no more material distils into the subsequent bulb. The vacuum (if applied) and the furnace are removed, the bulbs are separated and the various fractions of distillates are collected from the individual bulbs. This procedure is used for preliminary purification and the distillates are then redistilled or recrystallised.

Vacuum-lines, Schlenk and Glovebox Techniques. Manipulations involving materials sensitive to air or water vapour can be carried out by these procedures. Vacuum-line methods make use of quantitative transfers, and **P**(pressure)-**V**(volume)-**T**(temperature) measurements, of gases, and trap-to-trap separations of volatile substances.
It is usually more convenient to work under an inert-gas atmosphere, using **Schlenk** type apparatus. The *principle* of Schlenk methods is the bottle which has a standard ground-glass joint and a sidearm with a tap. The system can be purged by evacuating and flushing with an inert gas (usually nitrogen, or in some cases, argon), repeating the process until the contaminants in the vapour phases have been diminished to acceptable limits. If the bottom of the bottle has a tap and a cone, a dropping bottle is produced, while further addition of a sinter disk in the bottle converts it to a filter funnel. With these, and tailor-made pieces of glassware, inert atmospheres can be maintained during crystallisation, filtration, sublimation and transfer. Schlenk-type glassware is commercially available (as *Airless Ware*) from Kontes Glass Co, Vineland, NJ, USA and Embell Scientific, Murwillumbah, NSW 2484, Australia).
Syringe techniques have been worked out for small volumes, while for large volumes or where much manipulation is required, dryboxes (*glove boxes*) or dry chambers should be used.
For fuller discussion, see Sanderson *Vacuum Manipulation of Volatile Compounds* John Wiley and Sons Ltd, NY, 1948; L.W.Muller *Vacuum Technology: Principles and Applications*, Chapman & Hall Ltd, 1995; W.H.Kohl *Handbook of Materials & Techniques for Vacuum Devices*, American Institute of Physics Press, 1994; Shriver *The Manipulation of Air-sensitive Compounds* McGraw-Hill Book Co, NY, 1969; Brown *Organic Syntheses via Boranes*, Wiley, NY, 1975; A.Pelter *Borane Reagents*, Academic Press Inc., 1988.

Spinning-band Columns. Factors which limit the performance of distillation columns include the tendency to flood (which occurs when the returning liquid blocks the pathway taken by the vapour through the column) and the increased hold-up (which decreases the attainable efficiency) in the column that should, theoretically, be highly efficient. To overcome these difficulties, especially for distillation under high vacuum of heat sensitive or high-boiling highly viscous fluids, spinning band columns have become commercially available. In such units, the distillation columns contain a rapidly rotating, motor-driven, spiral band, which may be of polymer-coated metal, stainless steel or platinum. The rapid rotation of the band in contact with the walls of the still gives intimate mixing of descending liquid and ascending vapour while the screw-like motion of the band drives the liquid towards the still-pot, helping to reduce hold-up. There is very little pressure drop in such a system, and very high throughputs are possible, at high efficiency. For example, a 30-in 10-mm diameter commercial column is reported to have an efficiency of 28 plates and a pressure drop of 0.2mm Hg for a throughput of 330ml/h. The columns may be either vacuum jacketed or heated externally. The stills can be operated down to 10^{-5}mm Hg. The principle, which was first used commercially in the Podbielniak Centrifugal Superfractionator, has also been embodied in descending-film molecular distillation apparatus.

STEAM DISTILLATION

When two immmiscible liquids distil, the sum of their (independent) partial pressures is equal to the atmospheric pressure. Hence in steam distillation, the distillate has the composition

$$\frac{\text{Moles of substance}}{\text{Moles of water}} = \frac{P_{substance}}{P_{water}} = \frac{760 - P_{water}}{P_{water}}$$

where the P's are vapour pressures in mm Hg) in the boiling mixture. One of the advantages of using water in this way lies in its low molecular weight.
The customary technique consists of heating the substance and water in a flask (to boiling), usually with the passage of steam, followed by condensation and separation of the aqueous and non-aqueous phases. Its advantages are those of selectivity (because only some water-insoluble substances, such as naphthalene, nitrobenzene, phenol and aniline are volatile in steam) and of ability to distil certain high-boiling substances well below their boiling point. It also facilitates the recovery of a non-steam-volatile solid at a relatively low temperature from a high-boiling solvent such as nitrobenzene. The efficiency of steam distillation is increased if superheated steam is used (because the vapour pressure of the organic component is increased relative to water). In this case the flask containing the material is heated (without water) in an oil bath and the steam passing through it is superheated by prior passage through a suitable heating device (such as a copper coil over a bunsen burner or an oil bath). (For further detail, see Krell 1963, p 45).

AZEOTROPIC DISTILLATION

In some cases two or more liquids form constant-boiling mixtures, or azeotropes. Azeotropic mixtures are most likely to be found with components which readily form hydrogen bonds or are otherwise highly associated, especially when the components are dissimilar, for example an alcohol and an aromatic hydrocarbon, but have similar boiling points. (Many systems are summarised in *Azeotropic Data - III*, L.H.Horsley, *Advances in Chemistry Series 116*, American Chemical Society, Washington, *1973*).

Examples where the boiling point of the distillate is a minimum (less than either pure component) include:
Water with ethanol, *n*-propanol and isopropanol, *tert*-butanol, propionic acid, butyric acid, pyridine,
methanol with methyl iodide, methyl acetate, chloroform,
ethanol with ethyl iodide, ethyl acetate, chloroform, benzene, toluene, methyl ethyl ketone,
benzene with cyclohexane,
acetic acid with toluene.
Although less common, azeotropic mixtures are known which have higher boiling points than their components. These include water with most of the mineral acids (hydrofluoric, hydrochloric, hydrobromic, perchloric, nitric and sulphuric) and formic acid. Other examples are acetic acid-pyridine, acetone-chloroform, aniline-phenol, and chloroform-methyl acetate.

The following azeotropes are important commercially for drying ethanol:

ethanol 95.5% (by weight) - water 4.5%	**b** 78.1°
ethanol 32.4% - benzene 67.6%	**b** 68.2°
ethanol 18.5% - benzene 74.1% - water 7.4%	**b** 64.9°

Materials are sometimes added to form an azeotropic mixture with the substance to be purified. Because the azeotrope boils at a different temperature, this facilitates separation from substances distilling in the same range as the pure material. (Conversely, the impurity might form the azeotrope and be removed in this way). This method is often convenient, especially where the impurities are isomers or are otherwise closely related to the desired substance. Formation of low-boiling azeotropes also facilitates distillation.

One or more of the following methods can generally be used for separating the components of an azeotropic mixture:

1. By using a chemical method to remove most of one species prior to distillation. (For example, water can be removed by suitable drying agents; aromatic and unsaturated hydrocarbons can be removed by sulphonation).
2. By redistillation with an additional substance which can form a ternary azeotropic mixture (as in ethanol-water-benzene example given above).
3. By selective adsorption of one of the components. (For example , of water on to a silica gel or molecular sieve, or of unsaturated hydrocarbons on to alumina).
4. By fractional crystallisation of the mixture, either by direct freezing or after solution in a suitable solvent.

ISOPIESTIC OR ISOTHERMAL DISTILLATION

This technique can be useful for the preparation of metal-free solutions of volatile acids and bases for use in trace metal studies. The procedure involves placing two beakers, one of distilled water and the other of a solution of

the material to be purified, in a desiccator. The desiccator is sealed and left to stand at room temperature for several days. The volatile components distribute themselves between the two beakers whereas the non-volatile contaminants remain in the original beaker. This technique has afforded metal-free pure solutions of ammonia, hydrochloric acid and hydrogen fluoride.

SUBLIMATION

Sublimation differs from ordinary distillation because the vapour condenses to a solid instead of a liquid. Usually, the pressure in the heated system is diminished by pumping, and the vapour is condensed (after travelling a relatively short distance) on to a cold finger or some other cooled surface. This technique, which is applicable to many organic solids, can also be used with inorganic solids such as aluminium chloride, ammonium chloride, arsenious oxide and iodine. In some cases, passage of a stream of inert gas over the heated substance secures adequate vaporisation.

RECRYSTALLISATION

Techniques

The most commonly used procedure for the purification of a solid material by recrystallisation from a solution involves the following steps:

(a) The impure material is dissolved in a suitable solvent, by shaking or vigorous stirring, at or near the boiling point, to form a near-saturated solution.
(b) The hot solution is filtered to remove any insoluble particles. To prevent crystallisation during this filtration, a heated (jacketed) filter funnel can be used or the solution can be somewhat diluted with more of the solvent.
(c) The solution is then allowed to cool so that the dissolved substance crystallises out.
(d) The crystals are separated from the mother liquor, either by centrifuging or by filtering, under suction, through a sintered glass, a Hirsch or a Büchner, funnel. Usually, centrifuging is much preferred because of the much greater ease and efficiency of separating crystals and mother liquor, and also because of the saving of time and effort, particularly when very small crystals are formed or when there is entrainment of solvent.
(e) The crystals are washed free from mother liquor with a little fresh cold solvent, then dried.

If the solution contains extraneous coloured material likely to contaminate the crystals, this can often be removed by adding some activated charcoal (decolorising carbon) to the hot, but not boiling, solution which is then shaken frequently for several minutes before being filtered. (The large active surface of the carbon makes it a good adsorbent for this purpose.) In general, the cooling and crystallisation step should be rapid so as to give small crystals which occlude less of the mother liquor. This is usually satisfactory with inorganic material, so that commonly the filtrate is cooled in an ice-water bath while being vigorously stirred. In many cases, however, organic molecules crystallise much more slowly, so that the filtrate must be set aside to cool to room temperature or left in the refrigerator. It is often desirable to subject material that is very impure to preliminary purification, such as steam distillation, Soxhlet extraction, or sublimation, before recrystallising it. A greater degree of purity is also to be expected if the crystallisation process is repeated several times, especially if different solvents are used. The advantage of several crystallisations from different solvents lies in the fact that the material sought, and its impurities, are unlikely to have similar solubilities as solvents and temperatures are varied.

For the final separation of solid material, sintered-glass discs are preferable to filter paper. Sintered glass is unaffected by strongly acid solutions or by oxidising agents. Also, with filter paper, cellulose fibres are likely to become included in the sample, The sintered-glass discs or funnels can be readily cleaned by washing in freshly prepared *chromic acid cleaning mixture*. This mixture is made by adding 100ml of concentrated sulphuric acid slowly with stirring to a solution of 5g of sodium dichromate in 5ml of water. (The mixture warms to about 70°).

For materials with melting points below 70° it is sometimes convenient to use dilute solutions in acetone, methanol, pentane, ethyl ether or $CHCl_3$-CCl_4. The solutions are cooled to -78° in Dry-ice, to give a filtrable slurry which is filtered off through a precooled Büchner funnel. Experimental details, as applied to the purification of nitromethane, are given by Parrett and Sun [*J Chem Educ* **54** 448 *1977*].

Where substances vary little in solubility with temperature, isothermal crystallisation may sometimes be employed. This usually takes the form of a partial evaporation of a saturated solution at room temperature by leaving it under reduced pressure in a desiccator.

However, in rare cases, crystallisation is not a satisfactory method of purification, especially if the impurity forms crystals that are isomorphous with the material being purified. In fact, the impurity content may even be greater in

such recrystallised material. For this reason, it still remains necessary to test for impurities and to remove or adequately lower their concentrations by suitable chemical manipulation prior to recrystallisation.

Filtration

Filtration removes particulate impurities rapidly from liquids and is also used to collect insoluble or crystalline solids which separate or crystallise from solution. The usual technique is to pass the solution, cold or hot, through a fluted filter paper in a conical glass funnel (see Vogel's *Textbook of Practical Organic Chemistry*, p 46).

If a solution is hot and needs to be filtered rapidly a Büchner funnel and flask are used and filtration is performed under a slight vacuum (water pump), the filter medium being a circular cellulose filter paper wet with solvent. If filtration is slow, even under high vacuum, a pile of about twenty filter papers, wet as before, are placed in the Büchner funnel and, as the flow of solution slows down, the upper layers of the filter paper are progressively removed. Alternatively, a filter aid, e.g. Celite, Florisil or Hyflo-supercel, is placed on top of a filter paper in the funnel. When the flow of the solution (under suction) slows down the upper surface of the filter aid is scratched gently. Filter papers with various pore sizes are available covering a range of filtration rates. Hardened filter papers are slow filtering but they can withstand acidic and alkaline solutions without appreciable hydrolysis of the cellulose (see Table 3). When using strong acids it is preferable to use glass micro fibre filters which are commercially available (see Table 3).

Freeing a solution from extremely small particles (e.g. for ORD or CD measurements) requires filters with very small pore size. Commercially available (Millipore, Gelman, Nucleopore) filters other than cellulose or glass include nylon, Teflon, and polyvinyl chloride, and the pore diameter may be as small as 0.01 micron (see Table 4). Special containers are used to hold the filters, through which the solution is pressed by applying pressure, e.g. from a syringe. Some of these filters can be used to clear strong sulphuric acid solutions .
As an alternative to the Büchner funnel for collecting crystalline solids, a funnel with a sintered glass-plate under suction may be used. Sintered-glass funnels with various porosities are commercially available and can easily cleaned with warm chromic or nitric acid (see above).

When the solid particles are too fine to be collected on a filter funnel because filtration is extremely slow, separation by **centrifugation** should be used. Bench type centrifuges are most convenient for this purpose. The solid is placed in the centrifuge tube, the tubes containing the solutions on opposite sides of the rotor should be balanced accurately (at least within 0.05 to 0.1g), and the solutions are spun at maximum speed for as long as it takes to settle the solid (usually *ca* 3-5 minutes). The solid is washed with cold solvent by centrifugation, and finally twice with a pure volatile solvent in which the solid is insoluble, also by centrifugation. After decanting the supernatant the residue is dried in a vacuum, at elevated temperatures if necessary. In order to avoid "spitting" and contamination with dust while the solid in the centrifuge tube is dried, the mouth of the tube is covered with silver paper and held fast with a tight rubber band near the lip. The flat surface of the silver paper is then perforated in several places with a pin.

Choice of Solvents

The best solvents for recrystallisation have the following properties:

(a) The material is much more soluble at higher temperatures than it is at room temperature or below.
(b) Well-formed (but not large) crystals are produced.
(c) Impurities are either very soluble or only sparingly soluble.
(d) The solvent must be readily removed from the purified material.
(e) There must be no reaction between the solvent and the substance being purified.
(f) The solvent must not be inconveniently volatile or too highly flammable. (These are reasons why ethyl ether and carbon disulphide are not commonly used in this way.)

The following generalisations provide a rough guide to the selection of a suitable solvent:

(a) Substances usually dissolve best in solvents to which they are most closely related in chemical and physical characteristics. Thus, hydroxylic compounds are likely to be most soluble in water, methanol, ethanol, acetic acid or acetone. Similarly, petroleum ether might be used with water-insoluble substances. However, if the resemblance is too close, solubilities may become excessive.
(b) Higher members of homologous series approximate more and more closely to their parent hydrocarbon.
(c) Polar substances are more soluble in polar, than in non-polar, solvents.

Although Chapters 3, 4 and 5 provide details of the solvents used for recrystallising a large portion of commercially available laboratory chemicals, they cannot hope to be exhaustive, nor need they necessarily be the best choice. In other cases where it is desirable to use this process, it is necessary to establish whether a given solvent is suitable. This is usually done by taking only a small amount of material in a small test-tube and adding enough solvent to cover it. If it dissolves readily in the cold or on gentle warming, the solvent is unsuitable. Conversely, if it remains insoluble when the solvent is heated to boiling (adding more solvent if necessary), the solvent is again unsuitable. If the material dissolves in the hot solvent but does not crystallise readily within several minutes of cooling in an ice-salt mixture, another solvent should be tried.
Solvents commonly used for recrystallisation, and their boiling points, are given in Table 5.

Mixed Solvents
Where a substance is too soluble in one solvent and too insoluble in another, for either to be used for recrystallisation, it is often possible (provided they are miscible) to use them as a mixed solvent. (In general, however, it is preferable to use a single solvent if this is practicable.) Table 6 contains many of the common pairs of miscible solvents.
The technique of recrystallisation from a mixed solvent is as follows:
The material is dissolved in the solvent in which it is the more soluble, then the other solvent (heated to near boiling) is added cautiously to the hot solution until a slight turbidity persists or crystallisation begins. This is cleared by adding several drops of the first solvent, and the solution is allowed to cool and crystallise in the usual way.
A variation of this procedure is simply to precipitate the material in a microcrystalline form from solution in one solvent at room temperature, by adding a little more of the second solvent, filtering this off, adding a little more of the second solvent and repeating the process. This ensures, at least in the first or last precipitation, a material which contains as little as possible of the impurities which may also be precipitated in this way. With salts the first solvent is commonly water, and the second solvent is alcohol or acetone.

Recrystallisation from the Melt
A crystalline solid melts when its temperature is raised sufficiently for the thermal agitation of its molecules or ions to overcome the restraints imposed by the crystal lattice. Usually, impurities weaken crystal structures, and hence lower the melting points of solids (or the freezing points of liquids). If an impure material is melted and cooled slowly (with the addition, if necessary, of a trace of solid material near the freezing point to avoid supercooling), the first crystals that form will usually contain less of the impurity, so that fractional solidification by partial freezing can be used as a purification process for solids with melting points lying in a convenient temperature range (or for more readily frozen liquids). In some cases, impurities form higher melting eutectics with substances to be purified, so that the first material to solidify is less pure than the melt. For this reason, it is often desirable to discard the first crystals and also the final portions of the melt. Substances having similar boiling points often differ much more in melting points, so that fractional solidification can offer real advantages, especially where ultrapurity is sought.
The technique of recrystallisation from the melt as a means of purification dates back from its use by Schwab and Wichers (*J Res Nat Bur Stand* **25** 747 *1940*) to purify benzoic acid. It works best if material is already nearly pure, and hence tends to be a final purification step. A simple apparatus for purifying organic compounds by progressive freezing is described by Matthias and Coggeshall (*AC* **31** 1124 *1959*). In principle, the molten substance is cooled slowly by progressive lowering of the tube containing it into a suitable bath. For temperatures between 0° and 100°, waterbaths are convenient. Where lower temperatures are required, the cooling baths given in Table 7 can be used. Cooling is stopped when part of the melt has solidified, and the liquid phase is drained off. Column crystallisation has been used to purify stearyl alcohol, cetyl alcohol, myristic acid; fluorene, phenanthrene, biphenyl, terphenyls, dibenzyl; phenol, 2-naphthol; benzophenone and 2,4-dinitrotoluene; and many other organic (and inorganic) compounds. [See, for example, *Developments in Separation Science* N.N.Lee (ed), CRC Press, Cleveland, Ohio, *1972*]. Thus, an increase in purity from 99.80 to 99.98 mole% was obtained when acetamide was slowly crystallised in an insulated round bottom flask until half the material had solidified and the solid phase was then recrystallised from benzene [Schwab and Wichers *J Res Nat Bur Stand* **32** 253 *1944*].
Fractional solidification and its applications to obtaining ultrapure chemical substances, has been treated in detail in *Fractional Solidification* by M.Zief and W.R.Wilcox eds, Edward Arnold Inc, London *1967*, and *Purification of Inorganic and Organic Materials* by M.Zief, Marcel Dekker Inc, New York *1969*. These monographs should be consulted for discussion of the basic principles of solid-liquid processes such as zone melting, progressive freezing and column crystallisation, laboratory apparatus and industrial scale equipment, and examples of applications. These include the removal of cyclohexane from benzene, and the purification of aromatic amines, dienes and naphthalene,

and inorganic species such as the alkali iodides, potassium chloride, indium antimonide and gallium trichloride. The authors also discuss analytical methods for assessing the purity of the final material.

Zone Refining

Zone refining (or zone melting) is a particular development for fractional solidification and is applicable to all crystalline substances that show differences in soluble impurity concentration in liquid and solid states at solidification. The apparatus used in this technique consists essentially of a device by which a narrow molten zone moves slowly down a long tube filled with the material to be purified. The machine can be set to recycle repeatedly. At its advancing side, the zone has a melting interface with the impure material whereas on the upper surface of the zone there is a constantly growing face of higher-melting, resolidified material. This leads to a progressive increase in impurity in the liquid phase which, at the end of the run, is discarded. Also, because of the progressive increase in impurity in the liquid phase, the resolidified material becomes correspondingly less further purified. For this reason, it is usually necessary to make several zone-melting runs before a sample is satisfactorily purified. This is also why the method works most successfully if the material is already fairly pure. In all these operations the zone must travel slowly enough to enable impurities to diffuse or be convected away from the area where resolidification is occurring.

The technique finds commercial application in the production of metals of extremely high purity (impurities down to 10^{-9} ppm), in purifying refractory oxides, and in purifying organic compounds, using commercially available equipment. Criteria for indicating that definite purification is achieved include elevation of melting point, removal of colour, fluorescence or smell, and a lowering of electrical conductivity. Difficulties likely to be met with in organic compounds, especially those of low melting points and low rates of crystallisation, are supercooling and, because of surface tension and contraction, the tendency of the molten zone to seep back into the recrystallised areas. The method is likely to be useful in cases where fractional distillation is not practicable, either because of unfavourable vapour pressures or ease of decomposition, or where super-pure materials are required. It has been used for the latter purpose with anthracene, benzoic acid, chrysene, morphine and pyrene. (See references on p. 47).

DRYING

Removal of Solvents

Where substances are sufficiently stable, removal of solvent from recrystallised materials presents no problems. The crystals, after filtering at the pump (and perhaps air-drying by suction), are heated in an oven above the boiling point of the solvent (but below their melting point), followed by cooling in a desiccator. Where this treatment is inadvisable, it is still often possible to heat to a lower temperature under reduced pressure, for example in an Abderhalden pistol. This device consists of a small chamber which is heated externally by the vapour of a boiling solvent. Inside this chamber, which can be evacuated by a water pump or some other vacuum pump, is placed a small boat containing the sample to be dried and also a receptacle with a suitable drying agent. Convenient liquids for use as boiling liquids in an Abderhalden pistol, and their temperatures, are given in Table 9. In cases where heating above room temperature cannot be used, drying must be carried out in a vacuum desiccator containing suitable absorbants. For example, hydrocarbons, such as benzene, cyclohexane and petroleum ether, can be removed by using shredded paraffin wax, and acetic acid and other acids can be absorbed by pellets of sodium, or potassium, hydroxide. However, in general, solvent removal is less of a problem than ensuring that the water content of solids and liquids is reduced below an acceptable level.

Removal of Water

Methods for removing water from solids depends on the thermal stability of the solids or the time available. The safest way is to dry in a vacuum desiccator over concentrated sulphuric acid, phosphorus pentoxide, silica gel, calcium chloride, or some other desiccant. Where substances are stable in air and melt above 100° drying in an air oven may be adequate. In other cases, use of an Abderhalden pistol may be satisfactory.

Often, in drying inorganic salts, the final material that is required is a hydrate. In such cases, the purified substance is left in a desiccator to equilibrate above an aqueous solution having a suitable water-vapour pressure. A convenient range of solutions used in this way is given in Table 10.

The choice of desiccants for drying liquids is more restricted because of the need to avoid all substances likely to react with the liquids themselves. In some cases, direct distillation of an organic liquid is a suitable method for drying both solids and liquids, especially if low-boiling azeotropes are formed. Examples include acetone, aniline, benzene, chloroform, carbon tetrachloride, ethylene dichloride, heptane, hexane, methanol, nitrobenzene, petroleum ether, toluene and xylene. Addition of benzene can be used for drying ethanol by distillation. In carrying out distillations intended to yield anhydrous products, the apparatus should be fitted with guard-tubes containing calcium chloride or silica gel to prevent entry of moist air into the system. (Many anhydrous organic liquids are appreciably hygroscopic).

Traces of water can be removed from solvents such as benzene, 1,2-dimethoxyethane, ethyl ether, CH_2Cl_2, pentane, toluene and tetrahydrofuran by refluxing under nitrogen a solution containing **sodium benzophenone ketyl**, and fractionally distilling. Drying with, and distilling from CaH_2 is applicable to a number of solvents including aniline, benzene, *tert*-butylamine, *tert*-butanol, 2,4,6-collidine, diisopropylamine, dimethylformamide, hexamethylphosphoramide, methylenedichloride, pyridine, tetramethylethylenediamine, toluene, triethylamine.

Removal of water from gases may be by physical or chemical means, and is commonly by adsorption on to a drying agent in a low-temperature trap. The effectiveness of drying agents depends on the vapour pressure of the hydrated compound - the lower the vapour pressure the less the remaining moisture in the gas.
The most usually applicable of the specific methods for detecting and determining water in organic liquids is due to Karl Fischer. (See J.Mitchell and D.M.Smith, *Aquametry*, Interscience, New York, *1948*; Fieser and Fieser *Reagents for Organic Synthesis*, J.Wiley & Sons, NY, Vol 1, 528 *1967*). Other techniques include electrical conductivity measurements and observation of the temperature at which the first cloudiness appears as the liquid is cooled (applicable to liquids in which water is only slightly soluble). Addition of anhydrous cobalt (II) iodide (blue) provides a convenient method (colour change to pink on hydration) for detecting water in alcohols, ketones, nitriles and some esters. Infrared absorption measurements of the broad band for water near 3500 cm^{-1} can also sometimes be used for detecting water in non-hydroxylic substances.

Intensity and Capacity of Common Desiccants

Drying agents can be conveniently be grouped into three classes, depending on whether they combine with water reversibly, they react chemically (irreversibly) with water, or they are molecular sieves. The first group vary in their drying intensity with the temperature at which they are used, depending on the vapour pressure of the hydrate that is formed. This is why, for example, drying agents such as anhydrous sodium sulphate, magnesium sulphate or calcium chloride should be filtered off from the liquids before the latter are heated. The intensities of drying agents belonging to this group fall in the sequence:

P_2O_5 >> BaO > $Mg(ClO_4)_2$, CaO, MgO, KOH (fused), conc H_2SO_4, $CaSO_4$, Al_2O_3 > KOH (sticks), silica gel, $Mg(ClO_4)_2.3H_2O$ > NaOH (fused), 95% H_2SO_4, $CaBr_2$, $CaCl_2$ (fused) > NaOH (sticks), $Ba(ClO_4)_2$, $ZnCl_2$ (sticks), $ZnBr_2$ > $CaCl_2$ (technical) > $CuSO_4$ > Na_2SO_4, K_2CO_3.

Where large amounts of water are to be removed, a preliminary drying of liquids is often possible by shaking with concentrated solutions of calcium chloride or potassium carbonate, or by adding sodium chloride to salt out the organic phase (for example, in the drying of lower alcohols).
Drying agents that combine irreversibly with water include the alkali metals, the metal hydrides (discussed in Chapter 2), and calcium carbide.

Suitability of Individual Desiccants

Alumina. (Preheated to 175° for about 7h). Mainly as a drying agent in a desiccator or as a column through which liquid is percolated.

Aluminium amalgam. Mainly used for removing traces of water from alcohols, which are distilled from it after refluxing.

Barium oxide. Suitable for drying organic bases.

Barium perchlorate. Expensive. Used in desiccators (*covered with a metal guard*). Unsuitable for drying solvents or organic material where contact is necessary, because of the danger of **EXPLOSION**

Boric anhydride. (Prepared by melting boric acid in an air oven at a high temperature, cooling in a desiccator, and powdering.) Mainly used for drying formic acid.

Calcium chloride (anhydrous). Cheap. Large capacity for absorption of water, giving the hexahydrate below 30°, but is fairly slow in action and not very efficient. Its main use is for preliminary drying of alkyl and aryl halides, most esters, saturated and aromatic hydrocarbons and ethers. Unsuitable for drying alcohols and amines (which form addition compounds), fatty acids, amides, amino acids, ketones, phenols, or some aldehydes and esters. Calcium chloride is suitable for drying the following gases: hydrogen, hydrogen chloride, carbon monoxide, carbon dioxide, sulphur dioxide, nitrogen, methane, oxygen, also paraffins, ethers, olefines and alkyl chlorides.

Calcium hydride. See Chapter 2.

Calcium oxide. (Preheated to 700-900° before use.) Suitable for alcohols and amines (but does not dry them completely). Need not be removed before distillation, but in that case the head of the distillation column should be packed with glass wool to trap any calcium oxide powder that might be carried over. Unsuitable for acidic compounds and esters. Suitable for drying gaseous amines and ammonia.

Calcium sulphate (anhydrous). (Prepared by heating the dihydrate or the hemihydrate in an oven at 235° for 2-3h; it can be regenerated.) Available commercially as Drierite. It forms the hemihydrate, $2CaSO_4.H_2O$, so that its capacity is fairly low (6.6% of its weight of water), and hence is best used on partially dried substances. It is very efficient (being comparable with phosphorus pentoxide and concentrated sulphuric acid). Suitable for most organic compounds. Solvents boiling below 100° can be dried by direct distillation from calcium sulphate.

Copper (II) sulphate (anhydrous). Suitable for esters and alcohols. Preferable to sodium sulphate in cases where solvents are sparingly soluble in water (for example, benzene or toluene).

Lithium aluminium hydride. See Chapter 2.

Magnesium amalgam. Mainly used for removing traces of water from alcohols, which are distilled from it after refluxing.

Magnesium perchlorate (anhydrous). (Available commercially as Dehydrite. Expensive.) Used in desiccators. Unsuitable for drying solvents or any organic material where contact is necessary, because of the **danger of EXPLOSION**.

Magnesium sulphate (anhydrous). (Prepared from the heptahydrate by drying at 300° under reduced pressure.) More rapid and effective than sodium sulphate. It has a large capacity, forming $MgSO_4.7H_2O$ below 48°. Suitable for the preliminary drying of most organic compounds.

Molecular sieves. See page 28.

Phosphorus pentoxide. Very rapid and efficient, but difficult to handle and should only be used after the organic material has been partially dried, for example with magnesium sulphate. Suitable for acid anhydrides, alkyl and aryl halides, ethers, esters, hydrocarbons and nitriles, and for use in desiccators. Not suitable with acids, alcohols, amines or ketones, or with organic molecules from which a molecule of water can be fairly readily abstracted by an elimination rection. Suitable for drying the following gases: hydrogen, oxygen, carbon dioxide, carbon monoxide, sulphur dioxide, nitrogen, methane, ethylene and paraffins. It is available with an indicator (cobalt salt, blue when dry and pink when wet) under the name *Sicapent* (from Merck).

Potassium (metal). Properties and applications are similar to those for sodium, and it is a correspondingly hazardous substance.

Potassium carbonate (anhydrous). Has a moderate efficiency and capacity, forming the dihydrate. Suitable for an initial drying of alcohols, bases, esters, ketones and nitriles by shaking with them, then filtering off. Also suitable for salting out water-soluble alcohols, amines and ketones. Unsuitable for acids, phenols and other acidic substances.

Potassium hydroxide. Solid potassium hydroxide is very rapid and efficient. Its use is limited almost entirely to the initial drying of organic bases. Alternatively, sometimes the base is shaken first with a concentrated solution of potassium hydroxide to remove most of the water present. Unsuitable for acids, aldehydes, ketones, phenols, amides and esters. Also used for drying gaseous amines and ammonia.

Silica gel. Granulated silica gel is a commercially available drying agent for use with gases, in desiccators, and (because of its chemical inertness) in physical instruments (pH meters, spectrometers, balances). Its drying action depends on physical adsorption, so that silica gel must be used at room temperature or below. By incorporating cobalt chloride into the material it can be made self indicating, re-drying in an oven at 110° being necessary when the colour changes from blue to pink.

Sodium (metal). Used as a fine wire or as chips, for more completely drying ethers, saturated hydrocarbons and aromatic hydrocarbons which have been partially dried (for example with calcium chloride or magnesium sulphate). Unsuitable for acids, alcohols, alkyl halides, aldehydes, ketones, amines and esters. Reacts violently if much water is present and can cause a fire with highly flammable liquids.

Sodium hydroxide. Properties and applications are similar to those for potassium hydroxide.

Sodium-potassium alloy. Used as lumps. Lower melting than sodium, so that its surface is readily renewed by shaking. Properties and applications are similar to those for sodium.

Sodium sulphate (anhydrous). Has a large capacity for absorption of water, forming the decahydrate below 33°, but drying is slow and inefficient, especially for solvents that are sparingly soluble in water. It is suitable for the preliminary drying of most types of organic compounds.

Sulphuric acid (concentrated). Widely used in desiccators. Suitable for drying bromine, saturated hydrocarbons, alkyl and aryl halides. Also suitable for drying the following gases: hydrogen, nitrogen, carbon dioxide, carbon monoxide, chlorine, methane and paraffins. Unsuitable for alcohols, bases, ketones or phenols. Also available with an indicator (a cobalt salt, blue when dry and pink when wet) under the name *Sicacide* (from Merck) for desiccators.

For convenience, many of the above drying agents are listed in Table 11 under the classes of organic compounds for which they are commonly used.

Freeze-pump-thaw and Purging

Volatile contaminants, e,g, traces of low boiling solvent residue or oxygen, in liquid samples or solutions can be very deleterious to the samples on storage. These contaminants can be removed by repeated freeze-pump-thaw cycles. This involves freezing the liquid material under high vacuum in an appropriate vessel (which should be large enough to avoid contaminating the vacuum line with liquid that has bumped) connected to the vacuum line *via* efficient liquid nitrogen traps. The frozen sample is then thawed until it liquefies, kept in this form for some time (*ca*, 10-15min), refreezing the sample and the cycle repeated several times without interupting the vacuum. This procedure applies equally well to solutions, as well as purified liquids, e.g. as a means of removing oxygen from solutions for NMR and other measurements. If the presence of nitrogen, helium or argon, is not a serious contaminant then solutions can be freed from gases, e.g. oxygen, carbon dioxide, and volatile impurities by purging with N_2, He or Ar at room, or slightly elevated, temperature. The gases used for purging are then removed by freeze-pump-thaw cycles or simply by keeping in a vacuum for several hours.

CHROMATOGRAPHY

Chromatography is often used with advantage for the purification of small amounts of complex organic mixtures, either as liquid chromatography or as vapour phase (gas) chromatography.

Liquid Chromatography

The mobile phase in liquid chromatography is a liquid and the stationary phase is of four main types. These are for adsorption, partition, ion-chromatography, and gel filtration. The technique of chromatography which applies to all liquid chromatography at atmospheric pressure comprises the following distinct steps. The material is adsorbed as a level bed onto the column of stationary phase. (It is important that this bed is as narrow as possible because the bands of components in the mixture that is applied widen as they move with the mobile phase down the column.) The column is washed (developed) with a quantity of pure solvent or solvent mixture. The column may be pushed out of the tube so that it can be divided into zones. The desired components are then extracted from the appropriate zones using a suitable solvent. Alternatively, and more commonly, the column is left intact and the bands are progressively eluted by passing more solvent through the column.

Adsorption Chromatography

Adsorption chromatography is based on the difference in the extent to which substances in solution are adsorbed onto a suitable surface. The substances to be purified are usually placed on the top of the column and the solvent is run down the column. In a more common variation of this method, the column containing the adsorbent is full of solvent before applying the mixture at the top of the column. In another application the mixture is adsorbed onto a small amount of stationary phase and placed at the bottom of the column with the dry stationary phase above it. By applying a slight vacuum at the top of the column, the eluting solvent can be sucked slowly upwards from the bottom of the column. When the solvent has reached the top of the column the separation is complete and the vacuum is released. The packing is pushed gently out of the tube and cut into strips as above. Alternatively the vacuum is kept and the effluent from the top of the column is collected in fractions. The fractions are monitored by UV or visible spectra, colour reactions or other means for identifying the components.

Graded Adsorbents and Solvents. Materials used in columns for adsorption chromatography are grouped in Table 12 in an approximate order of effectiveness. Other adsorbents sometimes used include barium carbonate, calcium sulphate, charcoal (usually mixed with kieselguhr or other form of diatomaceous earth, for example, the filter aid Celite), cellulose, glucose and lactose. The alumina can be prepared in several grades of activity (see below).

In most cases, adsorption takes place most readily from non-polar solvents, such as petroleum ether or benzene, and least readily from polar solvents such as alcohols, esters, and acetic acid. Common solvents, arranged in approximate order of increasing eluting ability are also given in Table 12.

Eluting power roughly parallels the dielectric constants of solvents. The series also reflects the extent to which the solvent binds to the column material, thereby displacing the substances that are already adsorbed. This preference of alumina and silica gel for polar molecules explains, for example, the use of percolation through a column of silica gel for the following purposes-drying of ethylbenzene, removal of aromatics from 2,4-dimethylpentane and of ultraviolet absorbing substances from cyclohexane.

Mixed solvents are intermediate in strength, and so provide a finely graded series. In choosing a solvent for use as an eluent it is necessary to consider the solubility of the substance in it, and the ease with which it can subsequently be removed.

Preparation and Standardisation of Alumina. The activity of alumina depends inversely on its water content, and a sample of poorly active material can be rendered more active by leaving for some time in a round bottomed flask heated up to about 200° in an oil bath or a heating mantle while a slow stream of a dry inert gas is passed through it. Alternatively, it is heated to red heat (380-400°) in an open vessel for 4-6h with occasional stirring and then cooled in a vacuum desiccator: this material is then of grade I activity. Conversely, alumina can be rendered less active by adding small amounts of water and thoroughly mixing for several hours. Addition of about 3% (w/w) of water converts grade I alumina to grade II.

Used alumina can be regenerated by repeated extraction, first with boiling methanol, then with boiling water, followed by drying and heating. The degree of activity of the material can be expressed conveniently in terms of the scale due to Brockmann and Schodder (*B* B **74** 73 *1941*). This system is based on the extent of adsorption of five pairs of azo dyestuffs, being adjacent members of the set: azobenzene, *p*-methoxyazobenzene, Sudan yellow, Sudan red, aminoazobenzene, hydroxyazobenzene. In testing the alumina, a tube 10cm long by 1.5cm internal diameter is packed with alumina to a depth of 5cm and covered with a disc of filter paper. The dyestuff solutions are prepared by dissolving 2mg of each azo dye of the pair in 2ml of purified benzene (distilled from potassium hydroxide) and 8ml of

petroleum ether. The solution is applied to the column and developed with 20ml of benzene-petroleum ether mixture (1:4 v/v) at a flow rate of about 20-30 drops per min. The behaviour in the following Table is observed:

GRADE	POSITION OF ZONES (a)	(b)	(c)
I	*p*-Methoxyazobenzene	Azobenzene	
II	*p*-Methoxyazobenzene(d)	Azobenzene	
II	Sudan Yellow	*p*-Methoxyazobenzene	
III		Sudan Yellow	*p*-Methoxy-azobenzene
III	Sudan Red	Sudan Yellow	
IV	Sudan Red		Sudan Yellow
IV	Aminoazobenzene	Sudan Red	
V	Hydroxyazobenzene	Aminoazobenzene	

(a) Near top of column. (b) Near bottom of column. (c) In effluent. (d) 1 to 2 cm from top. Grade I is most active, Grade V is least active.

Alumina is normally slightly alkaline. A (less strongly adsorbing) neutral alumina can be prepared by making a slurry in water and adding 2M hydrochloric acid until the solution is acid to Congo red. The alumina is then filtered off, washed with distilled water until the wash water gives only a weak violet colour with Congo red paper, and dried.
Alumina used in TLC can be recovered by washing in ethanol for 48h with occasional stirring, to remove binder material and then washed with successive portions of ethyl acetate, acetone and finally with distilled water. Fine particles are removed by siphoning. The alumina is first suspended in 0.04M acetic acid, then in distilled water, siphoning off 30 minutes after each wash. The process is repeated 7-8 times. It is then dried and activated at 200° [Vogh and Thomson *AC* **53** 1365 *1981*].

Preparation of other adsorbents. Silica gel can be prepared from commercial water-glass by diluting it with water to a density of 1.19 and, while keeping it cooled to 5°, adding concentrated hydrochloric acid with stirring until the solution is acid to thymol blue. After standing for 3h, the precipitate is filtered off, washed on a Büchner funnel with distilled water, then suspended in 0.2M hydrochloric acid. The suspension is stood for 2-3days, with occasional stirring, then filtered, washed well with water and dried at 110°. It can be activated by heating up to about 200° as described for alumina.
Powdered commercial silica gel can be purified by suspending and standing overnight in concentrated hydrochloric acid (6ml/g), decanting the supernatant and repeating with fresh acid until the latter remains colourless. After filtering with suction on a sintered-glass funnel, the residue is suspended in water and washed by decantation until free of chloride ions. It is then filtered, suspended in 95% ethanol, filtered again and washed on the filter with 95% ethanol. The process is repeated with anhydrous ethyl ether before the gel is heated for 24h at 100° and stored for another 24h in a vacuum desiccator over phosphorus pentoxide.
Commercial silica gel has also been purified by suspension of 200g in 2L of 0.04M ammonia, allowed to stand for 5min before siphoning off the supernatant. The procedure was repeated 3-4 times, before rinsing with distilled water and drying and activating the silica gel in an oven at 110° [Vogh and Thomson, *AC* **53** 1345 *1981*].

Diatomaceous earth. (Celite 535 or 545, Hyflo Super-cel, Dicalite, Kieselguhr) is purified before use by washing with 3M hydrochloric acid, then water, or it is made into a slurry with hot water, filtered at the pump and washed with water at 50° until the filtrate is no longer alkaline to litmus. Organic materials can be removed by repeated extraction at 50° with methanol, benzene or chloroform, followed by washing with methanol, filtering and drying at 90-100°.

Activation of **charcoal** is generally achieved satisfactorily by heating gently to red heat in a crucible or quartz beaker in a muffle furnace, finally allowing to cool under an inert atmosphere in a desiccator. To improve the porosity, charcoal columns are usually prepared in admixture with diatomaceous earth.

Purification of **cellulose** for chromatography is by sequential washing with chloroform, ethanol, water, ethanol, chloroform and acetone. More extensive purification uses aqueous ammonia, water, hydrochloric acid, water, acetone and ethyl ether, followed by drying in a vacuum. Trace metals can be removed from filter paper by washing for several hours with 0.1M oxalic or citric acid, followed by repeated washing with distilled water.

Partition Chromatography

Partition chromatography is concerned with the distribution of substances between a mobile phase and a non-volatile liquid which is itself adsorbed onto an inert supporting stationary phase. The mobile phase may be a gas (see vapour phase chromatography) or a liquid. Paper chromatography, and reverse-phase thin layer chromatography are other applications of partition chromatography. Yet another application is paired-ion chromatography which is used for the separation of substances by virtue of their ionic properties. In principle, the separation of components of a mixture depends on the differences in their distribution ratios between the mobile phase and the liquid stationary phase. The more the distribution of a substance favours the stationary phase, the more slowly it progresses through the column.

When cellulose is used as a stationary phase, with water or aqueous organic solvents as eluents, the separation of substances is by partition between the eluting mixture and the water adsorbed on the column. This is similar to the cellulose in paper chromatography.

For chromatography on dextran gels see page 22.

Flash Chromatography

A faster method of separating components of a mixture is *flash chromatography* (see Still et al. *JOC* **43** 2923 *1978*). In flash chromatography the eluent flows through the column under a pressure of *ca* 1 to 4 atmospheres. The lower end of the chromatographic column has a relatively long taper closed with a tap. The upper end of the column is connected through a ball joint to a tap. The tapered portion is plugged with cotton, or quartz, wool and *ca* 1 cm of fine washed sand. The adsorbant is then placed in the column as a dry powder or as a slurry in a solvent and allowed to fill about one third of the column. A fine grade of adsorbant is required in order to slow the flow rate at the higher pressure, e.g. Silica 60, 230 to 400 mesh (ASTM) with particle size 0.040-0.063mm (from Merck). The top of the adsorbant is layered with *ca* 1 cm of fine washed sand. The mixture in the smallest volume of solvent is applied at the top of the column and allowed to flow into the adsorbant under gravity by opening the lower tap momentarily. The top of the column is filled with eluent, the ball joint assembled, clipped together, the upper tap is connected by a tube to a nitrogen supply from a cylinder, or to compressed air, and turned on to the desired pressure (monitor with a gauge). The lower tap is turned on and fractions are collected rapidly until the level of eluent has reached the top of the adsorbant (do not allow the column to run dry). If further elution is desired then both taps are turned off, the column is filled with more eluting solvent and the process repeated. The top of the column can be modified so that gradient elution can be performed. Alternatively, an apparatus for producing the gradient is connected to the upper tap by a long tube and placed high above the column in order to produce the required hydrostatic pressure. Flash chromatography is more efficient and gives higher resolution than conventional chromatography at atmospheric pressure and is completed in a relatively shorter time. A successful separation of components of a mixture by TLC using the same adsorbant is a good indication that flash chromatography will give the desired separation on a larger scale.

Paired-ion Chromatography

Mixtures containing ionic compounds (e.g. acids and/or bases), non-ionisable compounds, and zwitterions, can be separated successfully by paired-ion chromatography (PIC). It utilises the 'reverse-phase' technique (Eksberg and Schill *AC* **45** 2092 *1973*). The stationary phase is lipophilic, such as μ-BONDAPAK C_{18} (Waters Assoc) or any other adsorbent that is compatible with water. The mobile phase is water or aqueous methanol containing the acidic or basic counter ion. Thus the mobile phase consists of dilute solutions of strong acids (e.g. 5mM 1-heptanesulphonic acid) or strong bases (e.g. 5 mM tetrabutylammonium phosphate) that are completely ionised at the operating *p*H values which are usually between 2 and 8. An equilibrium is set up between the neutral species of a mixture in the stationary phase and the respective ionised (anion or cation) species which dissolve in the mobile phase containing the counter ions. The extent of the equilibrium will depend on the ionisation constants of the respective components of the mixture, and the solubility of the unionised species in the stationary phase. Since the ionisation constants and the solubility in the stationary phase will vary with the water-methanol ratio of the mobile phase, the separation may be improved by altering this ratio gradually (gradient elution) or stepwise. If the compounds are eluted too rapidly the water content of the mobile phase should be increased, e.g. by steps of 10%. Conversely, if components do not move, or move slowly, the methanol content of the mobile phase should be increased by steps of 10%.

The application of pressure to the liquid phase in liquid chromatography generally increases the separation (see HPLC). Also in PIC improved efficiency of the column is observed if pressure is applied to the mobile phase (Wittmer, Nuessle and Haney *AC* **47** 1422 *1975*).

Ion-exchange Chromatography

Ion-exchange chromatography involves an electrostatic process which depends on the relative affinities of various types of ions for an immobilised assembly of ions of opposite charge. The stationary phase is an aqueous buffer with a fixed pH or an aqueous mixture of buffers in which the pH is continuously increased or decreased as the separation may require. This form of liquid chromatography can also be performed at high inlet pressures of liquid with increased column performances.

Ion-exchange Resins. An ion-exchange resin is made up of particles of an insoluble elastic hydrocarbon network to which is attached a large number of ionisable groups. Materials commonly used comprise synthetic ion-exchange resins made, for example, by crosslinking polystyrene to which has been attached non-diffusible ionised or ionisable groups. Resins with relatively high crosslinkage (8-12%) are suitable for the chromatography of small ions, whereas those with low crosslinkage (2-4%) are suitable for larger molecules. Applications to hydrophobic systems are possible using aqueous gels with phenyls bound to the rigid matrix (Phenyl-Superose, Pharmacia) or neopentyl chains (Alkyl-Superose, Pharmacia). (Superose is a cross-linked agarose-based medium with an almost uniform bead size.) These groups are further distinguishable as strong ($-SO_2OH$, $-NR_3^+$) or weak ($-OH$, $-CO_2H$, $-PO(OH)_2$, $-NH_2$). Their charges are counterbalanced by diffusible ions, and the operation of a column depends on its ability and selectivity to replace these ions. The exchange that takes place is primarily an electrostatic process but adsorptive forces and hydrogen bonding can also be important. A typical sequence for the relative affinities of some common anions (and hence the inverse order in which they pass through such a column), is the following, obtained using a quaternary ammonium (strong base) anion-exchange column:

Fluoride < acetate < bicarbonate < hydroxide < formate < chloride < bromate < nitrite < cyanide < bromide < chromate < nitrate < iodide < thiocyanate < oxalate < sulphate < citrate.

For an amine (weak base) anion-exchange column in its chloride form, the following order has been observed:

Fluoride < chloride < bromide = iodide = acetate < molybdate < phosphate < arsenate < nitrate < tartrate < citrate < chromate < sulphate < hydroxide.

With strong cation-exchangers, the usual sequence is that polyvalent ions bind more firmly than mono- or di- valent ones, a typical series being as follows:

$Th^{4+} > Fe^{3+} > Al^{3+} > Ba^{2+} > Pb^{2+} > Sr^{2+} > Ca^{2+} > Co^{2+} > Ni^{2+} = Cu^{2+} > Zn^{2+} = Mg^{2+} > UO_2^+ = Mn^{2+} > Ag^+ > Tl^+ > Cs^+ > Rb^+ > NH_4^+ = K^+ > Na^+ > H^+ > Li^+$.

Thus, if an aqueous solution of a sodium salt contaminated with heavy metals is passed through the sodium form of such a column, the heavy metal ions will be removed from the solution and will be replaced by sodium ions from the column. This effect is greatest in dilute solution. Passage of sufficiently strong solutions of alkali metal salts or mineral acids readily displaces all other cations from ion-exchange columns. (The regeneration of columns depends on this property.) However, when the cations lie well to the left in the above series it is often advantageous to use a complex-forming species to facilitate removal. For example, iron can be displaced from ion-exchange columns by passage of sodium citrate or sodium ethylenediaminetetraacetate.

Some of the more common commercially available resins are listed in Table 13.

Ion-exchange resins swell in water to an extent which depends on the amount of crosslinking in the polymer, so that columns should be prepared from the wet material by adding it as a suspension in water to a tube already partially filled with water. (This also avoids trapping air bubbles,) The exchange capacity of a resin is commonly expressed as mg equiv./ml of wet resin. This quantity is pH-dependent for weak-acid or weak-base resins but is constant at about 0.6-2 for most strong-acid or strong-base types.

Apart from their obvious applications to inorganic species, sulphonic acid resins have been used in purifying amino acids, aminosugars, organic acids, peptides, purines, pyrimidines, nucleosides, nucleotides and polynucleotides. Thus, organic bases can be applied to the H^+ form of such resins by adsorbing them from neutral solution and, after washing with water, they are eluted sequentially with suitable buffer solutions or dilute acids. Alternatively, by passing alkali solution through the column, the bases will be displaced in an order that is governed by their pK values. Similarly, strong-base anion exchangers have been used for aldehydes and ketones (as bisulphite addition compounds), carbohydrates (as their borate complexes), nucleosides, nucleotides, organic acids, phosphate esters and uronic acids. Weakly acidic and weakly basic exchange resins have also found extensive applications, mainly in resolving weakly basic and acidic species. For demineralisation of solutions without large changes in pH, mixed-bed resins can be prepared by mixing a cation-exchange resin in its H^+ form with an anion-exchange resin in its OH^- form. Commercial examples include Amberlite MB-1 (IR-120 + IRA-400) and Bio-Deminrolit (Zeo-Karb 225 and Zerolit FF). The latter is also available in a self-indicating form.

Ion-exchange Celluloses and Sephadex. A different type of ion-exchange column that is finding extensive application in biochemistry for the purification of proteins, nucleic acids and acidic polysaccharides derives from cellulose by incorporating acidic and basic groups to give ion-exchangers of controlled acid and basic strengths. Commercially available cellulose-type resins are given in Tables 14 and 15. AG 501 x 8 (Bio-Rad) is a mixed-bed resin containing equivalents of AG 50W-x8 H^+ form and AG 1-x8 OH^- form, and Bio-Rex MSZ 501 resin. A dye marker indicates when the resin is exhausted. Removal of unwanted cations, particularly of the transition metals, from amino acids and buffer can be achieved by passage of the solution through a column of Chelex 20 or Chelex 100. The metal-

acids and buffer can be achieved by passage of the solution through a column of Chelex 20 or Chelex 100. The metal-chelating abilities of the resin reside in the bonded iminodiacetate groups. Chelex can be regenerated by washing in two bed volumes of 1M HCl, two bed volumes of 1M NaOH and five bed volumes of water.
Ion-exchange celluloses are available in different particle sizes. It is important that the amounts of 'fines' are kept to a minimum otherwise the flow of liquid through the column can be extremely slow and almost stop. Celluloses with a large range of particle sizes should be freed from 'fines' before use. This is done by suspending the powder in the required buffer and allowing it to settle for one hour and then decanting the 'fines'. This separation appears to be wasteful but it is necessary for reasonable flow rates without applying high pressures at the top of the column. Good flow rates can be obtained if the cellulose column is packed dry whereby the 'fines' are evenly distributed throughout the column. Wet packing causes the fines to rise to the top of the column, which thus becomes clogged.
Several ion-exchange celluloses require recycling before use, a process which must be applied for recovered celluloses. Recycling is done by stirring the cellulose with 0.1M aqueous sodium hydroxide, washing with water until neutral, then suspending in 0.1M hydrochloric acid and finally washing with water until neutral. When regenerating a column it is advisable to wash with a salt solution (containing the required counter ions) of increasing ionic strength up to 2M. The cellulose is then washed with water and recycled if necessary. Recycling can be carried out more than once if there are doubts about the purity of the cellulose and when the cellulose had been used previously for a different purification procedure than the one to be used. The basic matrix of these ion-exchangers is cellulose and it is important not to subject them to strong acid (> 1M) and strongly basic (> 1M) solutions.
When storing ion-exchange celluloses, or during prolonged usage, it is important to avoid growth of microorganisms or moulds which slowly destroy the cellulose. Good inhibitors of microorganisms are phenyl mercuric salts (0.001%, effective in weakly alkaline solutions), chlorohexidine (Hibitane at 0.002% for anion exchangers), 0.02% aqueous sodium azide or 0.005% of ethyl mercuric thiosalicylate (Merthiolate) are most effective in weakly acidic solutions for cation exchangers. Trichlorobutanol (Chloretone, at 0.05% is only effective in weakly acidic solutions) can be used for both anion and cation exchangers. Most organic solvents (e.g. methanol) are effective antimicrobial agents but only at high concentrations. These inhibitors must be removed by washing the columns thoroughly before use because they may have adverse effects on the material to be purified (e.g. inactivation of enzymes or other active preparations).

In recent years other carbohydrate matrices such as *Sephadex* (based on dextran) have been developed which have more uniform particle sizes. Their advantages over the celluloses include faster and more reproducible flow rates and they can be used directly without removal of 'fines'.
Sephadex, which can also be obtained in a variety of ion-exchange forms (see Table 15) consists of beads of a cross-linked dextran gel which swells in water and aqueous salt solutions. The smaller the bead size the higher the resolution that is possible but the slower the flow rate. Typical applications of Sephadex gels are the fractionation of mixtures of polypeptides, proteins, nucleic acids, polysaccharides and for desalting solutions.
Sephadex is a bead form of cross-linked dextran gel. *Sepharose CL* and *Bio-Gel A* are derived from agarose. Sephadex ion-exchangers, unlike celluloses, are available in narrow ranges of particle sizes. These are of two medium types, the G-25 and G-50, and their dry bead diameter sizes are *ca* 50 to 150 microns. They are available as cation and anion exchange Sephadex. One of the disadvantages of using Sephadex ion-exchangers is that the bed volume can change considerably with alteration of pH. *Ultragels* also suffer from this disadvantage to a varying extent, but ion-exchangers of the bead type have been developed e.g. *Fractogels, Toyopearl*, which do not suffer from this disadvantage.

Sepharose (e.g. *Sepharose CL and Bio-Gel A*) is a bead form of agarose gel which is useful for the fractionation of high molecular weight substances, for molecular weight determinations of large molecules (molecular weight > 5000), and for the immobilisation of enzymes, antibodies, hormones and receptors usually for affinity chromatography applications.
In preparing any of the above for use in columns, the dry powder is evacuated, then mixed under reduced pressure with water or the appropriate buffer solution. Alternatively it is stirred gently with the solution until all air bubbles are removed. Because some of the wet powders change volumes reversibly with alteration of pH or ionic strength (see above), it is imperative to make allowances when packing columns (see above) in order to avoid overflowing of packing when the pH or salt concentrations are altered.

Cellex CM ion-exchange cellulose can be purified by treatment of 30-40g (dry weight) with 500ml of 1mM cysteine hydrochloride. It is then filtered through a Büchner funnel and the filter cake is suspended in 500ml of 0.05M NaCl/0.5M NaOH. This is filtered and the filter cake is resuspended in 500ml of distd water and filtered again. The process is repeated until the washings are free from chloride ions. The filter cake is again suspended in 500ml of 0.01M buffer at the desired pH for chromatography, filtered, and the last step repeated several times.
Cellex D and other anionic celluloses are washed with 0.25M NaCl/0.25M NaOH solution, then twice with deionised water. This is followed with 0.25M NaCl and then washed with water until chloride-free. The Cellex is then equilibrated with the desired buffer as above.

Crystalline Hydroxylapatite is a structurally organised, highly polar material which, in aqueous solution (in buffers) strongly adsorbs macromolecules such as proteins and nucleic acids, permitting their separation by virtue of the interaction with charged phosphate groups and calcium ions, as well by physical adsorption. The

procedure therefore is not entirely ion-exchange in nature. Chromatographic separations of singly and doubly stranded DNA are readily achievable whereas there is negligible adsorption of low molecular weight species.

Gel Filtration

The gel-like, bead nature of wet Sephadex (a modified dextran) enables small molecules such as inorganic salts to diffuse freely into it while, at the same time, protein molecules are unable to do so. Hence, passage through a Sephadex column can be used for complete removal of salts from protein solutions. Polysaccharides can be freed from monosaccharides and other small molecules because of their differential retardation. Similarly, amino acids can be separated from proteins and large peptides.

Gel filtration using Sephadex G-types (50 to 200, from Pharmacia, Uppsala, Sweden) is essentially useful for fractionation of large molecules with molecular weights above 1000. For Superose (Pharmacia) the range is given as 5000 to 5 x 10^6. Fractionation of lower molecular weight solutes (e,g, ethylene glycols, benzyl alcohols) can now be achieved with Sephadex G-10 (up to Mol.Wt 700) and G-25 (up to Mol.Wt 1500). These dextrans are used only in aqueous solutions. More recently, however, Sephadex LH-20 and LH-60 (prepared by hydroxypropylation of Sephadex) have become available and are used for the separation of small molecules (Mol.Wt less than 500) using most of the common organic solvents as well as water.

Sephasorb HP (ultrafine, prepared by hydroxypropylation of crossed-linked dextran) can also be used for the separation of small molecules in organic solvents and water, and in addition it can withstand pressures up to 1400 psi making it useful in HPLC. Because solutions with high and low pH values slowly decompose, these gels are best operated at pH values between 2 and 12 (see further in Chapter 5).

High Performance Liquid Chromatography (HPLC)

When pressure is applied at the inlet of a liquid chromatographic column the performance of the column can be increased by several orders of magnitude. This is partly because of the increased speed at which the liquid flows through the column and partly because fine column packings can be used which have larger surface areas. Because of the improved efficiency of the columns this technique has been referred to as high performance, high pressure, or high speed liquid chromatography.

Equipment consists of a hydraulic system to provide the pressure at the inlet of the column, a column, a detector and a recorder. The pressures used in HPLC vary from a few psi to 4000-5000 psi. The most convenient pressures are, however, between 500 and 1800psi. The plumbing is made of stainless steel or non-corrosive metal tubing to withstand high pressures. Plastic tubing and connectors are used for low pressures, e.g. up to ~500psi. Increase of temperature has a very small effect on the performance of a column in liquid chromatography. Small variations in temperatures, however, do upset the equilibrium of the column, hence it is advisable to place the column in an oven at ambient temperature in order to achieve reproducibility. The packing (stationary phase) is specially prepared for withstanding high pressures. It may be an adsorbent (for adsorption or solid-liquid HPLC), a material impregnated with a high boiling liquid (e.g. octadecyl sulphate, in *reverse-phase* or *liquid-liquid or paired-ion* HPLC), an ion-exchange material (in *ion-exchange* HPLC), or a highly porous non-ionic gel (for high performance *gel filtration*). The mobile phase is water, aqueous buffers, salt solutions, organic solvents or mixtures of these. The more commonly used detectors have UV, visible, or fluorescence monitoring for light absorbing substances, and refractive index monitoring for transparent compounds. The sensitivity of the refractive index monitoring is usually lower than the light absorpting monitoring by a factor of ten or more. The cells of the monitoring devices are very small (*ca* 5 µl) and the detection is very good. The volumes of the analytical columns are quite small (*ca* 2ml for a 1 metre column) hence the result of an analysis is achieved very quickly. Larger columns have been used for preparative work and can be used with the same equipment. Most modern machines have solvent mixing chambers for solvent gradient or ion gradient elution. The solvent gradient (for two solvents) or pH or ion gradient can be adjusted in a linear, increasing or decreasing exponential manner. Some of the more common column packings are listed in Table 16.

Purification of stereoisomers has been achieved by applying HPLC using a chiral stationary phase such as (*R*)-*N*-3,5-dinitrobenzoylphenylglycine or (*S*)-3,5-dinitrobenzoylleucine. Examples covering a wide range of compounds are given in references by Pirkle et al. in *JACS* **103** 3964 *1981*, and *ACS Symposium Series no 185, "Asymmetric Reactions and Processes in Chemistry"*, Eliel and Otsuka eds (*Amer Chem Soc*, Washington DC, *pp* 245-260, *1982*); see more recent references on *chiral chromatography* on p 44.

Other Types of Liquid Chromatography

New stationary phases for specific purposes in chromatographic separation are being continually proposed. *Charge transfer adsorption chromatography* makes use of a stationary phase which contains immobilised aromatic compounds and permits the separation of aromatic compounds by virtue of the ability to form charge

transfer complexes (sometimes coloured) with the stationary phase. The separation is caused by the differences in stability of these complexes (Porath and Dahlgren-Caldwell *JC* **133** 180 *1977*).
In *metal chelate adsorption chromatography* a metal is immobilised by partial chelation on a column which contains bi- or tri- dentate ligands. Its application is in the separation of substances which can complex with the bound metals and depends on the stability constants of the various ligands (Porath, Carlsson, Olsson and Belfrage *Nature* **258** 598 *1975*; Loennerdal, Carlsson and Porath *FEBS LETT* **75** 89 *1977*).
An application of chromatography which has found extensive use in biochemistry and has brought a new dimension in the purification of enzymes is *affinity chromatography*. A specific enzyme inhibitor is attached by covalent bonding to a stationary phase (e.g. AH-Sepharose 4B for acidic inhibitors and CH-Sepharose 4B for basic inhibitors), and will strongly adsorb only the specific enzyme which is inhibited, allowing all other proteins to flow through the column. The enzyme is then eluted with a solution of high ionic strength (e.g. 1M sodium chloride) or a solution containing a substrate or reversible inhibitor of the specific enzyme. (The ionic medium can be removed by gel filtration using a mixed-bed gel.) Similarly, an immobilised lectin may interact with the carbohydrate moiety of a glycoprotein. The most frequently used matrixes are cross-linked (4-6%) agarose and polyacrylamide gel. Many adsorbents are commercially available for nucleotides, coenzymes and vitamins, amino acids, peptides and lectins. Considerable purification can be achieved by one passage through the column and the column can be reused several times.
The affinity method may be *biospecific*, for example as an antibody-antigen interaction chemical as in the chelation of boronate by *cis*-diols, or of unknown origin as in the binding of certain dyes to albumin.

Hydrophobic adsorption chromatography takes advantage of the hydrophobic properties of substances to be separated and has also found use in biochemistry (Hoftsee *BBRC* **50** 751 *1973*; Jennissen and Heilmayer Jr *Biochemistry* **14** 754 *1975*). Specific covalent binding with the stationary phase, a procedure that was called *covalent chromatography*, has been used for separation of compounds and for immobilising enzymes on a support: the column was then used to carry out specific bioorganic reactions (Mosbach *Methods in Enzymology* **44**, 1976; A.Rosevear, J.F.Kennedy and J.M.S.Cabral, *Immobilised Enzymes and Cells: A Laboratory Manual*, Adam Hilger, Bristol, 1987).

Vapour Phase Chromatography

The mobile phase in vapour phase chromatography is a gas (e.g. hydrogen, helium, nitrogen or argon) and the stationary phase is a non-volatile liquid impregnated onto a porous material. The mixture to be purified is injected into a heated inlet whereby it is vaporised and taken into the column by the carrier gas. It is separated into its components by partition between the liquid on the porous support and the gas. For this reason vapour-phase chromatography is sometimes referred to as gas-liquid chromatography.

Although this technique was first used for analytical purposes in 1952, its application to the purification of chemicals at a preparative level is much more recent and commercial instruments for this purpose are currently in a state of rapid development. This type of partition chromatography uses a tubular column packed with an inert material which is impregnated with a liquid. This liquid separates components of gases or vapours as they flow through the column. On a preparative scale, use of a large column heated slightly above the boiling point of the material to be processed makes it possible to purify in this way small quantities of many volatile organic substances. For example, if the impurities have a greater affinity for the liquid in the column than the desired component has, the latter will emerge first and in a substantially pure form.
In operation, the organic material is carried as a vapour in a *carrier* gas such as hydrogen, helium, carbon dioxide, nitrogen or argon (in a manner analogous to a solution in a suitable solvent in liquid chromatography). The technique that is almost invariably used is to inject the substance (for example, by means of a hypodermic syringe) over a relatively short time on to the surface of the column through which is maintained a slow continuous passage of the chemically inert carrier gas. This leads to the progressive elution of individual components from the column in a manner analogous to the movement of bands in conventional chromatography. As substances emerge from the column they can be condensed in suitable traps. The carrier gas blows the vapour through these traps hence these traps have to be very efficient. Improved collection of the effluent vaporised fractions in preparative work is attained by strong cooling, increasing the surface of the traps by packing them with glass wool, and by applying an electrical potential which neutralises the charged vapour and causes it to condense.
The choice of carrier gas is largely determined by the type of detection system that is available (see below). Column efficiency is greater in argon, nitrogen or carbon dioxide than it is in helium or hydrogen, but the latter are less impeded by flowing through packed columns so that lower pressure differentials exist between inlet and outlet. The packing in the column is usually an inert supporting material such as powdered firebrick, or a firebrick-Celite mixture

coated with a high-boiling organic liquid as the stationary phase. These liquids include Apiezon oils and greases, di-esters (such as dibutylphthalate or di-2-ethylhexyl sebacate), polyesters (such as diethyleneglycol sebacate), polyethylene glycols, hydrocarbons (such as Nujol or squalene), silicone oils and tricresyl phosphate.
The coating material (about 75ml per 100ml of column packing) is applied as a solution in a suitable solvent such as methylene chloride, acetone, methanol or pentane, which is then allowed to evaporate in air, over a steam-bath, or in a vacuum oven (provided the adsorbed substance is sufficiently non-volatile). The order in which a mixture of substances travels through such columns depends on their relative solubilities in the materials making up the stationary phases.

Stationary Phase	Mixture
Benzyl diphenyl	Aromatic molecules
Benzyl ether	Saturated hydrocarbons and olefines
Bis(2-*n*-butoxyethyl)phthalate	Saturated hydrocarbons and olefines
Diethylene glycol adipate	Methyl esters of fatty acids up to C_{24}
Dimethyl sulpholane (below 40°)	Saturated and unsaturated hydrocarbons
Dinonyl phthalate	Paraffins, olefines, low molecular weight aromatics, alcohols (up to amyl alcohol), lower ethers, esters and carbonyl compounds.
Hexadecane	Low-boiling hydrocarbons
Mineral oil	Aliphatic and aromatic amines
2,2'-Oxydipropionitrile	Paraffins, cycloalkanes, olefines, ethers, alkylbenzenes, acetates, aldehydes, alcohols, acetals and ketones
Polyethylene glycols	Aromatic molecules from paraffins
Silicone oil	Aromatic hydrocarbons, alcohols, esters
Silicone-stearic acid	Fatty acids
Squalane	Saturated hydrocarbons
Tricresyl phosphate	Hexanes, heptanes, aromatics, organic sulphur compounds and aliphatic chlorides

The three main requirements of a liquid for use in a gas chromatograph column are that it must have a high boiling point, a low vapour pressure, and at the same time permit adequate separation of components fairly rapidly. As a rough guide, the boiling point should be at least 250° above the temperature of the column, and, at column temperatures, the liquid should not be too viscous, nor should it react chemically with the sample. Liquids suitable for use as stationary phases in gas chromatography are given in Table 17 and above.
Where the stationary phase is chemically similar to the material to be separated, the main factors governing the separation will be the molecular weight and the shape. Otherwise, polar interactions must also be considered, for example hydroxylated compounds used for stationary phases are likely to retard the movement through the column of substances with hydrogen accepting groups. A useful guide to the selection of a suitable stationary phase is to compare, on the basis of polarity, possible materials with the components to be separated. This means that, in general, solute and solvent will be members of the same, or of adjacent, classes in the following groupings:

A. Water, polyhydric alcohols, aminoalcohols, oxyacids, polyphenols, di- and tri-carboxylic acids.
B. Alcohols, fatty acids, phenols, primary and secondary amines, oximes, nitro compounds, nitriles with α-H atoms.
C. Ethers, ketones, aldehydes, esters, tertiary amines, nitriles without α-H atoms.
D. Chlorinated aromatic or olefinic hydrocarbons.
E. Saturated hydrocarbons, carbon disulphide, tetrachloromethane.

Material emerging from the column is detected by a thermal-conductivity cell, an ionisation method, or a gas-density balance.
The first of these methods, which is applicable when hydrogen or helium is used as carrier gas, depends on the differences in heat conductivities between these gases and most others, including organic substances. The resistance of a tungsten or platinum wire heated by a constant electric current will vary with its temperature which, in turn, is a function of the thermal conductivity through the gas. These devices, also known as catharometers, can detect about 10^{-8} moles of substance. When argon is used as carrier gas, an ionisation method is practicable. It is based on measurement of the current between two electrodes at different voltages in the presence of a suitable emitter of ß-radiation. The gas-density balance method depends on measurement of the difference in thermal e.m.f. between two equally warmed copper-constantan thermocouples located in the cross-channel of what constitutes a mechanical equivalent to the Wheatstone bridge. Any increase in density of the effluent gas relative to the reference gas will cause

movement of gas along the cross-channel, and hence cool one of the thermocouples relative to the other. The technique is comparable in sensitivity with the thermal-conductivity method.

More recently *glass capillary columns* have been used. These columns can be several metres long. The glass capillary wall acts as the support onto which is coated the liquid phase. These columns have much superior separating powers than the conventional columns. In some cases the resolution is so good that enantiomeric and diastereomeric compounds have been separated. When these columns are attached to a mass spectrometer a very powerful analytical tool (*gas chromatography-mass spectrometry*; **GC-MS**) is produced. Because of the relatively small amounts of material required for mass spectrometry, a splitting system is inserted between the column and the mass spectrometer. This enables only a small fraction of the effluent to enter the spectrometer, the rest of the effluent is usually vented to the air. Even more recently a liquid chromatographic column has replaced the gas chromatographic column in the chromatography-mass spectrometry analyses

Paper Chromatography

Paper chromatography is basically a type of partition chromatography between water adsorbed onto the cellulose fibre of the paper and a liquid mobile phase in a closed tank. The most common application is the ascending solvent technique. The paper is hung by means of clips or string and the lower end is made to dip into the eluting solvent. The material under test is applied as a spot 2.5 cm or so above the lower end of the paper and marked with a pencil. It is important that the spots are above the eluting solvent before it begins to rise up the paper by capillarity. Eluents are normally aqueous mixtures of organic solvents, acids or bases. (For solvent systems see Lederer and Lederer, p 44). The descending technique has also been used, and in this case the top of the paper dips into a trough containing the eluent which travels downwards, also by capillarity. The spots are applied at the top of the paper close to the solvent trough. A closed tank is necessary for these operations because better reproducibility is achieved if the solvent and vapour in the tank are in equilibrium. The tanks have to be kept away from draughts. Elution times vary from several hours to a day depending on the solvent system and paper. For more efficient separations the dried paper is eluted with a different solvent along a direction which is 90° from that of the first elution. This is referred as *two dimensional paper chromatography*. In a third application (*circular paper chromatography*) ordinary circular filter papers are used. The filter paper is placed between two glass plates. The upper plate has a hole in the centre which is coincident with the centre of the paper. A strong solution of the mixture is then separated radially by the eluting solvent. A strong solution of the mixture is placed in this hole followed by the eluting solvent. After the solvents have travelled the required distances in the above separations, the papers are air dried and the spots are revealed by their natural colours or, by spraying with a reagent that forms a coloured product with the spots. In many cases, the positions of the spots can be seen as light fluorescing or absorbing spots when viewed under UV light.
The use of *thick paper* such as Whatman nos 3 or 31 (0.3-0.5mm) increases the amounts that can be handled (up to about 100mg per sheet). Larger quantities require multiple sheets or cardboard, e.g. Scheicher and Schüll nos 2071 (0.65mm), 2230 (0.9mm) or 2181 (4mm). For even larger amounts recourse may be had to *chromatopack* or *chromatopile* procedures. The latter use a large number (200-500) of identical filter papers stacked and compressed in a column, the material to be purified being adsorbed onto a small number of these discs which, after drying, are placed almost at the top of the column. The column is then subjected to descendiing development, and bands are separated mechanically by disassembling the filter papers. Instead of filter papers, *cellulose powder* may be suitable, the column being packed by first suspending the powder in the solvent to be used for development. Yet another variation employs tightly wound *paper roll columns* contained in thin polythene skins. (These are unsuitable for such solvents as benzene, chloroform, collidine, ethyl ether, pyridine and toluene).
The technique of paper chromatography has been almost entirely superseded by thin- or thick-layer chromatography (see below).

Thin or Thick Layer Chromatography (TLC)

Thin layer chromatography is in principle similar to paper chromatography when used in the ascending method, i.e. the solvent creeps up the stationary phase by capillarity. The adsorbent (e.g. silica, alumina, cellulose) is spread on a rectangular glass plate (or solid inert plastic sheet). Some adsorbents (e.g. silica) are mixed with a setting material (e.g. $CaSO_4$) by the manufacturers which causes the film to set on drying. The adsorbent can

be activated by heating at 100-110° for a few hours. Other adsorbents (e.g. celluloses) adhere on glass plates without a setting agent. The materials to be purified are spotted in the solvent close to the lower end of the plate and allowed to dry. The spots will need to be placed at such a distance as to ensure that when the lower end of the plate is immersed in the solvent, the spots are a few mm above the eluting solvent. The plate is placed upright in a tank containing the eluting solvent. Elution is carried out in a closed tank as in paper chromatography to ensure equilibrium. It requires less than three hours for the solvent to reach the top of the plate. Good separations can be achieved with square plates if a second elution is performed at right angles to the first as in two dimensional paper chromatography. For rapid work plates of the size of microscopic slides or even smaller are used which can decrease the elution time to as little as fifteen minutes without loss of resolution. The advantage of plastic backed plates is that the size of the plate can be made as required by cutting the sheet with scissors.

The thickness of the plates could be between 0.2mm to 2mm or more. The thicker plates are used for preparative work in which hundreds of milligrams of mixtures can be purified conveniently and quickly. The spots or areas are easily scraped off the plates and eluted with the required solvent. These can be revealed on the plates by UV light if they are UV absorbing or fluorescing substances, by spraying with a reagent that gives coloured products with the spot (e.g. iodine solution or vapour gives brown colours with amines), or with dilute sulphuric acid (organic compounds become coloured or black when the plates are heated at 100°) if the plates are of alumina or silica, but not cellulose. Some alumina and silica powders are available with fluorescent materials in them, in which case the whole plate fluoresces under UV light. Non-fluorescing spots are thus clearly visible, and fluorescent spots invariably fluoresce with a different colour. The colour of the spots can be different under UV light at 254nm and at 365nm. Another useful way of showing up non-UV absorbing spots is to spray the plate with a 1-2% solution of Rhodamine 6G in acetone. Under UV light the dye fluoresces and reveals the non-fluorescing spots. If the material in the spot is soluble in ether, benzene or light petroleum, the spots can be extracted from the powder with these solvents which leave the water soluble dye behind.

Thin and thick layer chromatography have been used successfully with ion-exchange celluloses as stationary phases and various aqueous buffers as mobile phases. Also, gels (e.g. Sephadex G-50 to G-200 superfine) have been adsorbed on glass plates and are good for fractionating substances of high molecular weights (1500 to 250,000). With this technique, which is called *thin layer gel filtration* (**TLG**), molecular weights of proteins can be determined when suitable markers of known molecular weights are run alongside.

Commercially available precoated plates with a variety of adsorbents are generally very good for quantitative work because they are of a standard quality. More recently plates of a standardised silica gel 60 (as medium porosity silica gel with a mean porosity of 6mm) were released by Merck. These have a specific surface of 500 m^2/g and a specific pore volume of 0.75 ml/g. They are so efficient that they have been called *high performance thin layer chromatography* (**HPTLC**) plates (Ropphahn and Halpap *JC* **112** 81 *1975*). In another variant of thin layer chromatography the adsorbent is coated with an oil as in gas chromatography thus producing *reverse-phase thin layer chromatography*.

A very efficient thin layer form of circular paper chromatography makes use of a circular glass disc coated with an adsorbent (silica, alumina or cellulose). The apparatus is called a **Chromatotron** (available from Harrison Research, USA). The disc is rotated by a motor, and the sample followed by the eluting solvent are allowed to drip onto a central position on the plate. As the plate rotates the solvent elutes the mixture, centrifugally, while separating the components in the form of circles radiating from the central point. When elution is complete the revolving circular plate is stopped and the circular bands are scraped off and extracted with a suitable solvent.

SOLVENT EXTRACTION AND DISTRIBUTION

Extraction of a substance from suspension or solution into another solvent can sometimes be used as a purification process. Thus, organic substances can often be separated from inorganic impurities by shaking an aqueous solution or suspension with suitable immiscible solvents such as benzene, carbon tetrachloride, chloroform, ethyl ether, isopropyl ether or petroleum ether. After several such extractions the combined organic phase is dried and the solvent is evaporated. Grease from the glass taps of conventional separating funnels is invariably soluble in the solvents used. Contamination with grease can be very troublesome particularly when the amounts of material to be extracted are very small. Instead, the glass taps should be lubricated with the extraction solvent; or better, the taps of the extraction funnels should be made of the more expensive material *Teflon*. Immiscible solvents suitable for extractions are given in Table 18. Addition of electrolytes (such as ammonium sulphate, calcium chloride or sodium chloride) to the aqueous phase helps to ensure that the organic

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layer separates cleanly and also decreases the extent of extraction into the latter. Emulsions can also be broken up by filtration (with suction) through Celite, or by adding a little octyl alcohol or some other paraffinic alcohol. The main factor in selecting a suitable immiscible solvent is to find one in which the material to be extracted is readily soluble, whereas the substance from which it is being extracted is not. The same considerations apply irrespective of whether it is the substance being purified, or one of its contaminants, that is taken into the new phase. (The second of these processes is described as washing.)

Common examples of washing with aqueous solutions include the following:

Removal of acids from water-immiscible solvents by washing with aqueous alkali, sodium carbonate or sodium bicarbonate.

Removal of phenols from similar solutions by washing with aqueous alkali.

Removal of organic bases by washing with dilute hydrochloric or sulphuric acids.

Removal of unsaturated hydrocarbons, of alcohols and of ethers from saturated hydrocarbons or alkyl halides by washing with cold concentrated sulphuric acid.

This process can also be applied to purification of the substance if it is an acid, a phenol or a base, by extracting into the appropriate aqueous solution to form the salt which, after washing with pure solvent, is again converted to the free species and re-extracted. Paraffin hydrocarbons can be purified by extracting them with phenol (in which aromatic hydrocarbons are highly soluble) prior to fractional distillation.

For extraction of solid materials with a solvent, a *Soxhlet* extractor is commonly used. This technique is applied, for example, in the alcohol extraction of dyes to free them from insoluble contaminants such as sodium chloride or sodium sulphate.

Acids, bases and amphoteric substances can be purified by taking advantage of their ionisation constants. Thus an acid can be separated from other acidic impurities which have different pK_a values and from basic and neutral impurities, by extracting a solution of the organic acid into an organic solvent (e.g. benzene or amyl alcohol) with a set of inorganic buffers of increasing pH (see Table 19). The acid will dissolve to form its salt in a set of buffers of pH greater than the pK_a value. It can then be isolated by adding excess mineral acid to the buffer and extracting the free acid with an organic solvent. On a large scale, a *countercurrent distribution* machine (e.g. Craig type, see Quickfit and Quartz catalogue) can be used. In this way a very large number of liquid-liquid extractions can be carried out automatically. The closer the ionisation constants of the impurities are to those of the required material, the larger should the be the number of extractions to effect a good separation. A detailed discussion is available in review articles such as that in C.G.Casinovi's review, "A Comprehensive Bibliography of Separations of Organic Substances by Countercurrent Distribution" in *Chromatographic Reviews* **5** 161 *1963*, and references on p. 47 under *Solvents, Solvent Extraction and Distribution.* This technique, however, appears to have been displaced almost completely by chromatographic methods.

MOLECULAR SIEVES

Molecular sieves are types of adsorbents composed of crystalline zeolites (sodium and calcium aluminosilicates). By heating them, water of hydration is removed, leaving holes of molecular dimensions in the crystal lattices. These holes are of uniform size and allow the passage into the crystals of small molecules, but not of large ones. This *sieving* action explains their use as very efficient drying agents for gases and liquids. The pore size of these sieves can be modified (within limits) by varying the cations built into the lattices. The three types of Linde (Union Carbide) molecular sieves currently available are:

Type 4A, a crystalline sodium aluminosilicate.
Type 5A, a crystalline calcium aluminosilicate.
Type 13X, a crystalline sodium aluminosilicate.

They are unsuitable for use with strong acids but are stable over the pH range 5-11.

Type 4A sieves. The pore size is about 4 Angstroms, so that, besides water, the ethane molecules (but not butane) can be adsorbed. Other molecules removed from mixtures include carbon dioxide, hydrogen sulphide, sulphur dioxide, ammonia, methanol, ethanol, ethylene, acetylene, propylene, *n*-propyl alcohol, ethylene oxide and (below -30°) nitrogen, oxygen and methane. The material is supplied as beads, pellets or powder.

Type 5A sieves. Because the pore size is about 5 Angstroms, these sieves adsorb larger molecules than type 4A. For example, as well as the substances listed above, propane, butane, hexane, butene, higher *n*-

olefines, *n*-butyl alcohol and higher *n*-alcohols, and cyclopropane can be adsorbed, but not branched-chain C_6 hydrocarbons, cyclic hydrocarbons such as benzene and cyclohexane, or secondary and tertiary alcohols, carbon tetrachloride or boron trifluoride. This is the type generally used for drying gases.

Type 13X sieves. Their pore size of about 10 Angstroms enables many branched-chain and cyclic materials to be adsorbed, in addition to all the substances taken out by type 5A sieves.

Because of their selectivity, molecular sieves offer advantages over silica gel, alumina or activated charcoal, especially in their very high affinity for water, polar molecules and unsaturated organic compounds. Their relative efficiency is greatest when the impurity to be removed is present at low concentrations. Thus, at 25° and a relative humidity of 2%, type 5A molecular sieves adsorb 18% by weight of water, whereas for silica gel and alumina the figures are 3.5 and 2.5% respectively. Even at 100° and a relative humidity of 1.3% molecular sieves adsorb about 15% by weight of water.

The much greater preference of molecular sieves for combining with water molecules explains why this material can be used for drying ethanol and why molecular sieves are probably the most universally useful and efficient drying agent. Percolation of ethanol with an initial water content of 0.5% through a 57-in long column of type 4A molecular sieves reduced the water content to 10ppm. Similar results have been obtained with pyridine.

The main applications of molecular sieves to purification comprise:

1. Drying of gases and liquids containing traces of water.
2. Drying of gases at elevated temperatures.
3. Selective removal of impurities (including water) from gas streams.

(For example, carbon dioxide from air or ethylene; nitrogen oxides from nitrogen; methanol from ethyl ether. In general, carbon dioxide, carbon monoxide, ammonia, hydrogen sulphide, mercaptans, ethane, ethylene, acetylene, propane and propylene are readily removed at 25°. In mixtures of gases, the more polar ones are preferentially adsorbed).

The following applications include the removal of straight-chain from branched-chain or cyclic molecules. For example, type 5A sieves will adsorb *n*-butyl alcohol but not its branched-chain isomers. Similarly, it separates *n*-tetradecane from benzene, or *n*-heptane from methylcyclohexane. A logical development is the use of molecular sieves as chromatographic columns for particular preparations.

The following liquids have been dried with molecular sieves: acetone, acetonitrile, acrylonitrile, allyl chloride, amyl acetate, benzene, butadiene, *n*-butane, butene, butyl acetate, *n*-butylamine, *n*-butyl chloride, carbon tetrachloride, chloroethane, 1-chloro-2-ethylhexane, cyclohexane, dichloromethane, dichloroethane, 1,2-dichloropropane, 1,1-dimethoxyethane, dimethyl ether, 2-ethylhexanol, 2-ethylhexylamine, *n*-heptane, *n*-hexane, isoprene, isopropyl alcohol, isopropyl ether, methanol, methyl ethyl ketone, oxygen, *n*-pentane, phenol, propane, *n*-propyl alcohol, propylene, pyridine, styrene, tetrachloroethylene, toluene, trichloroethylene and xylene. In addition, the following gases have been dried: acetylene, air, argon, carbon dioxide, chlorine, ethylene, helium, hydrogen, hydrogen chloride, hydrogen sulphide, nitrogen, oxygen and sulphur hexafluoride.

After use, molecular sieves can be regenerated by heating at between 150° and 300° for several hours, preferably in a stream of dry air, then cooling in a desiccator.

However, care must be exercised in using molecular sieves for drying organic liquids. Appreciable amounts of impurities were *formed* when samples of acetone, 1,1,1-trichloroethane and methyl-*t*-butyl ether were dried in the liquid phase by contact with molecular sieves 4A (Connett *Lab.Practice* **21** 545 *1972*). Other, less reactive types of sieves may be more suitable but, in general, it seems desirable to make a preliminary test to establish that no unwanted reaction takes place. For the principles of synthesis and identification see R. Szostak *Molecular Sieves*, Chapman & Hall, London *1988*, and for structure, synthesis and properties see R.Szostak *Handbook of Molecular Sieves*, Chapman & Hall 1992.

SOME HAZARDS OF CHEMICAL MANIPULATION IN PURIFICATION AND RECOVERY FROM RESIDUES

Performing chemical manipulations calls for some practical knowledge if danger is to be avoided. However, with care, hazards can be kept to an acceptable minimum. A good general approach is to consider every operation as potentially perilous and then to adjust one's attitude as the operation proceeds. A few of the commonest dangers are set out below. For a larger coverage of the following sections, and of the literature, the bibliography at the end of this chapter should be consulted. Several precautions on **Safety in the chemical laboratory** have been emphasised earlier in this monograph on page 3.

Perchlorates and perchloric acid. At 160° perchloric acid is an exceedingly strong oxidising acid and a strong dehydrating agent. Organic perchlorates, such as methyl and ethyl perchlorates, are unstable and are violently

explosive compounds. A number of heavy-metal perchlorates are extremely prone to explode. The use of anhydrous magnesium perchlorate *anhydrone* as a drying agent for organic vapours is **not** recommended. Desiccators which contain this drying agent should be adequately shielded at all times and kept in a cool place, i.e **never** on a window sill where sunlight can fall on it.
No attempt should be made to purify perchlorates, except for ammonium, alkali metal and alkaline earth salts which, in water or aqueous alcoholic solutions are insensitive to heat or shock. Note that perchlorates react relatively slowly in aqueous organic solvents, but as the water is removed there is an increased possibility of an explosion. Perchlorates, often used in non-aqueous solvents, are explosive in the presence of even small amounts of organic compounds when heated. Hence stringent care should be taken when purifying perchlorates, and direct flame and infrared lamps should be avoided. Tetra-alkylammonium perchlorates should be dried below 50° under vacuum (and protection). Only very small amounts of such materials should be prepared, and stored, at any one time.

Peroxides. These are formed by aerial oxidation or by autoxidation of a wide range of organic compounds, including ethyl ether, allyl ethyl ether, allyl phenyl ether, benzyl ether, benzyl butyl ether, *n*-butyl ether, *iso*-butyl ether, *t*-butyl ether, dioxane, tetrahydrofuran, olefines, and aromatic and saturated aliphatic hydrocarbons. They accumulate during distillation and can detonate violently on evaporation or distillation when their concentration becomes high. If peroxides are likely to be present materials should be tested for peroxides before distillation (for tests see entry under "Ethers", in Chapter 2). Also, distillation should be discontinued when at least one quarter of the residue is left in the distilling flask.

Heavy-metal-containing explosives. Ammoniacal silver nitrate, on storage or treating, will eventually deposit the highly explosive silver nitride *"fulminating silver"*. Silver nitrate and ethanol may give silver fulminate (see Chapter 4), and in contact with azides or hydrazine and hydrazides may form silver azide. Mercury can form such compounds. Similarly, ammonia or ammonium ions can react with gold salts to form *"fulminating gold"*. Metal fulminates of cadmium, copper, mercury and thallium are powerfully explosive, and some are detonators [Luchs, *Photog Sci Eng* **10** 334 *1966*]. Heavy metal containing solutions, particularly when organic material is present should be treated with great respect and precautions towards possible explosion should be taken.

Strong acids. In addition to perchloric acid (see above), extra care should be taken when using strong mineral acids. Although the effects of concentrated sulphuric acid are well known these cannot be stressed strongly enough. Contact with tissues will leave irreparable damage. **ALWAYS DILUTE THE CONCENTRATED ACID BY CAREFULLY ADDING THE ACID DOWN THE SIDE OF THE FLASK WHICH CONTAINS WATER, AND THE PROCESS SHOULD BE CARRIED OUT UNDER COOLING. THIS SOLUTION IS NOT SAFE TO HANDLE UNTIL THE ACID HAS BEEN THOROUGHLY MIXED WITH THE WATER. PROTECTIVE FACE AND BODY COVERAGE SHOULD BE USED AT ALL TIMES.** Fuming sulphuric acid and chlorosulphonic acid are even more dangerous than concentrated sulphuric acid and adequate precautions should be taken. Chromic acid cleaning mixture (hot and cold, see p.4) contains strong sulphuric acid and should be treated in the same way; and in addition the mixture is potentially *carcinogenic*.
Concentrated and fuming nitric acids are also dangerous because of their severe deleterious effects on tissues.

Reactive halides and anhydrides. Substances like acid chlorides, low molecular weight anhydrides and some inorganic halides (e.g. PCl_3) can be **HIGHLY TOXIC, LACHRYMATORY AFFECTING MUCOUS MEMBRANES AND LUNG TISSUES. UTMOST CARE SHOULD BE TAKEN WHEN WORKING WITH THESE MATERIALS. WORK SHOULD BE DONE IN A VERY EFFICIENT FUMECUPBOARD.**

Solvents. The flammability of low-boiling organic liquids cannot be emphasised strongly enough. These invariably have very low flash points and can ignite spontaneously. Special precautions against explosive flammability should be taken when recovering such liquids. Care should be taken with small volumes (*ca* 250ml) as well as large volumes (> 1L), and the location of all the fire extinguishers, and fire blankets, in the immediate vicinity of the apparatus should be checked. The fire extinguisher should be operational. The following flammable liquids (in alphabetical order) are common fire hazards in the laboratory: acetaldehyde, acetone, acrylonitrile, acetonitrile, benzene, carbon disulphide, cyclohexane, diethyl ether, ethyl acetate, hexane, low-boiling petroleum ethers, tetrahydrofuran and toluene. Toluene should always be used in place of benzene due to the potential *carcinogenic* effects of the liquid and vapour of the latter.
The drying of flammable solvents with sodium or potassium metal and metal hydrides poses serious potential fire hazards and adequate precautions should be stressed.

Salts. In addition to the dangers of perchlorate salts, other salts such as nitrates and diazo salts can be hazardous and care should be taken when these are dried. Large quantities should never be prepared or stored for long periods.

TABLE 1A. PREDICTED EFFECT OF PRESSURE ON BOILING POINT*

	Temperature in degrees Centigrade									
760 mmHg	0	20	40	60	80	100	120	140	160	180
0.1	-111	-99	-87	-75	-63	-51	-39	-27	-15	-4
0.2	-105	-93	-81	-69	-56	-44	-32	-19	-7	5
0.4	-100	-87	-74	-62	-49	-36	-24	-11	2	15
0.6	-96	-83	-70	-57	-44	-32	-19	-6	7	20
0.8	-94	-81	-67	-54	-41	-28	-15	-2	11	24
1.0	-92	-78	-65	-52	-39	-25	-12	1	15	28
2.0	-85	-71	-58	-44	-30	-16	-3	11	25	39
4.0	-78	-64	-49	-35	-21	-7	8	22	36	51
6.0	-74	-59	-44	-30	-15	-1	14	29	43	58
8.0	-70	-56	-41	-26	-11	4	19	34	48	63
10.0	-68	-53	-38	-23	-8	7	22	37	53	68
14.0	-64	-48	-33	-23	-2	13	28	44	59	74
16.0	-61	-45	-29	-14	2	17	33	48	64	79
20.0	-59	-44	-28	-12	3	19	35	50	66	82
30.0	-54	-38	-22	-6	10	26	42	58	74	90
40.0	-50	-34	-17	-1	15	32	48	64	81	97
50.0	-47	-30	-14	3	19	36	52	69	86	102
60.0	-44	-28	-11	6	23	40	56	73	86	107
80.0	-40	-23	-6	11	28	45	62	79	97	114
100.0	-37	-19	-2	15	33	50	67	85	102	119
150.0	-30	-12	6	23	41	59	77	95	112	130
200.0	-25	-7	11	29	47	66	84	102	120	138
300.0	-18	1	19	38	57	75	94	113	131	150
400.0	-13	6	25	44	64	83	102	121	140	159
500.0	-8	11	30	50	69	88	108	127	147	166
600.0	-5	15	34	54	74	93	113	133	152	172
700.0	-2	18	38	58	78	98	118	137	157	177
750.0	0	20	40	60	80	100	120	140	160	180
770.0	0	20	40	60	80	100	120	140	160	180
800.0	1	21	41	61	81	101	122	142	162	182

* *How to use the Table*: Take as an example a liquid with a b.p. of 80°C at 760mm Hg. The Table gives values of the b.ps of this liquid at pressures from 0.1 to 800mm Hg. Thus at 50mm Hg this liquid has a b.p. of 19°C, and at 2mm Hg its b.p. would be -30°C.

TABLE 1B. PREDICTED EFFECT OF PRESSURE ON BOILING POINT*

	Temperature in degrees Centigrade										
760mmHg	200	220	240	260	280	300	320	340	360	380	400
0.1	8	20	32	44	56	68	80	92	104	115	127
0.2	17	30	42	54	67	79	91	103	116	128	140
0.4	27	40	53	65	78	91	103	116	129	141	154
0.6	33	40	59	72	85	98	111	124	137	150	163
0.8	38	51	64	77	90	103	116	130	143	156	169
1.0	41	54	68	81	94	108	121	134	147	161	174
2.0	53	66	80	94	108	121	135	149	163	176	190
4.0	65	79	93	108	122	136	151	156	179	193	208
6.0	72	87	102	116	131	146	160	175	189	204	219
8.0	78	93	108	123	137	152	167	182	197	212	227
10.0	83	98	113	128	143	158	173	188	203	218	233
14.0	90	105	120	136	151	166	182	197	212	228	243
18.0	95	111	126	142	157	173	188	204	219	235	251
20.0	97	113	129	144	160	176	191	207	223	238	254
30.0	106	123	139	155	171	187	203	219	235	251	267
40.0	113	130	146	162	179	195	211	228	244	260	277
50.0	119	135	152	168	185	202	218	235	251	268	284
60.0	123	140	157	174	190	207	224	241	257	274	291
80.0	131	148	165	182	199	216	233	250	267	284	301
100.0	137	154	171	189	206	223	241	258	275	293	310
150.0	148	166	184	201	219	237	255	273	290	308	326
200.0	156	174	193	211	229	247	265	283	302	320	338
300.0	169	187	206	225	243	262	281	299	318	337	355
400.0	178	197	216	235	254	273	292	311	330	350	369
500.0	185	205	224	244	263	282	302	321	340	360	379
600.0	192	211	231	251	270	290	310	329	349	368	388
700.0	197	217	237	257	277	296	316	336	356	376	396
750.0	200	220	239	259	279	299	319	339	359	279	399
770.0	200	220	241	261	281	301	321	341	361	381	401
800.0	202	222	242	262	282	302	322	342	262	382	403

* *How to use the Table*: Taking as an example a liquid with a b.p. of 340°C at 760mm Hg, the column headed 340°C gives values of the b.ps of this liquid at each value of pressures from 0.1 to 800mm Hg. Thus, at 100mm Hg its b.p. is 258°C, and at 0.8mm Hg its b.p. will be 130°C.

TABLE 2. HEATING BATHS

Up to 100°	Water baths
-20 to 200°	Glycerol or di-*n*-butyl phthalate
Up to about 200°	Medicinal paraffin
Up to about 250°	Hard hydrogenated cotton-seed oil (m 40-60°) or a 1:1 mixture of cotton-seed oil and castor oil containing about 1% of hydroquinone.
-40 to 250°	(to 400° under nitrogen); D.C. 550 silicone fluid
Up to about 260°	A mixture of 85% orthophosphoric acid (4 parts) and metaphosphoric acid (1 part)
Up to 340°	A mixture of 85% orthophosphoric acid (2parts) and metaphosphoric acid (1 part)
60 to 500°	Fisher bath wax (highly unsaturated)
150 to 500°	A mixture of $NaNO_2$ (40%), $NaNO_3$ (7%) and KNO_3 (53%)
73 to 350°	Wood's Metal*
250 to 800°	Solder*
350 to 800°	Lead*

* In using metal baths, the container (usually a metal crucible) should be removed while the metal is still molten.

TABLE 3. WHATMAN FILTER PAPERS

Grade No.	1	2	3	4	5	6	113
Particle size retained in microns	11	8	5	12	2.4	2.8	28
Filtration speed* sec/100ml	40	55	155	20	<300	125	9

Whatman routine ashless filters

Grade No.	40	41	42	43	44
Particle size retained in microns	7.5	12	3	12	4
Filtration speed* sec/100ml	68	19	200	38	125

Whatman	------Hardened------			---Hardened ashless--		
Grade No.	50	52	54	540	541	542
Particle size retained in microns	3	8	20	9	20	3
Filtration speed* sec/100ml	250	55	10	55	12	250

continued

Whatman Glass Micro Filters (TABLE 3 continued)

Grade No	GF/A	GF/B	GF/C	GF/D	GF/F
Particle size retained in microns	1.6	1.0	1.1	2.2	0.8
Filtration speed* sec/100ml	8.3	20.0	8.7	5.5	17.2

* *Filtration speeds are rough estimates of initial flowrates and should be considered on a relative basis.*

TABLE 4. MICRO FILTERS*

Nucleopore (polycarbonate) Filters

Mean Pore Size (microns)	8.0	2.0	1.0	0.1	0.03	0.015
Av. pores/cm^2	10^5	$2x10^6$	$2x10^7$	$3x10^8$	$6x10^8$	$1\text{-}6x10^9$
Water flowrate ml/min/cm^2	2000	2000	300	8	0.03	0.1-0.5

Millipore Filters

Type	*Cellulose ester*			*Teflon*		*Microweb*#	
	MF/SC	MF/VF	LC	LS	WS	WH	
Mean Pore Size (microns)	8		0.01	10	5	3	0.45
Water flowrate ml/min/cm^2	850		0.2	170	70	155	55

Gelman Membranes

Type	*Cellulose ester*				*Copolymer*	
	GA-1	TCM-450	VM-1	DM-800	AN-200	Tuffryn-450
Mean Pore Size(microns)	5	0.45	5	0.8	0.2	0.45
Water flow-rate(ml/min/cm^2)	320	50	700	200	17	50

Sartorius Membrane Filters (SM)

Application	Gravi-metric	Biological clarificatn.	Sterili-zation	Particle count in H_2O	For acids & bases
Type No.	11003	11004	11006	11011	12801
Mean Pore Size (microns)	1.2	0.6	0.45	0.01	8
Water flowrate ml/min/cm^2	300	150	65	0.6	1100

* Only a few representative filters are tabulated (available ranges are more extensive). # Reinforced nylon.

TABLE 5. COMMON SOLVENTS USED IN RECRYSTALLISATION (and their boiling points)

Acetic acid (118°)
*Acetone (56°)
Acetylacetone (139°)
*Benzene (80°)
Benzyl alcohol (93°/10mm)
n-Butanol (118°)
Butyl acetate (126.5°)
n-Butyl ether (142°)
γ-Butyrolactone (206°)
Carbon tetrachloride (77°)
Cellosolve (135°)
Chlorobenzene (132°)
Chloroform (61°)
*Cyclohexane (81°)
Diethyl cellosolve (121°)
*Diethyl ether (34.5°)
Dimethyl formamide (76°/39mm)
*Dioxane (101°)
*Ethanol (78°)
*Ethyl acetate (78°)
Ethyl benzoate (98°/19mm)
Ethylene glycol (68°/4mm)
Formamide (110°/10mm)
Glycerol (126°/11mm)
Isoamyl alcohol (131°)
*Methanol (64.5°)
Methyl cyanide (82°)
Methylene chloride (41°)
*Methyl ethyl ketone (80°)
Methyl isobutyl ketone (116°)
Nitrobenzene (210°)
Nitromethane (101°)
*Petroleum ether (various)
Pyridine (115.5°)
Pyridine trihydrate (93°)
*Tetrahydrofuran (64-66°)
Toluene (110°)
Trimethylene glycol (59°/11mm)
Water (100°)

***Highly flammable, should be heated or evaporated on steam or electrically heated water baths only (preferably in a nitrogen atmosphere).**

TABLE 6. PAIRS OF MISCIBLE SOLVENTS

Acetic acid: with chloroform, ethanol, ethyl acetate, methyl cyanide, petroleum ether, or water.
Acetone: with benzene, butyl acetate, butyl alcohol, carbon tetrachloride, chloroform, cyclohexane, ethanol, ethyl acetate, methyl acetate, methyl cyanide, petroleum ether or water.
Ammonia: with ethanol, methanol, pyridine.
Aniline: with acetone, benzene, carbon tetrachloride, ethyl ether, *n*-heptane, methanol, methyl cyanide or nitrobenzene.
Benzene: with acetone, butyl alcohol, carbon tetrachloride, chloroform, cyclohexane, ethanol, methyl cyanide, petroleum ether or pyridine.
Butyl alcohol: with acetone or ethyl acetate.
Carbon disulphide: with petroleum ether.
Carbon tetrachloride: with cyclohexane.
Chloroform: with acetic acid, acetone, benzene, ethanol, ethyl acetate, hexane, methanol or pyridine.
Cyclohexane: with acetone, benzene, carbon tetrachloride, ethanol or ethyl ether.
Dimethyl formamide: with benzene, ethanol or ether.
Dimethyl sulphoxide: with acetone, benzene, chloroform, ethanol, ethyl ether or water.
Dioxane: with benzene, carbon tetrachloride, chloroform, ethanol, ethyl ether, pet. ether, pyridine or water.
Ethanol: with acetic acid, acetone, benzene, chloroform, cyclohexane, dioxane, ethyl ether, pentane, toluene, water or xylene.
Ethyl acetate: with acetic acid, acetone, butyl alcohol, chloroform, or methanol.
Ethyl ether: with acetone, cyclohexane, ethanol, methanol, methylal, methyl cyanide, pentane or pet.ether.
Glycerol: with ethanol, methanol or water.
Hexane: with benzene, chloroform or ethanol.
Methanol: with chloroform, ethyl ether, glycerol or water.
Methylal: with ethyl ether.
Methyl ethyl ketone: with acetic acid, benzene, ethanol or methanol.
Nitrobenzene: with aniline, methanol or methyl cyanide.
Pentane: with ethanol or ethyl ether.
Petroleum ether: with acetic acid, acetone, benzene, carbon disulphide or ethyl ether.
Phenol: with carbon tetrachloride, ethanol, ethyl ether or xylene.
Pyridine: with acetone, ammonia, benzene, chloroform, dioxane, petroleum ether, toluene or water.
Toluene: with ethanol, ethyl ether or pyridine.
Water: with acetic acid, acetone, ethanol, methanol, or pyridine.
Xylene: with ethanol or phenol.

TABLE 7. MATERIALS FOR COOLING BATHS

Temperature	Composition	Temperature	Composition
0°	Crushed ice	-77°	Solid CO_2 with chloroform or acetone
-5° to -20°	Ice-salt mixtures	-78°	Solid CO_2 (powdered)
-33°	Liquid ammonia	-100°	Solid CO_2 with ethyl ether
-40° to -50°	Ice (3.5-4 parts) - $CaCl_2$ $6H_2O$ (5 parts)	-192°	liquid air
-72°	Solid CO_2 with ethanol	-196°	liquid nitrogen (see footnote*)

Alternatively, the following liquids can be used, partially frozen, as cryostats, by adding solid CO_2 from time to time to the material in a Dewar-type container and stirring to make a slush:

13°	*p*-Xylene	-30°	Bromobenzene
12°	Dioxane	-32°	*m*-Toluidine
6°	Cyclohexane	-32.6°	Dipropyl ketone
5°	Benzene	-38°	Thiophen
2°	Formamide	-41°	Methyl cyanide
-8.6°	Methyl salicylate	-42°	Pyridine or diethyl ketone
-9°	Hexane-2,5-dione	-44°	Cyclohexyl chloride
-10.5°	Ethylene glycol	-45°	Chlorobenzene
-11.9°	*tert*-Amyl alcohol	-47°	*m*-Xylene
-12°	Cycloheptane or methyl benzoate	-50°	Ethyl malonate or *n*-butylamine
-15°	Benzyl alcohol	-52°	Benzyl acetate or diethylcarbitol
-16.3°	*n*-Octanol	-55°	Diacetone
-18°	1,2-Dichlorobenzene	-56°	*n*-Octane
-22°	Tetrachloroethylene	-60°	Isopropyl ether
-22.4°	Butyl benzoate	-73°	Trichloroethylene or isopropyl acetate
-22.8°	Carbon tetrachloride	-74°	*o*-Cymene or *p*-cymene
-24.5°	Diethyl sulphate	-77°	Butyl acetate
-25°	1,3-Dichlorobenzene	-79°	Isoamyl acetate
-29°	*o*-Xylene or pentachloroethane	-83°	Propylamine
-83.6°	Ethyl acetate	-98°	Methanol or methyl acetate
-86°	Methyl ethyl ketone	-99°	Isobutyl acetate
-89°	*n*-Butanol	-104°	Cyclohexene
-90°	Nitroethane	-107°	Isooctane
-91°	Heptane	-108°	1-Nitropropane
-92°	*n*-Propyl acetate	-116°	Ethanol or ethyl ether
-93°	2-Nitropropane or cyclopentane	-117°	Isoamyl alcohol
-94°	Ethyl benzene or hexane	-126°	Methylcyclohexane
-94.6°	Acetone	-131°	*n*-Pentane
-95.1°	Toluene	-160°	Isopentane
-97°	Cumene		

For other organic materials used in low temperature slush-baths with liquid nitrogen see R.E.Rondeau [*J.Chem.Eng.Data* **11** 124 *1966*]. **NOTE** that the liquid nitrogen should be oxygen-free. Liquid nitrogen that has been in contact with air will contain oxygen (see Table 8 for boiling points) and should not be used.

*** Use high quality pure nitrogen, do not use liquid air or liquid nitrogen that has been in contact with air for a long period (due to the dissolution of oxygen in it) which could EXPLODE in contact with organic matter. If the quality of the liquid nitrogen is not known, or is uncertain then it should NOT be used.**

TABLE 8. BOILING POINTS OF SOME USEFUL GASES AT ONE ATMOSPHERE PRESSURE

Argon	-185.6°	Krypton	-152.3°
Carbon dioxide (sublimes)	-78.5°	Methane	-164.0°
		Neon	-246.0°
Carbon monoxide	-191.3°	Nitrogen	-209.9°
Ethane	-88.6°	Nitrous oxide	-88.5°
Helium	-268.6°	Nitric oxide	-195.8°
Hydrogen	-252.6°	Oxygen	-182.96°

TABLE 9. LIQUIDS FOR DRYING PISTOLS

Boiling points (760mm)		Boiling points (760mm)	
Ethyl chloride	12.2°	Water	100.0°
Methylene dichloride	39.8°	Toluene	110.5°
Acetone	56.1°	Tetrachloroethylene	121.2°
Chloroform	62.0°	Chlorobenzene	132.0°
Methanol	64.5°	*m*-Xylene	139.3°
Carbon tetrachloride	76.5°	Isoamyl acetate	142.5°
Ethanol	78.3°	Tetrachloroethane	146.3°
Benzene	79.8°	Bromobenzene	155.0°
Trichloroethylene	86.0°	*p*-Cymene	176.0°
		Tetralin	207.0°

TABLE 10. VAPOUR PRESSURES (mm Hg) OF SATURATED AQUEOUS SOLUTIONS IN EQUILIBRIUM WITH SOLID SALTS

Salt	Temperature					% Humidity
	10°	15°	20°	25°	30° at 20°	
$LiCl.H_2O$				2.6		15
$CaBr_2.6H_2O$		2.1	2.7	3.3	4.0 4.8	19
KOAc				3.5		20
$CaCl_2.6H_2O$		3.5	4.5	5.6	6.9 8.3	20
CrO_3				6.1		32
$Zn(NO_3)_2.6H_2O$				7.4		42
$K_2CO_3.2H_2O$				7.7	10.7	44
KCNS				8.2		47
$Na_2Cr_2O_7.2H_2O$				9.1		52
$Ca(NO_3)_2.4H_2O$		6.0	7.7	9.6	11.9 14.2	55
$Mg(NO_3)_2.6H_2O$				9.8		56
$NaBr.2H_2O$		5.8	7.8	10.3	13.5 17.5	58
$NaNO_2$				11.6		66
$NaClO_3$				13.1		75
NaCl		6.9	9.6	13.2	17.8 21.4	75
NaOAc				13.3		76
NH_4Cl				13.8		79
$(NH_4)_2SO_4$				14.2		81
KBr				14.7		84
$KHSO_4$				15.1		86
KCl				15.1	20.2 27.0	86
K_2CrO_4				15.4		88
$ZnSO_4.7H_2O$				15.8		90
$NH_4.H_2PO_4$				16.3		93
KNO_3				16.7	22.3 29.8	95
$Pb(NO_3)_2$				17.2		98
(Water)		9.21	12.79	17.53	23.76 31.82	100

TABLE 11. DRYING AGENTS FOR CLASSES OF COMPOUNDS

Class	Dried with
Acetals	Potassium carbonate
Acids (organic)	Calcium sulphate, magnesium sulphate, sodium sulphate.
Acyl halides	Magnesium sulphate, sodium sulphate.
Alcohols	Calcium oxide, calcium sulphate, magnesium sulphate, potassium carbonate, followed by magnesium and iodine.
Aldehydes	Calcium sulphate, magnesium sulphate, sodium sulphate.
Alkyl halides	Calcium chloride, calcium sulphate, magnesium sulphate, phosphorus pentoxide, sodium sulphate.
Amines	Barium oxide, calcium oxide, potassium hydroxide, sodium carbonate, sodium hydroxide.
Aryl halides	Calcium chloride, calcium sulphate, magnesium sulphate, phosphorus pentoxide, sodium sulphate.
Esters	Magnesium sulphate, potassium carbonate, sodium sulphate.
Ethers	Calcium chloride, calcium sulphate, magnesium sulphate, sodium, lithium aluminium hydride.
Heterocyclic bases	Magnesium sulphate, potassium carbonate, sodium hydroxide.
Hydrocarbons	Calcium chloride, calcium sulphate, magnesium sulphate, phosphorus pentoxide, sodium (not for olefines).
Ketones	Calcium sulphate, magnesium sulphate, potassium carbonate, sodium sulphate.
Mercaptans	Magnesium sulphate, sodium sulphate.
Nitro compounds and Nitriles	Calcium chloride, magnesium sulphate, sodium sulphate.
Sulphides	Calcium chloride, calcium sulphate.

TABLE 12. GRADED ADSORBENTS AND SOLVENTS

Adsorbents (decreasing effectiveness)	Solvents (inreasing eluting ability)
Fuller's earth (hydrated aluminosilicate)	Petroleum ether, b 40-60°.
Magnesium oxide	Petroleum ether, b 60-80°.
Charcoal	Carbon tetrachloride.
Alumina	Cyclohexane.
Magnesium trisilicate	Benzene.
Silica gel	Ethyl ether.
Calcium hydroxide	Chloroform.
Magnesium carbonate	Ethyl acetate.
Calcium phosphate	Acetone.
Calcium carbonate	Ethanol.
Sodium carbonate	Methanol.
Talc	Pyridine.
Inulin	Acetic acid.
Sucrose = starch	

TABLE 13. REPRESENTATIVE ION-EXCHANGE RESINS

Sulphonated polystyrene	Distributor
Strong-acid cation exchanger	
AG 50W-x8	(Bio-Rad, USA)
Amberlite IR-120	(Rohm and Haas, USA)
Dowex 50W-x8	(Dow Chemical Co., USA)
Duolite 225	(Dia-Prosim Ltd)
Permutit RS	(Permutit AG, Germany)
Permutite C50D	(Phillips and Pain-Vermorel, France)
Carboxylic acid-type	
Weak acid cation exchangers	
Amberlite IRC-50	(Rohm and Haas, USA)
Bio-Rex 70	(Bio-Rad, USA)
Chelex 100	(Bio-Rad, USA)
Duolite 436	(Dia-Prosim Ltd)
Permutit C	(Permutit AG, Germany)
Permutits H and H-70	(Permutit Co, USA)
Aliphatic amine-type	
weak base anion exchangers	
Amberlites IR-45 and IRA-67	(Rohm and Haas, USA)
Dowex 3-x4A	(Dow Chemical Co, USA)
Permutit E	(Permutit AG, Germany)
Permutit A 240A	(Phillips and Pain-Vermorel, France)
Strong Base, anion exchangers	
AG 2x8	(Bio-Rad, USA)
Amberlite IRA-400	(Rohm and Haas, USA)
Dowex 2-x8	(Dow Chemical Co, USA)
Duolite 113	(Dia-Prosim Ltd)
Permutit ESB	(Permutit AG, Germany)
Permutite 330D	(Phillips and Pain-Vermorel, France)

TABLE 14. MODIFIED FIBROUS CELLULOSES FOR ION-EXCHANGE

Cation exchange	Anion exchange
CM cellulose (carboxymethyl)	DEAE cellulose (diethylaminoethyl)
CM 22, 23 cellulose	DE 22, 23 cellulose
P cellulose (phosphate)	PAB cellulose (*p*-aminobenzyl)
SE cellulose (sulphoethyl)	TEAE cellulose (triethylaminoethyl)
SM cellulose (sulphomethyl)	ECTEOLA cellulose

SE and SM are much stronger acids than CM, whereas P has two ionisable groups (pK 2-3, 6-7), one of which is stronger, the other weaker, than for CM (3.5 - 4.5).

For basic strengths, the sequence is:
TEAE » DEAE (pK 8 - 9.5) > ECTEOLA (pK 5.5 - 7) > PAB.

Their exchange capacities lie in the range 0.3 to 1.0 mg equiv./g.

TABLE 15. BEAD FORM ION-EXCHANGE PACKAGINGS[1]

Cation exchange	Capacity (meq/g)	Anion exchange	Capacity (meq/g)
CM-Sephadex C-25, C-50.[2](weak acid)	4.5±0.5	DEAE-Sephadex A-25, A-50.[7] (weak base)	3.5±0.5
SP-Sephadex C-25, C-50.[3](strong acid)	2.3±0.3	QAE-Sephadex A-25, A-50.[8] (strong base)	3.0±0.4
CM-Sepharose CL-6B.[4]	0.12±0.02	DEAE-Sepharose CL-6B.[4]	0.13±0.02
		DEAE-Sephacel.[9]	1.4±0.1
Fractogel EMD,CO_2^-(pK ~4.5), SO_3^- (pK ~<1).[5]		Fractogel EMD, DMAE (pK ~9), DEAE (pK ~10.8), TMAE (pK >13).[5]	
CM-32 Cellulose.		DE-32 Cellulose.	
CM-52 Cellulose.[6]		DE-52 Cellulose	

[1] May be sterilised by autoclaving at pH 7 and below 120°. [2] Carboxymethyl. [3] Sulphopropyl. [4] Crosslinked agarose gel, no precycling required, pH range 3-10. [5] Hydrophilic methacrylate polymer with very little volume change on change of pH (equivalent to *Toyopearl*), available in superfine 650S, and medium 650M particle sizes. [6] Microgranular, pre-swollen, does not require precycling. [7] Diethylaminoethyl. [8] Diethyl(2-hydroxypropyl)aminoethyl. [9] Bead form cellulose, pH range 2-12, no precycling. Sephadex and Sepharose from Pharmacia, Fractogel from Merck, Cellulose from Whatman

TABLE 16. COLUMNS FOR HPLC[1,2]

Column	Mobile Phase[3]	Application
DUPONT		
ODS"permaphase" (octadecyl silane).	Most solvents, not strong acids and bases, for gradient elution.	Aromatic compds, sterols, drugs, natural products.
HCP (hydrocarbon polymer).	Aqueous alcohols up to 50% isopropanol.	Aromatic compds. quinones.
CWT (carbowax 4000).	Hydrocarbons only.	Steroids and polar organic compounds.
TMG (trimethylene methylene glycol)	Hydrocarbons, $CHCl_3$, dioxane and tetra-hydrofuran. Not alcohols, Phase must be saturated with tri-methylene glycol.	Hydroxy and amino compds, pesticides, polymer inter-mediates.

continued

TABLE 16 (cont.). COLUMNS FOR HPLC[1,2]

Column	Mobile Phase[3]	Application
BOP (2,2'-oxydi-propionitrile).	Hydrocarbons, butyl ether, up to 15% of THF. Phase must be satd with 2,2'-oxydi-propionitrile.	Alkaloids, pesticides, polymer additives, steroids
WAX (weak anion exchange).	Water only, retention and resolution are modified by *p*H and ionic strength	Ionic compounds.
SAX (strong anion exchange).	Water only, as above.	As above.
SCX (strong cation exchange).	Water only, as above.	As above.
MERCK		
Silica Gel 60-Kieselgel 60.	EtOH, $CHCl_3$, CH_2Cl_2, *n*-C_7H_{16}, EtOAc, acetic acid.[2]	Vitamins, alkaloids esters, steroids, drugs, aromatic, compds.
LiChromosorb SI60 SI 100 and Altex T.	Hydrocarbons, ether aliphatic acids, Me_2SO, $CHCl_3$, CH_2Cl_2 *t*-BuOH.	As above, phthalimido-acids, antioxidants.
Perisorb A.	Hexane, acetic acid, isooctane, EtOAc.	Acids, esters, aromatic amines and hydrocarbons.
Perisorb PA6.	MeOH, H_2O, AcOH.	As above.
Perisorb KAT.	Aq. Buffers to pH 11.	Heterocycles, nucleosides, acids and bases.
BAKER		
Bakerbond Chiral DNBPG (ionic or covalent).[4]	*t*-BuOH, 2-PrOH, Butyl methyl ether, hexane, $CHCl_3$, and phases below.	Chiral mixts of alcohols, acids, amines, variety of enantiomeric compds
DNBLeu (covalent).[5]	Chiral phases: *S*-Aspartyl-*S*-phenylalanine methyl ester, *N,N*-Dipropyl-*S*-alanine cupric acetate.	Phosphonates, arylsulphoxides, nitrogen heterocycles, di-ß-naphthols.

[1] Only a few representative columns are tabulated, there is a very much larger selection avaliable commerially.
[2] Altex, T.J.Baker, Bio-Rad, Merck, Pharmacia, Waters Assoc. also have a wide range of columns.
[3] Not to be used above 50°, halide acids and salts are corrosive and must be avoided.
[4] *R-N*-3,5-dinitrobenzoylphenylglycine. [5] *R-N*-3,5-dinitrobenzoylleucine.

TABLE 17. LIQUIDS FOR STATIONARY PHASES IN GAS CHROMATOGRAPHY

Material	Temp.	Retards
Dimethylsulpholane	0-40°	Olefines and aromatic hydrocarbons
Di-*n*-butyl phthalate	0-40°	General purposes
Squalane	0-150°	Volatile hydrocarbons and polar molecules
Silicone oil or grease	0-250°	General purposes
Diglycerol	20-120°	Water, alcohols, amines, esters, and aromatic hydrocarbons
Dinonyl phthalate	20-130°	General purposes
Polydiethylene glycol succinate	50-200°	Aromatic hydrocarbons, alcohols, ketones, esters.
Polyethylene glycol	50-200°	Water, alcohols, amines, esters and aromatic hydrocarbons
Apiezon grease	50-200°	Volatile hydrocarbons and polar molecules
Tricresyl phosphate	50-250°	General purposes

TABLE 18. SOME COMMON IMMISCIBLE OR SLIGHTLY MISCIBLE PAIRS OF SOLVENTS

Carbon tetrachloride with ethanolamine, ethylene glycol, formamide or water.
Dimethyl formamide with cyclohexane or petroleum ether.
Dimethyl sulphoxide with cyclohexane or petroleum ether.
Ethyl ether with ethanolamine, ethylene glycol or water.
Methanol with carbon disulphide, cyclohexane or petroleum ether.
Petroleum ether with aniline, benzyl alcohol, dimethyl formamide, dimethyl sulphoxide, formamide, furfuryl alcohol, phenol or water.
Water with aniline, benzene, benzyl alcohol, carbon disulphide, carbon tetrachloride, chloroform, cyclohexane, cyclohexanol, cyclohexanone, ether (particularly if acidified), ethyl acetate, isoamyl alcohol, methyl ethyl ketone, nitromethane, tributyl phosphate or toluene.

TABLE 19. AQUEOUS BUFFERS

Approx. pH	Composition
0	2N sulphuric acid or N hydrochloric acid
1	0.1N hydrochloric acid or 0.18N sulphuric acid
2	**Either** 0.01N hydrochloric acid or 0.013N sulphuric acid **Or** 50 ml of 0.1M glycine (also 0.1M NaCl) + 50 ml of 0.1N hydrochloric acid
3	**Either** 20 ml of the 0.2M Na_2HPO_4 + 80 ml of 0.1M citric acid **Or** 50 ml of 0.1M glycine + 22.8 ml of 0.1N hydrochloric acid in 100 ml
4	**Either** 38.5 ml of 0.2M Na_2HPO_4 + 61.5 ml of 0.1M citric acid **Or** 18 ml of 0.2M NaOAc + 82 ml of 0.2M acetic acid
5	**Either** 70 ml of 0.2M NaOAc + 30 ml of 0.2M acetic acid **Or** 51.5 ml of 0.2M Na_2HPO_4 + 48.5 ml of 0.1M citric acid
6	63 ml of 0.2M Na_2HPO_4 + 37 ml of 0.1M citric acid
7	82 ml of M Na_2HPO_4 + 18 ml of 0.1M citric acid
8	**Either** 50 ml of 0.1M Tris buffer + 29 ml of 0.1N hydrochloric acid, in 100 ml **Or** 30 ml of 0.05M borax + 70 ml of 0.2M boric acid
9	80 ml of 0.05M borax + 20 ml of 0.2M boric acid
10	**Either** 25 ml of 0.05M borax + 43 ml of 0.1N NaOH, in 100 ml **Or** 50 ml of 0.1M glycine + 32 ml of 0.1N NaOH, in 100 ml
11	50 ml of 0.15M Na_2HPO_4 + 15 ml of 0.1N NaOH
12	50 ml of 0.15M Na_2HPO_4 + 75 ml of 0.1N NaOH
13	0.1N NaOH or KOH
14	N NaOH or KOH

These buffers are suitable for use in obtaining ultraviolet spectra. Alternatively, for a set of accurate buffers of low, but constant, ionic strength (I = 0.01) *covering a pH range 2.2 to 11.6 at 20°, see* Perrin *Australian J Chem* **16** 572 *1963.*

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CHAPTER 2

CHEMICAL METHODS USED IN PURIFICATION

GENERAL REMARKS

Greater selectivity in purification can often be achieved by making use of differences in chemical properties between the substance to be purified and its contaminants. Unwanted metal ions may be removed by precipitation in the presence of a *collector* (see p 49). Sodium borohydride and other metal hydrides transform organic peroxides and carbonyl-containing impurities such as aldehydes and ketones in alcohols and ethers. Many classes of organic chemicals can be purified by conversion into suitable derivatives, followed by regeneration. This chapter describes relevant procedures.

REMOVAL OF TRACES OF METALS FROM REAGENTS

It is necessary to purify the reagents used for determinations of the more common heavy metals. Also, there should be very little if any metallic contamination of many of the materials required for biochemical studies. The main methods for removing impurities of this type are as follows.

Distillation. Reagents such as water, ammonia, hydrochloric acid, nitric acid, perchloric acid (under reduced pressure), and sulphuric acid can be purified in this way using all-glass stills. Isothermal distillation is convenient for ammonia: a beaker containing concentrated ammonia is left alongside a beaker of distilled water for several days in an empty desiccator so that some of the ammonia distils over into the water. Hydrochloric acid can be purified in the same way. The redistilled ammonia should be kept in polyethylene or paraffin-waxed bottles. In some cases, instead of attempting to purify a salt it is simpler to synthesise it from distilled components. Ammonium acetate is an example.

Use of ion-exchange resin. Application of ion-exchange columns has greatly facilitated the removal of heavy metal ions such as Cu^{2+}, Zn^{2+} and Pb^{2+} from aqueous solutions of many reagents. Thus, sodium salts and sodium hydroxide can be purified by passage through a column of a cation-exchange resin in its sodium form. Similarly, for acids, a resin in its H^+ form is used. In some cases, where metals form anionic complexes, they can be removed by passage through an anion-exchange resin. Iron in hydrochloric acid solution is an example.

Ion exchange resins are also useful for demineralising biochemical preparations such as proteins. Removal of metal ions from protein solutions using polystyrene-based resins, however, may lead to protein denaturation. This difficulty may be avoided by using a weakly acidic cation exchanger such as Bio-Rex 70 (which is a carboxylic acid exchange resin based on a polyacrylic lattice).

Heavy metal contamination of pH buffers can be removed by passage of the solutions through a Chelex X-100 column. For example when a solution of 0.02M HEPES containing 0.2M KCl (1L, pH 7.5) alone or with calmodulin, is passed through a column of Chelex X-100 (60g) in the K^+ form the level of Ca^{2+} ions falls to less than 2×10^{-7} M as shown by atomic absorption spectroscopy. Such solutions should be stored in polyethylene containers that have been washed with boiling deionised water (5min) and rinced several times with deionised water. TES and Tris have been similarly decontaminated from metal ions (see reference on atomic absorption analysis on p 62).

Water, with very low concentrations of ionic impurities (and approaching conductivity standards), is very readily obtained by percolation through alternate columns of cation- and anion-exchange resins, or through a mixed-bed resin, and many commercial devices are available for this purpose. For some applications, this method is unsatisfactory because the final water may contain traces of organic material after passage through the columns. However, organic matter can also be removed by using yet another special column in series for this purpose (see Milli Q water preparation, Millipore Corpn).

Precipitation. In removing traces of impurities by precipitation it is necessary to include a material to act as a *collector* of the precipitated substance so as to facilitate its removal by filtration or decantation. Aqueous hydrofluoric acid can be freed from lead by adding 1ml of 10% strontium chloride per 100ml of acid, lead being co-precipitated as lead fluoride with the strontium fluoride. If the acid is decanted from the precipitate and the process repeated, the final lead content in the acid is less than 0.003 ppm. Similarly, lead can be precipitated from a nearly saturated sodium carbonate solution by adding 10% strontium chloride dropwise (1-2ml per 100ml), then filtering. (If the sodium carbonate is required as a solid, the solution can be evaporated to dryness in a platinum dish.) Removal of lead from potassium chloride uses precipitation as lead sulphide, followed, after filtration, by evaporation and recrystallisation of the potassium chloride.
Several precipitation methods are available for iron. It has been removed from potassium thiocyanate solutions by adding a few milligrams of an aluminium salt, then precipitating aluminum and iron as their hydroxides by adding a few drops of ammonia. Iron is also carried down on the hydrated manganese dioxide precipitate formed in cadmium chloride or cadmium sulphate solutions by adding 0.5% aqueous potassium permanganate (0.5ml per 100ml of solution), sufficient ammonia to give a slight precipitate, and 1ml of ethanol. The solution is heated to boiling to coagulate the precipitate, then filtered. For the removal of iron from sodium potassium tartrate, a small amount of cadmium chloride solution and a slight excess of ammonium sulphide are added, the solution is stood for 1 hour, and the sulphide precipitate is filtered off. Ferrous iron can be removed from copper solutions by adding some hydrogen peroxide to the solution to oxidise the iron, followed by precipitation of ferric hydroxide by adding a small amount of sodium hydroxide.
Traces of calcium can be removed from solutions of sodium salts by precipitation at pH 9.5-10 as its 8-hydroxyquinolinate. The excess of 8-hydroxyquinoline acts as a *collector*. The magnesium content of calcium chloride solutions can be reduced by making them about 0.1M in sodium hydroxide and filtering.

Extraction. In some cases, a simple solvent extraction is sufficient to remove a particular impurity. For example, traces of gallium can be removed from titanous chloride in hydrochloric acid by extraction with isopropyl ether. Similarly, ferric chloride can be removed from aluminium chloride solutions containing hydrochloric acid by extraction with ethyl ether. Usually, however, it is necessary to extract with an organic solvent in the presence of a suitable complexing agent such as dithizone or sodium diethyl dithiocarbamate. When the former is used, weakly alkaline solutions are extracted with dithizone in chloroform (at about 25mg/L of chloroform) or carbon tetrachloride until the colour of some fresh dithizone solution remains unchanged after shaking. Excess dithizone is taken out by extracting with the pure solvent, the last traces of which, in turn, are removed by aeration. This method has been used with aqueous solutions of ammonium hydrogen citrate, potassium bromide, potassium cyanide, sodium acetate and sodium citrate. The advantage of dithizone for such a purpose lies in the wide range of metals with which it combines under these conditions. 8-Hydroxyquinoline (oxine) can also be used in this way. Sodium diethyl dithiocarbamate has been used to purify aqueous hydroxylamine hydrochloride (made just alkaline to thymol blue by adding ammonia) from copper and other heavy metals by repeated extraction with chloroform until no more diethyl dithiocarbamate remained in the solution (which was then acidified to thymol blue by adding hydrochloric acid).

Complexation. Although not strictly a removal of an impurity, addition of a suitable complexing agent such as ethylenediaminetetra-acetic acid often overcomes the undesirable effects of contaminating metal ions by reducing the concentrations of the free metal species to very low levels. For a detailed discussion of this *masking*, see *Masking and Demasking of Chemical Reactions*, D.D.Perrin, Wiley-Interscience, New York, 1970.

USE OF METAL HYDRIDES

This group of reagents has become commercially available in large quantities; some of its members - notably lithium aluminium hydride ($LiAlH_4$), calcium hydride (CaH_2), sodium borohydride ($NaBH_4$) and potassium borohydride (KBH_4) - have found widespread use in the purification of chemicals.

Lithium aluminium hydride. This solid is stable at room temperature, and is soluble in ether-type solvents. It reacts violently with water, liberating hydrogen, and is a powerful drying and reducing agent for organic compounds. It reduces aldehydes, ketones, esters, carboxylic acids, peroxides, acid anhydrides and acid chlorides to the corresponding alcohols. Similarly, amides, nitriles, aldimines and aliphatic nitro compounds yield amines, while aromatic nitro compounds are converted to azo compounds. For this reason it finds extensive application in purifying organic chemical substances by the removal of water and carbonyl containing impurities as well as peroxides formed by autoxidation. Reactions can generally be carried out at room temperature, or in refluxing ethyl ether, at atmospheric pressure. *When drying organic liquids with this reagent it is important that the concentration of water in the liquid is below 0.1% otherwise a violent reaction or* **EXPLOSION** *may occur. The mixing of the liquid with the reagent should be performed at ice bath temperature and under a reflux condenser.*

Calcium hydride. This powerful drying agent is suitable for use with hydrogen, argon, helium, nitrogen, hydrocarbons, chlorinated hydrocarbons, esters and higher alcohols.

Sodium borohydride. This solid which is stable in dry air up to 300° like potassium borohydride, is a less powerful reducing agent than lithium aluminium hydride, from which it differs also by being soluble in hydroxylic solvents and to a lesser extent in ether-type solvents. Sodium borohydride forms a dihydrate melting at 36-37°, and its aqueous solutions decompose slowly unless stabilised to above pH 9 by alkali. (For example, a useful solution is one nearly saturated at 30-40° and containing 0.2% sodium hydroxide.) Its solubility in water is 25, 55 and 88g per 100ml of water at 0°, 25° and 60°, respectively. Its aqueous solutions are rapidly decomposed by boiling or acidification. The reagent, available either as a hygroscopic solid or as an aqueous sodium hydroxide solution, is useful as a water soluble reducing agent for aldehydes, ketones and organic peroxides. This explains its use for the removal of carbonyl-containing impurities and peroxides from alcohols, polyols, esters, polyesters, amino-alcohols, olefines, chlorinated hydrocarbons, ethers, polyethers, amines (including aniline), polyamines and aliphatic sulphonates.
Purifications can be carried out conveniently using alkaline aqueous or methanolic solutions, allowing the reaction mixture to stand at room temperature for several hours. Other solvents that can be used with this reagent include isopropyl alcohol (without alkali), amines (including liquid ammonia, in which its solubility is 104g per 100g of ammonia at 25°, and ethylenediamine), diglyme, formamide, dimethylformamide and tetrahydrofurfuryl alcohol. Alternatively, the material to be purified can be percolated through a column of the borohydride. In the absence of water, sodium borohydride solutions in organic solvents such as dioxane or amines decompose only very slowly at room temperature. Treatment of ethers with sodium borohydride appears to inhibit peroxide formation.

Potassium borohydride. Potassium borohydride is similar in properties and reactions to sodium borohydride, and, like it, is used as a reducing agent for removing aldehydes, ketones and organic peroxides. It is non-hygroscopic and can be used in water, ethanol, methanol or water-alcohol mixtures, provided some alkali is added to minimise decomposition, but it is somewhat less soluble than sodium borohydride in most solvents. For example, its solubility in water at 25° is 19g per 100ml of water (compare sodium borohydride, 55g).

PURIFICATION *via* DERIVATIVES

Relatively few derivatives of organic substances are suitable for use as aids to purification. This is because of the difficuly in regenerating the starting material. For this reason, we list below, the common methods of preparation of derivatives that can be used in this way.
Whether or not any of these derivatives is likely to be satisfactory for the use of any particular case will depend on the degree of difference in properties, such as solubility, volatility or melting point, between the starting material, its derivative and likely impurities, as well as on the ease with which the substance can be recovered. Purification *via* a derivative is likely to be of most use when the quantity of pure material that is required is not too large. Where large quantities (for example, more than 50g) are available, it is usually more economical to purify the material directly and discard larger fractions (for example, in distillations and recrystallisations).

The most generally useful purifications *via* derivatives are as follows:

Alcohols. Aliphatic or aromatic alcohols are converted to solid esters. *p*-Nitrobenzoates are the most convenient esters to form because of their sharp melting points, and the ease with which they can be recrystallised and the alcohol recovered. The *p*-nitrobenzoyl chloride used in the esterification is prepared by refluxing dry *p*-nitrobenzoic acid with a 3 molar excess of thionyl chloride for 30min on a steam bath (*in a fume cupboard*). The solution is cooled slightly and the excess thionyl chloride is distilled off under (water-pump) vacuum, keeping the temperature below 40°. Dry toluene is added to the residue in the flask, then distilled off under vacuum, the process being repeated two or three times to ensure complete removal of thionyl chloride, hydrogen chloride and sulphur dioxide. (This freshly prepared *p*-nitrobenzoyl chloride cannot be stored without decomposition; it should be used directly.) A solution of the acid chloride (1mol) in dry toluene or alcohol-free chloroform (distilled from P_2O_5 or by passage through an activated Al_2O_3 column) under a reflux condenser is cooled in an ice bath while the alcohol (1mol), with or without a solvent (preferably miscible with toluene or alcohol-free chloroform), is added dropwise to it. When addition is over and the reaction subsides, the mixture is refluxed for 30min and the solvent is removed under reduced pressure. The solid ester is then recrystallised to constant melting point from toluene, acetone, light petroleum or mixtures of these, but not from alcohols.
Hydrolysis of the ester is achieved by refluxing in aqueous N or 2N NaOH solution until the insoluble ester dissolves. The solution is then cooled, and the alcohol is extracted into a suitable solvent, e.g. ether, toluene or alcohol-free chloroform. The extract is dried ($CaSO_4$, $MgSO_4$) and distilled, then fractionally distilled if liquid or recrystallised if solid. (The nitro acid can be recovered by acidification of the aqueous layer.) In most cases where the alcohol to be purified is readily freed from ethanol, the hydrolysis of the ester is best achieved with N or 2N ethanolic NaOH or 85% aqueous ethanolic N NaOH. The former is prepared by dissolving the necessary alkali in a minimum volume of water and diluting with absolute alcohol. The ethanolic solution is refluxed for one to two hours and hydrolysis is complete when an aliquot gives a clear solution on dilution with four or five times its volume of water. The bulk of the ethanol is

distilled off and the residue is extracted as above. Alternatively, use can be made of ester formation with benzoic acid, toluic acid or 3,5-dinitrobenzoic acid, by the above method.
Other derivtives can be prepared by reaction of the alcohol with an acid anhydride. For example, phthalic or 3-nitrophthalic anhydride (1 mol) and the alcohol (1mol) are refluxed for half to one hour in a non-hydroxylic solvent, e.g. toluene or alcohol-free chloroform, and then cooled. The phthalate ester crystallises out, is precipitated by the addition of light petroleum or is isolated by evaporation of the solvent. It is recrystallised from water, 50% aqueous ethanol, toluene or light petroleum. Such an ester has a characteristic melting point and the alcohol can be recovered by acid or alkaline hydrolysis.

Aldehydes and Ketones. The best derivative from which an aldehyde can be recovered readily is its bisulphite addition compound, the main disadvantage being the lack of a sharp melting point. The aldehyde (sometimes in ethanol) is shaken with a cold saturated solution of sodium bisulphite until no more solid adduct separates. The adduct is filtered off, washed with a little water, then alcohol. A better reagent is freshly prepared saturated aqueous sodium bisulphite solution to which 75% ethanol is added to near-saturation. (Water may have to be added dropwise to render this solution clear.) With this reagent the aldehyde need not be dissolved separately in alcohol and the adduct is finally washed with alcohol. The aldehyde is recovered by dissolving the adduct in the least volume of water and adding an equivalent quantity of sodium carbonate (not sodium hydroxide) or concentrated hydrochloric acid to react with the bisulphite, followed by steam distillation or solvent extraction.
Other derivatives that can be prepared are the Schiff bases and semicarbazones. Condensation of the aldehyde with an equivalent of primary aromatic amine yields the Schiff base, for example aniline at 100° for 10-30min.
Semicarbazones are prepared by dissolving semicarbazide hydrochloride (*ca* 1g) and sodium acetate (*ca* 1.5g) in water (8-10ml) and adding the aldehyde or ketone (0.5-1g) and stirring. The semicarbazone crystallises out and is recrystallised from ethanol or aqueous ethanol. These are hydrolysed by steam distillation in the presence of oxalic acid or better by exchange with pyruvic acid (Hershberg *JOC* **13** 542 *1948*).

Amines. (a) Picrates: The most versatile derivative from which the free base can be readily recovered is the picrate. This is very satisfactory for primary and secondary aliphatic amines and aromatic amines and is particularly so for heterocyclic bases. The amine, dissolved in water, alcohol or benzene, is treated with excess of a saturated solution of picric acid in water, alcohol or benzene, respectively, until separation of the picrate is complete. If separation does not occur, the solution is stirred vigorously and warmed for a few minutes, or diluted with a solvent in which the picrate is insoluble. Thus, a solution of the amine and picric acid in ethanol or benzene can be treated with benzene or light petroleum, repectively, to precipitate the picrate. Alternatively, the amine can be dissolved in alcohol and aqueous picric acid added. The picrate is filtered off, washed with water, ethanol or benzene, and recrystallised from boiling water, ethanol, methanol, aqueous ethanol or methanol, chloroform or benzene. The solubility of picric acid in water, ethanol and benzene is 1.4, 6.23 and 5.27% respectively at 20°.
It is not advisable to store large quantities of picrates for long periods, *particularly when they are dry due to their potential* **EXPLOSIVE** *nature*. The free base should be recovered as soon as possible. The picrate is suspended in an excess of 2N aqueous NaOH and warmed a little. Because of the limited solubility of sodium picrate, excess hot water must be added. Alternatively, because of the greater solubility of lithium picrate, aqueous 10% lithium hydroxide solution can be used. The solution is cooled, the amine is extracted with a suitable solvent such as ethyl ether or toluene, washed with 5N NaOH until the alkaline solution remains colourless, then with water, and the extract is dried with anhydrous sodium carbonate. The solvent is distilled off and the amine is fractionally distilled (under reduced pressure if necessary) or recrystallised.
If the amines are required as their hydrochlorides, picrates can often be decomposed by suspending them in much acetone and adding two equivalents of 10N HCl. The hydrochloride of the base is filtered off, leaving the picric acid in the acetone. Dowex No 1 anion-exchange resin in the chloride form is useful for changing solutions of the more soluble picrates (for example, of adenosine) into solutions of their hydrochlorides, from which sodium hydroxide precipitates the free base .

(b) Salts: Amines can also be purified *via* their salts, e.g. hydrochlorides. A solution of the amine in dry toluene, ether, methylene chloride or chloroform is saturated with dry hydrogen chloride (generated by addition of concentrated sulphuric acid to dry sodium chloride, or to concentrated HCl followed by drying the gas through sulphuric acid, or from a hydrogen chloride cylinder) and the insoluble hydrochloride is filtered off and dissolved in water. The solution is made alkaline and the amine is extracted, as above. Hydrochlorides can also be prepared by dissolving the amine in ethanolic HCl and adding ether or light petroleum. Where hydrochlorides are too hygroscopic or too soluble for satisfactory isolation, other salts, e.g. nitrate, sulphate, bisulphate or oxalate, can be used.

(c) Double Salts: The amine (1mol) is added to a solution of anhydrous zinc chloride (1mol) in concentrated hydrochloric acid (42ml) in ethanol (200ml, or less depending on the solubility of the double salt). The solution is stirred for 1h and the precipitated salt is filtered off and recrystallised from ethanol. The free base is recovered by adding excess of 5-10N NaOH (to dissolve the zinc hydroxide that separates) and is steam distilled. Mercuric chloride in hot water can be used instead of zinc chloride and the salt is crystallised from 1% hydrochloric acid. Other double salts have been used, e.g. cuprous salts, but are not as convenient as the above salts.

(d) N-Acetyl derivatives: Purification as their N-acetyl derivatives is satisfactory for primary, and to a limited extent secondary, amines. The base is refluxed with slightly more than one equivalent of acetic anhydride for half to one hour, cooled and poured into ice-cold water. The insoluble derivative is filtered off, dried, and recrystallised from water, ethanol, aqueous ethanol, benzene or benzene-light petroleum. The derivative is then hydrolysed by

refluxing with 70% sulphuric acid for a half to one hour. The solution is cooled, poured onto ice, and made alkaline. The amine is steam distilled or extracted as above. Alkaline hydrolysis is very slow.

(e) N-Tosyl derivatives: Primary and secondary amines are converted into their tosyl derivatives by mixing equimolar amounts of amine and toluene-*p*-sulphonyl chloride in dry pyridine (*ca* 5-10mols) and allowing to stand at room temperature overnight. The solution is poured into ice-water and the pH adjusted to 2 with HCl. The solid derivative is filtered off, washed with water, dried (vac. desiccator) and recrystallised from an alcohol or aqueous alcohol solution to a sharp melting point. The derivative is decomposed by dissolving in liquid ammonia (*fume cupboard*) and adding sodium metal (in small pieces with stirring) until the blue colour persists for 10-15min. Ammonia is allowed to evaporate (*fume cupboard*), the residue treated with water and the solution checked that the pH is above 10. If the pH is below 10 then the solution has to be basified with 2N NaOH. The mixture is extracted with ether or toluene, the extract is dried (K_2CO_3), evaporated and the residual amine recrystallised if solid or distilled if liquid.

Aromatic hydrocarbons. (a) Adducts: Aromatic hydrocarbons can be purified as their picrates using the procedures described for amines. Instead of picric acid, 1,3,5-trinitrobenzene or 2,4,7-trinitrofluorenone can also be used. In all these cases, following recrystallisation, the hydrocarbon can be isolated either as described for amines or by passing a solution of the adduct through an activated alumina column and eluting with toluene or light petroleum. The picric acid and nitro compounds are more strongly adsorbed on the column.

(b) Sulphonation: Naphthalene, xylenes and alkyl benzene can be purified by sulphonation with concentrated sulphuric acid and crystallisation of the sodium sulphonates. The hydrocarbon is distilled out of the mixture with superheated steam.

Carboxylic acids (a) 4-Bromophenacyl esters: A solution of the sodium salt of the acid is prepared. If the salt is not available, the acid is dissolved in an equivalent of aqueous NaOH and the pH adjusted to 8-9 with this base. A solution of one equivalent of 4-bromophenacyl bromide (for a monobasic acid, two equivalents for a dibasic acid, etc) in ten times its volume of ethanol is then added. The mixture is heated to boiling, and, if necessary, enough ethanol is added to clarify the solution which is then refluxed for half to three hours depending on the number of carboxylic groups that have to be esterified. (One hour is generally sufficient for monocarboxylic acids.) On cooling, the ester should crystallise out. If it does not do so, the solution is heated to boiling, and enough water is added to produce a slight turbidity. The solution is again cooled. The ester is collected, and recrystallised or fractionally distilled.
The ester is hydrolysed by refluxing for 1-2h with 1-5% of barium carbonate suspended in water or with aqueous sodium carbonate solution. The solution is cooled and extracted with ether, toluene or chloroform. It is then acidified and the acid is collected by filtration or extraction, and recrystallised or fractionally distilled.
p-Nitrobenzyl esters can be prepared in an analogous manner using the sodium salt of the acid and *p*-nitrobenzyl bromide. They are readily hydrolysed.

(b) Alkyl esters: Of the alkyl esters, methyl esters are the most useful because of their rapid hydrolysis. The acid is refluxed with one or two equivalents of methanol in excess alcohol-free chloroform (or methylene chloride) containing about 0.1g of toluene-*p*-sulphonic acid (as catalyst), using a Dean and Stark trap. (The water formed by the esterification is carried away into the trap.) When the theoretical amount of water is collected in the trap, esterification is complete. The chloroform solution in the flask is washed with 5% aqueous sodium carbonate solution, then water, and dried over sodium sulphate or magnesium sulphate. The chloroform is distilled off and the ester is fractionally distilled through an efficient column. The ester is hydrolysed by refluxing with 5-10% aqueous NaOH solution until the insoluble ester has completely dissolved. The aqueous solution is concentrated a little by distillation to remove all of the methanol. It is then cooled and acidified. The acid is either extracted with ether, toluene or chloroform, or filtered off and isolated as above. Other methods for preparing esters are available.

(c) Salts: The most useful salt derivatives for carboxylic acids are the isothiouronium salts. These are prepared by mixing almost saturated solutions containing the acid (carefully neutralised with N NaOH using phenolphthalein indicator) then adding two drops of N HCl and an equimolar amount of *S*-benzylisothiouronium chloride in ethanol and filtering off the salt that crystallises out. After recrystallisation from water, alcohol or aqueous alcohol the salt is decomposed by suspending or dissolving in 2N HCl and extracting the carboxylic acid in ether, chloroform or toluene.

Hydroperoxides. These can be converted to their sodium salts by precipitation below 30° with aqueous 25% NaOH. The salt is then decomposed by addition of solid (powdered) carbon dioxide and extracted with low-boiling petroleum ether. The solvent should be removed under reduced pressure below 20°. **The apparatus should be adequately shielded at all times for the safety of the operator from EXPLOSIONS.**

Ketones. (a) Bisulphite adduct: The adduct can be prepared and decomposed as described for aldehydes. Alternatively, because no Cannizzaro reaction is possible, it can also be decomposed with 0.5N NaOH.

(b) Semicarbazones: A powdered mixture of semicarbazide hydrochloride (1mol) and anhydrous sodium acetate (1.3mol) is dissolved in water by gentle warming. A solution of the ketone (1mol) in the least volune of ethanol needed to dissolve it is then added. The mixture is warmed on a water bath until separation of the semicarbazone is complete. The solution is cooled, and the solid is filtered off. After washing with a little ethanol followed by water, it is recrystallised from ethanol or dilute aqueous ethanol. The derivative should have a characteristic melting point. The semicarbazone is decomposed by refluxing with excess of oxalic acid or with aqueous sodium carbonate solution. The ketone (which steam distils) is distilled off. It is extracted or separated from the

distillate (after saturating with NaCl), dried with $CaSO_4$ or $MgSO_4$ and fractionally distilled using an efficient column (under vacuum if necessary).

Phenols. The most satisfactory derivatives for phenols that are of low molecular weight or monohydric are the benzoate esters. (Their acetate esters are generally liquids or low-melting solids.) Acetates are more useful for high molecular weight and polyhydric phenols.

(a) Benzoates: The phenol (1mol) in 5% aqueous NaOH is treated (while cooling) with benzoyl chloride (1mol) and the mixture is stirred in an ice bath until separation of the solid benzoyl derivative is complete. The derivative is filtered off, washed with alkali, then water, and dried (in a vacuum desiccator over NaOH). It is recrystallised from ethanol or dilute aqueous ethanol. The benzoylation can also be carried out in dry pyridine at low temperature (*ca* 0°) instead of in NaOH solution, finally pouring the mixture into water and collecting the solid above. The ester is hydrolysed by refluxing in an alcohol (for example, ethanol, *n*-butanol) containing two or three equivalents of the alkoxide of the corresponding alcohol (for example sodium ethoxide or sodium *n*-butoxide) and a few (*ca* 5-10) millilitres of water, for half to three hours. When hydrolysis is complete, an aliquot will remain clear on dilution with four to five times its volume of water. Most of the solvent is distilled off. The residue is diluted with cold water and acidified, and the phenol is steam distilled. The latter is collected from the distillate, dried and either fractionally distilled or recrystallised.

(b) Acetates: These can be prepared as for the benzoates using either acetic anhydride with 3N NaOH or acetyl chloride in pyridine. They are hydrolysed as described for the benzoates. This hydrolysis can also be carried out with aqueous 10% NaOH solution, completion of hydrolysis being indicated by the complete dissolution of the acetate in the aqueous alkaline solution. On steam distillation, acetic acid also distils off but in these cases the phenols (see above) are invariably solids which can be filtered off and recrystallised.

Phosphate and phosphonate esters. These can be converted to their nitrate addition compounds. The crude or partially purified ester is saturated with uranyl nitrate solution and the adduct filtered off. It is recrystallised from *n*-hexane, toluene or ethanol. For the more soluble members crystallisation from hexane using low temperatures (-40°) has been successful. The adduct is decomposed by shaking with sodium carbonate solution and water, the solvent is steam distilled (if hexane or toluene is used) and the ester is collected by filtration. Alternatively, after decomposition, the organic layer is separated, dried with $CaCl_2$ or BaO, filtered, and fractionally distilled at high vacuum.

Alternatively, impurities can sometimes be removed by conversion to derivatives under conditions where the major component does not react. For example, normal (straight-chain) paraffins can be freed from unsaturated and branched-chain components by taking advantage of the greater reactivity of the latter with chlorosulphonic acid or bromine. Similarly, the preferential nitration of aromatic hydrocarbons can be used to remove e.g. benzene or toluene from cyclohexane by shaking for some hours with a mixture of concentrated nitric acid (25%), sulphuric acid (58%), and water (17%).

GENERAL METHODS FOR THE PURIFICATION OF CLASSES OF COMPOUNDS

Chapters 3, 4 and 5 list a large number of individual compounds, with a brief statement of how each one may be purified. For substances that are not included in these chapters the following procedures may prove helpful.

If the laboratory worker does not know of a reference to the preparation of a commercially available substance, he may be able to make a reasonable guess at the synthetic method used from published laboratory syntheses. This information, in turn, can simplify the necessary purification steps by suggesting probable contaminants. However, for other than macromolecules it is important that at least the NMR and IR spectra of the substance be measured. These measurements require no more than two to three milligrams (which are recoverable) of material and provides a considerable amount of information about the substance. Three volumes on the NMR spectra [C.J.Pouchert and J.Behnke, *The Aldrich Library of ^{13}C and ^{1}H FT-NMR Spectra, Vols 1—3*, Aldrich Chemical Co., Inc, Milwaukee, WI, *1993*], and one on the infrared spectra [C.J.Pouchert, *The Aldrich Library of FT-IR Spectra*, 3nd ed, Aldrich Chemical Co., Milwaukee, WI, *1989*], as well as computer software [*FT-IR Peak-search Data Base and Software*, for Apple IIE, IIC and II Plus computers; and for IBM PC computers, Nicholet Instruments, Madison, WI, 1984] contain data for all the compounds in the Aldrich catalogue and are extremely useful for identifying compounds and impurities. If the material appears to have several impurities these spectra should be followed by examination of their chromatographic properties and spot tests. Purification methods can then be devised to remove these impurities, and a monitoring method will have already been established.

Physical methods of purification depend largely on the melting and boiling points of the materials.. For gases and low-boiling liquids use is commonly made of the *freeze-pump-thaw* (see p. 19) procedure. Gas chromatography is also useful, especially for low-boiling point liquids. Liquids are usually purified by refluxing with drying agents, acids or bases, reducing agents, charcoal, etc., followed by fractional distillation under reduced pressure. For solids, general methods include fractional freezing of the melted material, taking the middle fraction. A related procedure is zone refining. Another procedure is sublimation of the solid under reduced pressure. The other commonly used method for purifying solids is by recrystallisation from a solution in a suitable solvent, by cooling with or without the prior addition of a solvent in which the solute is not very soluble.

Purification becomes meaningful only insofar as adequate tests of purity are applied: the higher the degree of purity that is sought, the more stringent must these tests be. If the material is an organic solid, its melting point should first be taken and compared with the recorded value. Also, as part of this preliminary examination, the sample might be examined by thin layer (or paper) chromatography (see E.Demole, *Chromatographic Reviews*, **4** 26 *1962*) in several different solvent systems and in high enough concentrations to facilitate the detection of minor components. On the other hand, if the substance is a liquid, its boiling point should be measured. If, further, it is a high boiling liquid, its chromatographic behaviour should be examined. Liquids, especially volatile ones, can be studied very satisfactorily by gas chromatography, preferably using at least two different stationary phases.

Application of these tests at successive steps will give a good indication of whether or not the purification is satisfactory and will also show when adequate purification has been achieved.

The nature of the procedure will depend to a large extent on the quantity of purified material that is required. For example, for small quantities (50-250mg) of a pure liquid, preparative gas chromatography is probably the best method. Two passes through a suitable column may well be sufficient. Similarly, for small amounts (100-500mg) of an organic solid, column chromatography is likely to be very satisfactory., the eluate being collected as a number of separate fractions (*ca* 5-10ml) which are examined by FT-IR, NMR or UV spectroscopy, TLC or by some other appropriate analytical technique. (For information on suitable adsorbents and eluents the texts referred to in the bibliography at the end of Chapters 1 and 2 should be consulted.) Preparative thin layer chromatography or HPLC can be used successfully for purifying up to 500mg of solid.

Where larger quantities (upwards of 1g) are required, most of the impurities should be removed by preliminary treatments, such as solvent extraction, liquid-liquid partition, or conversion to a derivative (*vide supra*) which can be purified by crystallisation or fractional distillation before being reconverted to the starting material. The substance is then crystallised or distilled. If the final amounts must be in excess of 25g, preparation of a derivative is sometimes omitted because of the cost involved. In all of the above cases, purification is likely to be more laborious if the impurity is an isomer or a derivative with closely similar physical properties.

In the general methods of purification described below, it is assumed that the impurities belong essentially to a class of compounds different from the one being purified. They are suggested for use in cases where substances are not listed in Chapters 3, 4 and the low molecular weight compounds in Chapter 5. In such cases, the experimenter is advised to employ them in conjunction with information given in these chapters for the purification of suitable analogues. Also, for a wider range of drying agents, solvents for extraction and solvents for recrystallisation, the reader is referred to Chapter 1. See Chapter 5 for general purification procedures used for macromolecules.

GENERAL PROCEDURES FOR THE PURIFICATION OF SOME CLASSES OF ORGANIC COMPOUNDS

Acetals. These are generally diethyl or dimethyl acetal derivatives of aldehydes. They are more stable to alkali than to acids. Their common impurities are the corresponding alcohol, aldehyde and water. Drying with sodium wire removes alcohols and water, and polymerizes aldehydes so that, after decantation, the acetal can be fractionally distilled. In cases where the use of sodium is too drastic, aldehydes can be removed by shaking with alkaline hydrogen peroxide solution and the acetal is dried with sodium carbonate or potassium carbonate. Residual water and alcohols (up to *n*-propyl) can be removed with Linde type 4A molecular sieves. The acetal is then filtered and fractionally

distilled. Solid acetals (i.e. acetals of high molecular weight aldehydes) are generally low-melting and can be recrystallised from low-boiling petroleum ether, toluene or a mixture of both.

Acids. (a) Carboxylic: Liquid carboxylic acids are first freed from neutral and basic impurities by dissolving them in aqueous alkali and extracting with ethyl ether. (The pH of the solution should be at least three units above the pK_a of the acid). The aqueous phase is then acidified to a pH at least three units below the pK_a of the acid and again extracted with ether. The extract is dried with magnesium sulphate or sodium sulphate and the ether is distilled off. The acid is fractionally distilled through an efficient column. It can be further purified by conversion to its methyl or ethyl ester (see p. 52) which is then fractionally distilled. Hydrolysis yields the original acid which is again purified as above.
Acids that are solids can be purified in this way, except that distillation is replaced by repeated crystallisation (preferable from at least two different solvents such as water, alcohol or aqueous alcohol, toluene, toluene/petroleum ether or acetic acid.) Water-insoluble acids can be partially purified by dissolution in N sodium hydroxide solution and precipitation with dilute mineral acid. If the acid is required to be free from sodium ions, then it is better to dissolve the acid in hot N ammonia, heat to *ca* 80°, adding slightly more than an equal volume of N formic acid and allowing to cool slowly for crystallisation.
The separation and purification of naturally occurring fatty acids, based on distillation, salt solubility and low temperature crystallisation, are described by K.S.Markley (ed), *Fatty Acids*, 2nd edn, part 3, Chap. 20, Interscience, New York. 1964.
Aromatic carboxylic acids can be purified by conversion to their sodium salts, recrystallisation from hot water, and reconversion to the free acids.

(b) Sulphonic: The low solubility of sulphonic acids in organic solvents and their high solubility in water makes necessary a treatment different from that for carboxylic acids. Sulphonic acids are strong, they have the tendency to hydrate, and many of them contain water of crystallisation. The lower-melting and liquid acids can generally be purified with only slight decomposition by fractional distillation, preferably under reduced pressure. A common impurity is sulphuric acid, but this can be removed by recrystallisation from concentrated aqueous solutions. The wet acid can be dried by azeotropic removal of water with toluene, followed by distillation. The higher-melting acids, or acids that melt with decomposition, can be recrystallised from water or, occasionally, from ethanol.

(c) Sulphinic: These acids are less stable, less soluble and less acidic than the corresponding sulphonic acids. The common impurities are the respective sulphonyl chlorides from which they have been prepared, and the thiolsulphonates (neutral) and sulphonic acids into which they decompose. The first two of these can be removed by solvent extraction from an alkaline solution of the acid. On acidification of an alkaline solution, the sulphinic acid crystallises out leaving the sulphonic acid behind. The lower molecular weight members are isolated as their metal (e.g. ferric) salts, but the higher members can be crystallised from water (made slightly acidic), or alcohol.

Acid chlorides. The corresponding acid and hydrogen chloride are the most likely impurities. Usually these can be removed by efficient fractional distillation. Where acid chlorides are not readily hydrolysed (e.g. aryl sulphonyl chlorides) the compound can be freed from contaminants by dissolving in a suitable solvent such as alcohol-free chloroform, dry toluene or petroleum ether and shaking with dilute sodium bicarbonate solution. The organic phase is then washed with water, dried with sodium sulphate or magnesium sulphate, and distilled. This procedure is *hazardous* with readily hydrolysable acid chlorides such as acetyl chloride and benzoyl chloride. Solid acid chlorides are satisfactorily crystallised from toluene, toluene-petroleum ether, petroleum ethers, alcohol-free chloroform/toluene, and, occasionally, from dry ethyl ether. Hydroxylic or basic solvents should be strictly avoided. *All operations should be carried out in a fume cupboard because of the* ***irritant*** *nature of these compounds.*

Alcohols. (a) Monohydric: The common impurities in alcohols are aldehydes or ketones, and water. [*Ethanol* in Chapter 3 is typical.] Aldehydes and ketones can be removed by adding a small amount of sodium metal and refluxing for 2 hours, followed by distillation. Water can be removed in a similar way but it is preferable to use magnesium metal instead of sodium because it forms a more insoluble hydroxide, thereby shifting the equilibrium more completely from metal alkoxide to metal hydroxide. The magnesium should be activated with iodine (or a small amount of methyl iodide), and the water content should be low, otherwise the magnesium will be deactivated.
Acidic materials can be removed by treatment with anhydrous Na_2CO_3, followed by a suitable drying agent, such as calcium hydride, and fractional distillation, using gas chromatography to establish the purity of the product [Ballinger and Long, *JACS* **82** 795 *1960*]. Alternatively, the alcohol can be refluxed with freshly ignited CaO for 4 hours and then fractionally distilled [McCurdy and Laidler, *Canad J Chem* **41** 1867 *1963*].
With higher-boiling alcohols it is advantageous to add some freshly prepared magnesium ethoxide solution (only slightly more than required to remove the water), followed by fractional distillation. Alternatively, in such cases, water can be removed by azeotropic distillation with toluene. Higher-melting alcohols can be purified by crystallisation from methanol or ethanol, toluene/petroleum ether or petroleum ethers. Sublimation in vacuum, molecular distillation and gas chromatography are also useful means of purification. For purification *via* derivatives, see p. 50.

(b) Polyhydric: These alcohols are more soluble in water than are the monohydric ones. Liquids can be freed from water by shaking with type 4A Linde molecular sieves and can safely be distilled only under high vacuum. Carbohydrate alcohols can be crystallised from strong aqueous solution or, preferably, from mixed solvents such as ethanol/petroleum ether or dimethyl formamide/toluene. Crystallisation usually requires seeding and is extremely slow. Further purification can be effected by conversion to the acetyl derivatives which are much less soluble in water and which can readily be recrystallised, e.g. from ethanol. Hydrolysis of the acetyl derivatives, followed by removal of acetate and metal ions by ion-exchange chromatography, gives the purified material. On no account should solutions of carbohydrates be concentrated above 40° because of darkening and formation of *caramel.* Ion exchange, charcoal or cellulose column chromatography has been used for the purification and separation of carbohydrates.

Aldehydes. Common impurities found in aldehydes are the corresponding alcohols, aldols and water from self-condensation, and the corresponding acids formed by autoxidation. Acids can be removed by shaking with aqueous 10% sodium bicarbonate solution. The organic liquid is then washed with water. It is dried with sodium sulphate or magnesium sulphate and then fractionally distilled. Water soluble aldehydes must be dissolved in a suitable solvent such as ethyl ether before being washed in this way. Further purification can be effected *via* the bisulphite derivative (see p. **51**) or the Schiff base formed with aniline or benzidine. Solid aldehydes can be dissolved in ethyl ether and purified as above. Alternatively, they can be steam distilled, then sublimed and crystallised from toluene or petroleum ether.

Amides. Amides are stable compounds. The lower-melting members (such as acetamide) can be readily purified by fractional distillation. Most amides are solids which have low solubilities in water. They can be recrystallised from large quantities of water, ethanol, ethanol/ether, aqueous ethanol, chloroform/toluene, chloroform or acetic acid. The likely impurities are the parent acids or the alkyl esters from which they have been made. The former can be removed by thorough washing with aqueous ammonia followed by recrystallisation, whereas elimination of the latter is by trituration or recrystallisation from an organic solvent. Amides can be freed from solvent or water by drying below their melting points. These purifications can also be used for sulphonamides and acid hydrazides.

Amines. The common impurities found in amines are nitro compounds (if prepared by reduction), the corresponding halides (if prepared from them) and the corresponding carbamate salts. Amines are dissolved in aqueous acid, the pH of the solution being at least three units below the pK_a value of the base to ensure almost complete formation of the cation. They are extracted with ethyl ether to remove neutral impurities and to decompose the carbamate salts. The solution is then made strongly alkaline and the amines that separate are extracted into a suitable solvent (ether or toluene) or steam distilled. The latter process removes coloured impurities. Note that chloroform cannot be used as a solvent for primary amines because, in the presence of alkali, poisonous carbylamines are formed. However, chloroform is a useful solvent for the extraction of heterocyclic bases. In this case it has the added advantage that while the extract is being freed from the chloroform most of the moisture is removed with the solvent.
Alternatively, the amine may be dissolved in a suitable solvent (e.g. toluene) and dry HCl gas is passed through the solution to precipitate the amine hydrochloride. This is purified by recrystallisation from a suitable solvent mixture (e.g. ethanol/ethyl ether). The free amine can be regenerated by adding sodium hydroxide and isolated as above.
Liquid amines can be further purified *via* their acetyl or benzoyl derivatives (see p. 51). Solid amines can be recrystallised from water, alcohol, toluene or toluene-petroleum ether. *Care should be taken in handling large quantities of amines because their vapours are* ***harmful*** *and they are readily absorbed through the skin.*

Amino acids. Because of their zwitterionic nature, amino acids are soluble in water. Their solubility in organic solvents rises as the fat-soluble portion of the molecule increases. The likeliest impurities are traces of salts, heavy metal ions, proteins and other amino acids. Purification of these is usually easy, by recrystallisation from water or ethanol/water mixtures. The amino acid is dissolved in the boiling solvent, decolorised if necessary by boiling with 1g of acid-washed charcoal/100g amino acid, then filtered hot, chilled, and stood for several hours to crystallise. The crystals are filtered off, washed with ethanol, then ether, and dried.
Amino acids have high melting or decomposition points and are best examined for purity by paper or thin layer chromatography. The spots are developed with ninhydrin (see Lederer and Lederer, p.44). Customary methods for the purification of small quantities of amino acids obtained from natural sources (i.e. 1-5g) are ion-exchange chromatography (see p. 20) or countercurrent distribution (see p. 28). For general treatment of amino acids see Greenstein and Winitz [*The Amino Acids*, Vols 1-3, J.Wiley & Sons, New York 1961].
A useful source of details such as likely impurities, stability and tests for homogeneity of amino acids is *Specifications and Criteria for Biochemical Compounds*, 3rd edn, 1972, National Academy of Sciences, USA].

Anhydrides. The corresponding acids, resulting from hydrolysis, are the most likely impurities. Distillation from phosphorus pentoxide, followed by fractional distillation, is usually satisfactory. With high boiling or solid anhydrides, another method involves refluxing for 0.5-1 hour with acetic anhydride, followed by fractional distillation. Acetic acid distils first, then acetic anhydride and finally the desired anhydride. Where the anhydride is a solid, removal of acetic acid and acetic anhydride at atmospheric pressure is followed by heating under vacuum. The solid anhydride is then either crystallised as for acid chlorides or (in some cases) sublimed in a vacuum. A preliminary purification when large quantities of acid are present in a solid anhydride (such as phthalic anhydride) can sometimes be

achieved by preferential solvent extraction of the (usually) more soluble anhydride from the acid (e.g. with chloroform in the case of phthalic anhydride). *All operations with liquid anhydrides should be carried out in a fume cupboard because of their* **LACHRYMATORY** *properties.*

Carotenoids. These usually are decomposed by light, air and solvents, so that degradation products are probable impurities. Chromatography and adsorption spectra permit the ready detection of coloured impurities, and separations are possible using solvent distribution, chromatography or crystallisation. Thus, in partition between immiscible solvents, xanthophyll remains in 90% methanol while carotenes pass into the petroleum ether phase. For small amounts of material, thin-layer or paper chromatography may be used, while column chromatography is suitable for larger amounts. Colourless impurities may be detected by IR, NMR or mass spectrometry. The more common separation procedures are described by P.Karrer and E.Jucker in *Carotenoids*, E.A.Braude (translator), Elsevier, NY, 1950.
Purity can be assayed by chromatography (on thin-layer plates, Kieselguhr paper or columns), by UV or NMR procedures.

Esters. The most common impurities are the corresponding acid and hydroxy compound (i.e. alcohol or phenol), and water. A liquid ester from a carboxylic acid is washed with 2N sodium carbonate or sodium hydroxide to remove acid material, then shaken with calcium chloride to remove ethyl or methyl alcohols (if it is a methyl or ethyl ester). It is dried with potassium carbonate or magnesium sulphate, and distilled. Fractional distillation then removes residual traces of hydroxy compounds. This method does not apply to esters of inorganic acids (e.g. dimethyl sulphate) which are more readily hydrolysed in aqueous solution when heat is generated in the neutralisation of the excess acid. In such cases, several fractional distillations, preferably under vacuum, are usually sufficient.
Solid esters are easily crystallisable materials. It is important to note that esters of alcohols must be recrystallised either from non-hydroxylic solvents (e.g. toluene) or from the alcohol from which the ester is derived. Thus methyl esters should be crystallised from methanol or methanol/toluene, but not from ethanol, *n*-butanol or other alcohols, in order to avoid alcohol exchange and contamination of the ester with a second ester. Useful solvents for crystallisation are the corresponding alcohols or aqueous alcohols, toluene, toluene/petroleum ether, and chloroform (ethanol-free)/toluene. Carboxylic acid esters derived from phenols are more difficult to hydrolyse and exchange, hence any alcoholic solvent can be used freely. Sulphonic acid esters of phenols are even more resistant to hydrolysis: they can safely be crystallised not only from the above solvents but also from acetic acid, aqueous acetic acid or boiling *n*-butanol.
Fully esterified phosphoric acid and phosphonic acids differ only in detail from the above mentioned esters. Their major contaminants are alcohols or phenols, phosphoric or phosphonic acids (from hydrolysis), and (occasionally) basic material, such as pyridine, which is used in their manufacture. Water-insoluble esters are washed thoroughly and successively with dilute acid (e.g. 0.2N sulphuric acid), water, 0.2N sodium hydroxide and water. After drying with calcium chloride they are fractionally distilled. Water-soluble esters should first be dissolved in a suitable organic solvent and, in the washing process, water should be replaced by saturated aqueous sodium chloride. Some esters (e.g. phosphate and phosphonate esters) can be further purified through their uranyl adducts (see p. 53). Traces of water or hydroxy compounds can be removed by percolation through, or shaking with, activated alumina (about 100g/L of liquid solution), followed by filtration and fractional distillation in a vacuum. For high molecular weight esters (which cannot be distilled without some decomposition) it is advisable to carry out distillation at as low a pressure as possible. Solid esters can be crystallised from toluene or petroleum ether. Alcohols can be used for recrystallising phosphoric or phosphonic esters of phenols.

Ethers. The purification of ethyl ether (see Chapter 3) is typical of liquid ethers. The most common contaminants are the alcohols or hydroxy compounds from which the ethers are prepared, their oxidation products (e.g. aldehydes), peroxides and water. Peroxides, aldehydes and alcohols can be removed by shaking with alkaline potassium permanganate solution for several hours, followed by washing with water, concentrated sulphuric acid, then water. After drying with calcium chloride, the ether is distilled. It is then dried with sodium or with lithium aluminium hydride, redistilled and given a final fractional distillation. The drying process should be repeated if necessary.
Alternatively, methods for removing peroxides include leaving the ether to stand in contact with iron filings or copper powder, shaking with a solution of ferrous sulphate acidified with sulphuric acid, shaking with a copper-zinc couple, passage through a column of activated alumina, and refluxing with phenothiazine. Cerium(III) hydroxide has also been used.
A simple test for ether peroxides is to add 10ml of the ether to a stoppered cylinder containing 1ml of freshly prepared 10% solution of potassium iodide containing a drop of starch indicator. No colour should develop during one minute. Alternatively, a 1% solution of ferrous ammonium sulphate, 0.1M in sulphuric acid and 0.01M in potassium thiocyanate should not increase appreciably in red colour when shaken with two volumes of the ether.
As a safety precaution against **EXPLOSION** (in case the purification has been insufficiently thorough) at least a quarter of the total volume of ether should remain in the distilling flask when the distillation is discontinued. To minimize peroxide formation, ethers should be stored in dark bottles and, if they are liquids, they should be left in contact with type 4A Linde molecular sieves, in a cold place, over sodium amalgam. The rate of formation of peroxides depends on storage conditions and is accelerated by heat, light, air and moisture. The formation of peroxides is inhibited in the presence of diphenylamine, di-*tert*-butylphenol, or other antioxidant as stabilizer.

Ethers that are solids (e.g. phenyl ethers) can be steam distilled from an alkaline solution which will hold back any phenolic impurity. After the distillate is made alkaline with sodium carbonate, the insoluble ether is collected either by extraction (e.g. with chloroform, ethyl ether or toluene) or by filtration. It is then crystallised from alcohols, alcohol/petroleum ether, petroleum ether, toluene or mixtures of these solvents, sublimed in a vacuum and recrystallised.

Halides. Aliphatic halides are likely to be contaminated with halogen acids and the alcohols from which they have been prepared, whereas in aromatic halides the impurities are usually aromatic hydrocarbons, amines or phenols. In both groups the halogen atom is less reactive than it is in acid chlorides. Purification is by shaking with concentrated hydrochloric acid, followed by washing successively with water, 5% sodium carbonate or bicarbonate, and water. After drying with calcium chloride, the halide is distilled and then fractionally distilled using an efficient column. For a solid halide the above purification is carried out by dissolving it in a suitable solvent such as toluene. Solid halides can also be purified by chromatography using an alumina column and eluting with toluene or petroleum ether. They can be crystallised from toluene, petroleum ethers, toluene/petroleum ether or toluene/chloroform/petroleum ether. Care should be taken when handling organic halogen compounds because of their **TOXICITY.**
Liquid aliphatic halides are obtained alcohol-free by distillation from phosphorus pentoxide. They are stored in dark bottles to prevent oxidation and, in some cases, the formation of phosgene.
A general method for purifying *chlorohydrocarbons* uses repeated shaking with concentrated sulphuric acid until no further colour develops in the acid, then washing with a solution of sodium bicarbonate, followed by water. After drying with calcium chloride, the chlorohydrocarbon is fractionally redistilled to constant boiling point.

Hydrocarbons. Gaseous hydrocarbons are best freed from water and gaseous impurities by passage through suitable adsorbents and (if olefinic material is to be removed) oxidants such as alkaline potassium permanganate solution, followed by fractional cooling (see p. 36 for cooling baths) and fractional distillation at low temperature. To effect these purifications and also to store the gaseous sample, a vacuum line is necessary.
Impurities in hydrocarbons can be characterised and evaluated by gas chromatography and mass spectrometry. The total amount of impurities present can be estimated from the thermometric freezing curve.
Liquid aliphatic hydrocarbons are freed from aromatic impurities by shaking with concentrated sulphuric acid whereby the aromatic compounds are sulphonated. Shaking is carried out until the sulphuric acid layer remains colourless for several hours. The hydrocarbon is then freed from the sulphuric acid and the sulphonic acids by separating the two phases and washing the organic layer successively with water, 2N sodium hydroxide, and water. It is dried with $CaCl_2$ or Na_2SO_4, and then distilled. The distillate is dried with sodium wire, P_2O_5, or metallic hydrides, or passage through a dry silica gel column, or preferably, and more safely, with molecular sieves (see p. 28) before being finally fractionally distilled through an efficient column. If the hydrocarbon is contaminated with olefinic impurities, shaking with aqueous alkaline permanganate is necessary prior to the above purification. Alicyclic and paraffinic hydrocarbons can be freed from water, non-hydrocarbon and aromatic impurities by passage through a silica gel column before the final fractional distillation. This may also remove isomers. (For the use of chromatographic methods to separate mixtures of aromatic, paraffinic and alicyclic hydrocarbons see references on pp. 44 and 45 under *Chromatography, Gas Chromatography and High Perforamance Liquid Chromatography*). Another method of removing branched-chain and unsaturated hydrocarbons from straight-chain hydrocarbons depends on the much faster reaction of the former with chlorosulphonic acid.
Isomeric materials which have closely similar physical properties can be serious contaminants in hydrocarbons. With aromatic hydrocarbons, e.g. xylenes and alkyl benzenes, advantage is taken of differences in ease of sulphonation. If the required compound is sulphonated more readily, the sulphonic acid is isolated, crystallised (e.g. from water), and decomposed by passing superheated steam through the flask containing the acid. The sulphonic acid undergoes hydrolysis and the liberated hydrocarbon distils with the steam. It is separated from the distillate, dried, distilled and then fractionally distilled. For small quantities (10-100mg), vapour phase chromatography is the most satisfactory method for obtaining a pure sample (for column materials for packings see p. 25).
Azeotropic distillation with methanol or 2-ethoxyethanol has been used to obtain highly purified saturated hydrocarbons and aromatic hydrocarbons such as xylenes and isopropylbenzenes.
Carbonyl-containing impurities can be removed from hydrocarbons (and other oxygen-lacking solvents such as $CHCl_3$ and CCl_4) by passage through a column of Celite 545 (100g) mixed with concentrated sulphuric acid (60ml). After first adding some solvent and about 10g of granular Na_2SO_4, the column is packed with the mixture and a final 7-8cm of Na_2SO_4 is added at the top [Hornstein and Crowe, *AC* **34** 1037 *1962*]. Alternatively, Celite impregnated with 2,4-dinitrophenylhydrazine can be used.
With solid hydrocarbons such as naphthalene, preliminary purification by sublimation in vacuum (or high vacuum if the substance is high melting), is followed by zone refining and finally by chromatography (e.g. on alumina) using low-boiling liquid hydrocarbon eluents. These solids can be recrystallised from alcohols, alcohol/petroleum ether or from liquid hydrocarbons (e.g. toluene) and dried below their melting points. Aromatic hydrocarbons that have been purified by zone melting include anthracene, biphenyl, fluoranthrene, naphthalene, perylene, phenanthrene, pyrene and terphenyl, among others.
Olefinic hydrocarbons have a very strong tendency to polymerise and commercially available materials are generally stabilized, e.g. with hydroquinone. When distilling compounds such as vinylpyridine or styrene, the stabilizer remains behind and the purified olefinic material is more prone to polymerization. The most common impurities are

higher-boiling dimeric or polymeric compounds. Vacuum distillation in a nitrogen atmosphere not only separates monomeric from polymeric materials but in some cases also depolymerizes the impurities. The distillation flask should be charged with a polymerization inhibitor and the purified material should be used immediately or stored in the dark and mixed with a small amount of stabilizer (e.g. 0.1% of hydroquinone).

Imides. Imides (e.g. phthalimide) can be purified by conversion to their potassium salts by reaction in ethanol with ethanolic potassium hydroxide. The imides are regenerated when the salts are hydrolysed with dilute acid. Like amides, imides readily crystallise from alcohols and, in some cases (e.g. quinolinic imide), from glacial acetic acid.

Imino compounds. These substances contain the -C=NH group and, because they are strong, unstable bases, they are kept as their more stable salts, such as the hydrochlorides. (The free base usually hydrolyses to the corresponding oxo compound and ammonia.) Like amine hydrochlorides, the salts are purified by solution in alcohol containing a few drops of hydrochloric acid. After treatment with charcoal, and filtering, dry ethyl ether (or petroleum ether if ethanol is used) is added until crystallisation sets in. The salts are dried and kept in a vacuum desiccator.

Ketones. Ketones are more stable to oxidation than aldehydes and can be purified from oxidisable impurities by refluxing with potassium permanganate until the colour persists, followed by shaking with sodium carbonate (to remove acidic impurities) and distilling. Traces of water can be removed with type 4A Linde molecular sieves. Ketones which are solids can be purified by crystallisation from alcohol, toluene, or petroleum ether, and are usually sufficiently volatile for sublimation in vacuum. Ketones can be further purified *via* their bisulphite, semicarbazone or oxime derivatives (see p. 51). The bisulphite addition compounds are formed only by aldehydes and methyl ketones but they are readily hydrolysed in dilute acid or alkali.

Macromolecules. See Chapter 5.

Nitriles. *All purifications should be carried out in an efficient fume cupboard because of the* **TOXIC** *nature of these compounds.*
Nitriles are usually prepared either by reacting the corresponding halide or diazonium salts with a cyanide salt or by dehydrating an amide. Hence, possible contaminants are the respective halide or alcohol (from hydrolysis), phenolic compounds, amines or amides. Small quantities of phenols can be removed by chromatography on alumina. More commonly, purification of liquid nitriles or solutions of solid nitriles in a solvent such as ethyl ether is by shaking with dilute aqueous sodium hydroxide, followed by washing successively with water, dilute acid and water. After drying with sodium sulphate, the solvent is distilled off. Liquid nitriles are best distilled from a small amount of P_2O_5 which, besides removing water, dehydrates any amide to the nitrile. About one fifth of the nitrile should remain in the distilling flask at the end of the distillation (*the residue may contain some inorganic cyanide*). This purification also removes alcohols and phenols. Solid nitriles can be recrystallised from ethanol, toluene or petroleum ether, or a mixture of these solvents. They can also be sublimed under vacuum. Preliminary purification by steam distillation is usually possible.
Strong alkali or heating with dilute acids may lead to hydrolysis of the nitrile, and should be avoided.

Nitro compounds. Aliphatic nitro compounds are acidic. They are freed from alcohols or alkyl halides by standing for a day with concentrated sulphuric acid, then washed with water, dried with magnesium sulphate followed by calcium sulphate and distilled. The principal impurities are isomeric or homologous nitro compounds. In cases where the nitro compound was originally prepared by vapour phase nitration of the aliphatic hydrocarbon, fractional distillation should separate the nitro compound from the corresponding hydrocarbon. Fractional crystallisation is more effective than fractional distillation if the melting point of the compound is not too low.
The impurities present in aromatic nitro compounds depend on the aromatic portion of the molecule. Thus, benzene, phenols or anilines are probable impurities in nitrobenzene, nitrophenols and nitroanilines, respectively. Purification should be carried out accordingly. Isomeric compounds are likely to remain as impurities after the preliminary purifications to remove basic and acidic contaminants. For example, *o*-nitrophenol may be found in samples of *p*-nitrophenol. Usually, the *o*-nitro compounds are more steam volatile than the *p*-nitro isomers, and can be separated in this way. Polynitro impurities in mononitro compounds can be readily removed because of their relatively lower solubilities in solvents. With acidic or basic nitro compounds which cannot be separated in the above manner, advantage may be taken of their differences in pK_a values. The compounds can thus be purified by preliminary extractions with several sets of aqueous buffers of known pH (see for example Table 19, p. 43) from a solution of the substance in a suitable solvent such as ethyl ether. This method is more satisfactory and less laborious the larger the difference between the pK_a value of the impurity and the desired compound. Heterocyclic nitro compounds require similar treatment to the nitroanilines. Neutral nitro compounds can be steam distilled.

Nucleic acids. See Chapter 5.

Phenols. Because phenols are weak acids, they can be freed from neutral impurities by dissolution in aqueous N sodium hydroxide and extraction with a solvent such as ethyl ether, or by steam distillation to remove the non-acidic

material. The phenol is recovered by acidification of the aqueous phase with 20% sulphuric acid, and either extracted with ether or steam distilled. In the second case the phenol is extracted from the steam distillate after saturating it with sodium chloride. A solvent is necessary when large quantities of liquid phenols are purified. The phenol is fractionated by distillation under reduced pressure, preferably in an atmosphere of nitrogen to minimize oxidation. Solid phenols can be crystallised from toluene, petroleum ether or a mixture of these solvents, and can be sublimed under vacuum. Purification can also be effected by fractional crystallisation or zone refining. For further purification of phenols *via* their acetyl or benzoyl derivatives, see p. 53.

Polypeptides and proteins . See Chapter 5.

Quinones. These are neutral compounds which are usually coloured. They can be separated from acidic or basic impurities by extraction of their solutions in organic solvents with aqueous basic or acidic solutions, respectively. Their colour is a useful property in their purification by chromatography through an alumina column with, e.g. toluene as eluent. They are volatile enough for vacuum sublimation, although with high-melting quinones a very high vacuum is necessary. *p*-Quinones are stable compounds and can be recrystallised from water, ethanol, aqueous ethanol, toluene, petroleum ether or glacial acetic acid. *o*-Quinones, on the other hand, are readily oxidised. They should be handled in an inert atmosphere, preferably in the absence of light.

Salts (organic). (a) With metal ions: Water-soluble salts are best purified by preparing a concentrated aqueous solution to which, after decolorising with charcoal and filtering, ethanol or acetone is added so that the salts crystallise. They are collected, washed with aqueous ethanol or aqueous acetone, and dried. In some cases. water-soluble salts can be recystallised satisfactorily from alcohols. Water-insoluble salts are purified by Soxhlet extraction, first with organic solvents and then with water, to remove soluble contaminants. The purified salt is recovered from the thimble.

(b) With organic ions: Organic salts (e.g. trimethylammonium benzoate) are usually purified by recrystallisation from polar solvents (e.g. water, ethanol or dimethyl formamide). If the salt is too soluble in a polar solvent, its concentrated solution should be treated dropwise with a miscible nonpolar solvent (see p. 14) until crystallisation begins.

(c) Sodium alkane disulphonates: Purified from sulphites by boiling with aq HBr. Purified from sulphates by adding $BaBr_2$. Sodium alkane disulphonates are finally pptd by addition of MeOH. [Pethybridge and Taba *JCSFT 1* **78** 1331 *1982*].

Sulphur compounds. (a) Disulphides can be purified by extracting acidic and basic impurities with aqueous base or acid, respectively. However, they are somewhat sensitive to strong alkali which slowly cleaves the disulphide bond. The lower-melting members can be fractionally distilled under vacuum. The high members can be recrystallised from alcohol, toluene or glacial acetic acid.

(b) Sulphones are neutral and extremely stable compounds that can be distilled without decomposition. They are freed from acidic and basic impurities in the same way as disulphides. The low molecular weight members are quite soluble in water but the higher members can be recrystallised from water, ethanol, aqueous ethanol or glacial acetic acid.

(c) Sulphoxides are odourless, rather unstable compounds, and should be distilled under vacuum in an inert atmosphere. They are water-soluble but can be extracted from aqueous solution with a solvent such as ethyl ether.

(d) Thioethers are neutral stable compounds that can be freed from acidic and basic impurities as described for disulphides. They can be recrystallised from organic solvents and distil without decomposition.

(e) Thiols are stronger acids than the corresponding hydroxy compounds but can be purified in a similar manner. However, care must be exercised in handling thiols to avoid their oxidation to disulphides. For this reason, purification is best carried out in an inert atmosphere in the absence of oxidising agents. Similarly, thiols should be stored out of contact with air. They can be distilled without change, and the higher-melting thiols (which are usually more stable) can be crystallised, e.g. from water or dilute alcohol. They oxidise readily in alkaline solution but can be separated from the disulphide which is insoluble in this medium. They should be stored in the dark below 0°. *All operations with thiols should be carried out in an efficient fume cupboard because of their unpleasant odour and their* **TOXICITY**.

(f) Thiolsulphonates (disulphoxides) are neutral and are somewhat light-sensitive compounds. Their most common impurities are sulphonyl chlorides (neutral) or the sulphinic acid or disulphide from which they are usually derived. The first can be removed by partial freezing or crystallisation, the second by shaking with dilute

alkali, and the third by recrystallisation because of the higher solubility of the disulphide in solvents. Thiolsulphonates decompose slowly in dilute, or rapidly in strong, alkali to form disulphides and sulphonic acids. Thiolsulphonates also decompose on distillation but they can be steam distilled. The solid members can be recrystallised from water, alcohols or glacial acetic acid.

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CHAPTER 3

PURIFICATION OF ORGANIC CHEMICALS

The general principles, techniques and methods of purification in Chapters 1 and 2 are applicable in this chapter. Most organic liquids and a number of solids can readily be purified by fractional distillation, usually at atmospheric pressure. Sometimes, particularly with high boiling or sensitive liquids, or when in doubt about stability, distillation or fractionation under reduced pressure should be carried out. To save space, the present chapter omits many substances for which the published purification methods involve simple distillation. Where boiling points are given, purification by distillation is another means of removing impurities. Literature references are omitted for methods which require simple recrystallisation from solution if the correct solvent can be guessed readily, and where no further information is given, e.g. spectra. Substances are listed alphabetically, usually with some criteria of purity, giving brief details of how they can be purified. Also noted are the molecular weights (to the first decimal place), melting points and/or boiling points together with the respective densities and refractive indexes for liquids, and optical rotations when the compounds are chiral. When the temperatures and/or the wavelengths are not given for the last three named properties then they should be assumed to be 20°C and the average of the wavelengths of the sodium D lines repectively; and densities are relative to water at 4°.

The present chapter includes commercially available organic chemicals. Most of the organo- phosphorus, boron, silicon, alkali metal compounds and metal ion salts are in Chapter 4. Naturally occurring commercially available organic compounds of use in biochemistry, molecular biology and biology are included in Chapter 5.

Abbreviations of words and some journal names are listed in Chapter 1, pages 1 and 2.

As a good general rule all low boiling (<100°) organic liquids should be treated as highly flammable and the necessary precautions should be taken.

Abietic acid *[514-10-3]* **M 302.5, m 172-175°,** $[\alpha]_D^{25}$ **-116° (-106°)(c 1, EtOH).** Crystd by dissolving 100g of acid in 95% EtOH (700ml), adding to H_2O (600ml) and cooling. Filter, dry in a vacuum (over KOH or $CaSO_4$) store in an O_2-free atmosphere. λ in EtOH nm(log ε): 2343(4.3), 241(4.4), 2505(4.2), 235(4.34) and 240(4.36). [*Org Synth* **23** 1 *1952* ; *JACS* **35** 3736 *1949*; *M* **116** 1345 *1985*].

Abscisic acid *[21293-39-8]* **M 264.3, m 160-161° (sublimation),** $[\alpha]_{287}$ **+ 24,000°,** $[\alpha]_{245}$ **-69,000° (c 1-50μg/ml in acidified MeOH or EtOH).** Crystd from CCl_4-pet.ether.

Acenaphthalene *[208-96-8]* **M 152.2, m 92-93°.** Dissolved in warm redistd MeOH, filtered through a sintered glass funnel and cooled to -78° to ppte the material as yellow plates [Dainton, Ivin and Walmsley *TFS* **56** 1784 *1960*]. Alternatively can be sublimed *in vacuo*.

Acenaphthaquinone *[82-86-0]* **M 182.2, m 260-261°.** Extracted with, then recrystd twice from C_6H_6. [LeFevre, Sundaram and Sundaram *JCS* 974 *1963*].

Acenaphthene *[83-32-9]* **M 154.2, m 94.0°.** Crystd from EtOH. Purified by chromatography from CCl_4 on alumina with benzene as eluent [McLaughlin and Zainal *JCS* 2485 *1960*].

***RS*-Acenaphthenol** *[6306-07-6]* **M 170.2, m 144.5-145.5°, 146°, 148°.** If highly coloured (yellow), dissolve in boiling benzene (14g in 200ml), add charcoal (0.5g), filter through a heated funnel, concentrate to 100ml and cool to give almost colourless needles. *Benzene vapour is* **TOXIC** *use good fumecupboard.* The *acetate* has **b** 166-168°/5mm (bath temp 180-185°). [*Org Synth* Col.Vol. III 3 *1955*]. It can also be recrystd from C_6H_6 or EtOH [Fieser and Cason *JACS* **62** 432 *1940*]. It forms a brick-red crystalline complex with 2,4,5,7-tinitrofluoren-9-one which is recrystd from AcOH and dried in a vacuum over KOH and P_2O_5 at room temp, **m** 170-172° [Newman and Lutz *JACS* **78** 2469 *1956*].

Acetal *[105-57-7]* **M 118.2, b 103.7-104°, d 0.831, n 1.38054, n^{25} 1.3682.** Dried over Na to remove alcohols and water, and to polymerise aldehydes, then fractionally distd. Or, treat with alkaline H_2O_2 soln at 40-45° to remove aldehydes, then the soln is saturated with NaCl, separated, dried with K_2CO_3 and distd from Na [Vogel *JCS* 616 *1948*].

Acetaldehyde *[75-07-0]* **M 44.1, b 20.2°, d 0.788, n 1.33113.** Usually purified by fractional distn in a glass helices-packed column under dry N_2, discarding the first portion of distillate. Or, shaken for 30min with $NaHCO_3$, dried with $CaSO_4$ and fractionally distd at 760mm through a 70cm Vigreux column. The middle fraction was taken and further purified by standing for 2h at 0° with a small amount of hydroquinone, followed by distn [Longfield and Walters *JACS* **77** 810 *1955*].

Acetaldehyde ammonia trimer (hexahydro-2,4,6-trimethyl-1,3,5-triazine trihydrate) *[76231-37-3]* **M 183.3, m 94-96°, 95-97°, 97°, b 110°(partly dec).** Crystd from EtOH-Et_2O. When prepared it separates as the *trihydrate* which can be dried in a vacuum over $CaCl_2$ at room temp to give the anhydrous compound with the same melting point. The *dihydrate* melts at 25-28° then resolidifies and melts again at 94-95°. *IRRITATES THE EYES AND MUCOUS MEMBRANES.* [*JOC* **38** 3288 *1973*].

Acetaldehyde dimethyl acetal *[534-15-6]* **M 90.1, b 63-65°, d_4^{20} 0.852, n_D^{25} 1.36678.** Distd through a fractionating column and fraction boiling at 63.8°/751mm is collected. It forms an azeotrope with MeOH.

Acetamide *[60-35-5]* **M 59.1, m 81°.** Crystd by soln in hot MeOH (0.8ml/g), diltd with Et_2O and allowed to stand [Wagner *J Chem Ed* **7** 1135 *1930*]. Alternate crystns are from acetone, benzene, chloroform, dioxane, methyl acetate or from benzene-ethyl acetate mixture (3:1 and 1:1). It has also been recrystd from hot water after treating with HCl-washed activated charcoal (which had been repeatedly washed with water until free from chloride ions), then crystd again from hot 50% aq. EtOH and finally twice from hot 95% EtOH [Christoffers and Kegeles *JACS* **85** 2562 *1963*]. Final drying is in a vacuum desiccator over P_2O_5. Acetamide is also purified by distn (**b** 221-223°) or by sublimation *in vacuo.* Also purified by recrystn twice from cyclohexane containing 5% (v/v) of benzene. Needle-like crystals separated by filtn, washed with a small volume of distd H_2O and dried with a flow of dry N_2. [Slebocka-Tilk et al. *JACS* **109** *4620 1987*].

Acetamidine hydrochloride *[124-42-5]* **M 94.5, m 164-166°, 165-170° (dec), 174°.** Can be recrystd from EtOH although it is quite soluble in it. Alternatively dissolve in EtOH, filter, add Et_2O, filter the crystalline salt off under N_2, dry in a vacuum desiccator over H_2SO_4. The salt is deliquescent and should be stored in a tightly stoppered container. Solubility in H_2O is 10% at room temperature, soluble in Me_2CO. The free base reacts strongly alkaline in H_2O and the pKa_1^{25} is 12.1. It has λ_{max} 224nm (ε 4000) in H_2O. The *picrate* has **m** 252° (sintering at ~245°). [Dox *Org Synth* Coll Vol I 5 *1941*; Davies and Parsons *Chemistry and Industry* 628 *1958*; Barnes et al. *JACS* **62** 1286 *1940* give **m** 177-178°].

1-Acetamidoadamantane see ***N*-(1-adamantyl)acetamide.**

N*-(2-Acetamido)-2-aminoethanolsulphonic acid *(ACES) *[7365-82-4]* **M 182.2, m > 220°(dec).** Recrystd from hot aqueous EtOH.

4-Acetamidobenzaldehyde *[122-85-0]* **M 163.2, m 156°.** Recrystd from water.

***p*-Acetamidobenzenesulphonyl chloride** *[121-60-8]* **M 233.7, m 149°(dec).** Crystd from toluene, $CHCl_3$, or ethylene dichloride.

α-Acetamidocinnamic acid *[5469-45-4]* **M 205.2, m 185-186° ($2H_2O$), 190-191°(anhydr), 193-195°.** Recrystd from H_2O as the dihydrate and on drying at 100° it forms the anhydrous compound which is *hygroscopic*. Alkaline hydrolysis yields NH_3 and phenylpyruvic acid. [Erlenmeyer and Früstück *A* **284** 47 *1895*].

Z-*O*-(2-Acetamido-2-deoxy-D-glycopyranosylideneamino)*N*-phenylcarbamate (PUGNAC) *[132489-69-1]* **M 335.3, m 171-174° (dec), 174-180° (dec), $[\alpha]_D^{20}$ +67.5° (c 0.2, MeOH).** Purified by flash chromatography (silica gel and eluted with AcOEt-hexane 3:2) evaporated, and the foam recrystallised from AcOEt-MeOH. TLC on Merck SiO_2 gel 60 F_{254} and detected by spraying with 0.025M I_2 in 10% aqueous H_2SO_4 and heat at 200° gave R_F 0.21. The acetate is hydrolysed with NH_3-MeOH. [*HCA* **68** 2254 *1985*; **73** 1918 *1990*].

2-Acetamidofluorene *[53-96-3]* **M 223.3, m 194°, 196-198°.** Recrystd from toluene (1.3mg in 100ml). Solubility in H_2O is 1.3mg/L; UV λ_{max} nm(log ε) : 288(4.43), 313(4.13). [*JOC* **21** 271 *1956*]. It can also be recrystd from 50% AcOH and sol in H_2O is 1.3mg/100ml at 25° [*B* **35** 3285 *1902*]. 9-^{14}C and ω-^{14}C 2-acetamidofluorene were recrystd from aqueous EtOH and had **m** 194-195° and 194° respectively. *Potent* **CARCINOGEN.** [*Cancer Research* **10** 616 *1950*; *JACS* **74** 5073 *1952*].

***N*-(2-Acetamido)iminodiacetic acid (ADA)** *[26239-55-4]* **M 190.2, m 219° (dec).** Dissolved in water by adding one equivalent of NaOH soln (to final pH of 8-9), then acidified with HCl to ppte the free acid. Filtered and washed with water.

Acetamidomethanol *[625-51-4]* **M 89.1, m 47-50°, 54-56°, 55°.** Recryst from freshly distd Me_2CO, wash the crystals with dry Et_2O and dry in a vacuum desiccator over P_2O_5. R_F 0.4 on paper chromatography with $CHCl_3$/EtOH (2:8) as solvent and developed with ammoniacal $AgNO_3$. Also crystallises in needles from EtOAc containing a few drops of Me_2CO. It is *hygroscopic* and should be stored under dry conditions. [*JACS* **73** 2775 *1951*; **B 99** 3204 *1966*; *A* **343** 265 *1905*].

2-Acetamido-5-nitrothiazole *[140-40-9]* **M 187.2, m 264-265°.** Recrystd from EtOH or glacial acetic acid.

2-Acetamidophenol *[614-80-2]* **M 151.2, m. 209°.** Recrystd from water or aqueous EtOH.

3-Acetamidophenol *[621-42-1]* **M 151.2, m 148-149°.** Recrystd from water.

4-Acetamidophenol *[103-90-2]* **M 151.2, m 169-170.5°.** Recrystd from water or EtOH.

4-Acetamido-2,2,6,6-tetramethylpiperidine-1-oxyl (acetamidoTEMPO) *[14691-89-5]* **M 213.3, m 144-146°, 146-147°.** Dissolve in CH_2Cl_2, wash with saturated K_2CO_3, then saturated aqueous NaCl, dry (Na_2SO_4), filter and evaporate. The red solid is recrystd from aqueous MeOH, **m** 147.5°. [*JOC* **56** 6110 *1991*; *BASU* **15** 1422 *1966*].

5-Acetamido-1,3,4-thiadiazole-2-sulphonamide *[59-66-5]* **M 222.3, m 256-259° (dec).** Recrystd from water.

Acetanilide *[103-84-4]* **M 135.2, m 114°.** Recrystd from water, aqueous EtOH, benzene or toluene.

Acetic acid (glacial) *[64-19-7]* **M 60.1, m 16.6°, b 118°, d 1.049, n 1.37171, n^{25} 1.36995.** Usual impurities are traces of acetaldehyde and other oxidisable substances and water. (Glacial acetic acid is very *hygroscopic*. The presence of 0.1% water lowers its m by 0.2°.) Purified by adding some acetic anhydride to react with water present, heating for 1h to just below boiling in the presence of 2g CrO_3 per 100ml and then

fractionally distilling [Orton and Bradfield *JCS* 960 *1924*, 983 *1927*]. Instead of CrO_3, 2-5% (w/w) of $KMnO_4$, with boiling under reflux for 2-6h, has been used.
Traces of water have been removed by refluxing with tetraacetyl diborate (prepared by warming 1 part of boric acid with 5 parts (w/w) of acetic anhydride at 60°, cooling, and filtering off), followed by distn [Eichelberger and La Mer *JACS* **55** 3633 *1933*].
Refluxing with acetic anhydride in the presence of 0.2g % of 2-naphthalenesulphonic acid as catalyst has also been used [Orton and Bradfield *JCS* 983 *1927*]. Other suitable drying agents include $CuSO_4$ and chromium triacetate: P_2O_5 converts some acetic acid to the anhydride. Azeotropic removal of water by distn with thiophene-free benzene or with butyl acetate has been used [Birdwhistell and Griswold *JACS* **77** 873 *1955*]. An alternative purification uses fractional freezing. Acetic acid has a pKa^{25} of 4.76 in water.

Acetic anhydride *[108-24-7]* **M 102.1, b 138°, d 1.082, n 1.3904.** Adequate purification can usually be obtained by fractional distn through an efficient column. Acetic acid can be removed by prior refluxing with CaC_2 or with coarse Mg filings at 80-90° for 5days, or by distn from synthetic quinoline (1% of total charge) at 75mm pressure. Acetic anhydride can also be dried by standing with Na wire for up to a week, removing the Na and distilling from it under vacuum. (Na reacts vigorously with acetic anhydride at 65-70°). Dippy and Evans [*JOC* **15** 451 *1950*] let the anhydride (500g) stand over P_2O_5 (50g) for 3h, then decanted it and stood it with ignited K_2CO_3 for a further 3h. The supernatant liquid was distd and the fraction **b** 136-138°, was further dried with P_2O_5 for 12h, followed by shaking with ignited K_2CO_3, before two further distns through a five-section Young and Thomas fractionating column. The final material distd at 137.8-138.0°. Can also be purified by azeotropic distn with toluene: the azeotrope boils at 100.6°. After removal of the remaining toluene, the anhydride is distd [sample had a specific conductivity of 5×10^{-9} $ohm^{-1}cm^{-1}$].

Acetin Blue Crystd from 1:3 benzene-methanol.

Acetoacetamide *[5977-14-0]* **M 101.1, m 54-55°, 54-56°.** Recrystallise from $CHCl_3$, or Me_2CO/pet ether. Crystallises from pyridine with 4mol of solvent. Slightly soluble in H_2O, EtOH and AcOH but insoluble in Et_2O. *Phenylhydrazone* has **m** 128°. [*Beilstein* 3 **4** 1545; *B* **35** 583 *1902*].

Acetoacetanilide *[102-01-2]* **M 177.2, m 86°.** Crystd from H_2O, aqueous EtOH or pet ether (b 60-80°).

Acetoacetylpiperidide *[1128-87-6]* **M 169.2, b 88.9°/0.1mm, n^{52} 1.4983.** Dissolved in benzene, extracted with 0.5M HCl to remove basic impurities, washed with water, dried, and distd at 0.1mm [Wilson *JOC* **28** 314 *1963*].

α-Acetobromoglucose *[572-09-8]* **M 411.2, m 88-89°, $[\alpha]_D^{25}$ +199.3° (c 3, $CHCl_3$).** Crystd from isopropyl ether or pet ether (b 40-60°).

Acetoin see **3-hydroxy-2-butanone.**

2-Acetonaphthalene *[93-08-3]* **M 170.2, m 55-56°.** Crystd from pet ether, EtOH or acetic acid. [Gorman and Rodgers *JACS* **108** 5074 *1986*].

2-Acetonaphthenone, see **2-acetonaphthalene.**

ß-Acetonaphthone *[93-08-3]* **M 170.2, m 54-55°.** Recrystd from EtOH [Levanon et al. *JPC* **91** 14 *1987*].

Acetone *[67-64-1]* **M 58.1, b 56.2°, d 0.791, n 1.35880.** The commercial preparation of acetone by catalytic dehydrogenation of isopropyl alcohol gives relatively pure material. Analytical reagent quality generally contains less than 1% organic impurities but may have up to about 1% H_2O. Dry acetone is appreciably *hygroscopic*. The main organic impurity in acetone is mesityl oxide, formed by the aldol condensation. It can be dried with anhydrous $CaSO_4$, K_2CO_3 or type 4A Linde molecular sieves, and then distd. Silica gel and alumina, or mildly acidic or basic desiccants cause acetone to undergo the aldol condensation, so that its water content is increased by passage through these reagents. This also occurs to some extent when

P_2O_5 or sodium amalgam is used. Anhydrous $MgSO_4$ is an inefficient drying agent, and $CaCl_2$ forms an addition compound. Drierite (anhydrous $CaSO_4$) offers the minimum acid and base catalysis of aldol formation and is the recommended drying agent for this solvent [Coetzee and Siao *Inorg Chem* **14v** 2 *1987*; Riddick and Bunger *Organic Solvents* Wiley-Interscience, N.Y., 3rd edn, 1970]. Acetone was shaken with Drierite (25g/L) for several hours before it was decanted and distd from fresh Drierite (10g/L) through an efficient column, maintaining atmospheric contact through a Drierite drying tube. The equilibrium water content is about 10^{-2}M. Anhydrous $Mg(ClO_4)_2$ **should not be used as drying agent because of the risk of EXPLOSION with acetone vapour.**
Organic impurities have been removed from acetone by adding 4g of $AgNO_3$ in 30ml of water to 1L of acetone, followed by 10ml of M NaOH, shaking for 10min, filtering, drying with anhydrous $CaSO_4$ and distilling [Werner *Analyst* **58** 335 *1933*]. Alternatively, successive small portions of $KMnO_4$ have been added to acetone at reflux, until the violet colour persists, followed by drying and distn. Refluxing with chromic anhydride has also been used. Methanol has been removed from acetone by azeotropic distn (at 35°) with methyl bromide, and treatment with acetyl chloride.
Small amounts of acetone can be purified as the NaI addition compound, by dissolving 100g of finely powdered NaI in 400g of boiling acetone, then cooling in ice and salt to -8°. Crystals of $NaI.3Me_2CO$ are filtered off and, on warming in a flask, acetone distils off readily. [This method is more convenient than the one using the bisulphite addition compound]. Also purified by gas chromatography on a 20% free fatty acid phthalate (on Chromosorb P) column at 100°.
For efficiency of desiccants in drying acetone see Burfield and Smithers [*JOC* **43** 3966 *1978*]. The water content of acetone can be determined by a modified Karl Fischer titration [Koupparis and Malmstadt *AC* **54** 1914 *1982*].

Acetone cyanohydrin *[75-86-5]* **M 85.1, b 48°/2.5mm, 68-70°/11mm, 78-82°/15mm,** d_4^{20} **0.93.** Dry with Na_2SO_4, and distil as rapidly as possible under vacuum to avoid decomposition. Discard fractions boiling below 78-82°/15mm. Store in the dark. **USE AN EFFICIENT FUME HOOD as HCN (POISONOUS) is always present.** [*Org Synth* Col.Vol. II 7 *1940*].

Acetonedicarboxylic acid *[542-05-2]* **M 146.1, m 138° (dec).** Crystd from ethyl acetate and stored over P_2O_5.

Acetone semicarbazone *[110-20-3]* **M 115.1, m 187°.** Crystd from water or from aqueous EtOH.

Acetonitrile *[75-05-8]* **M 41.1, b 81.6°,** d^{25} **0.77683, n 1.3441,** n^{25} **1.34163.** Commercial acetonitrile is a byproduct of the reaction of propylene and ammonia to acrylonitrile. The procedure that significantly reduces the levels of acrylonitrile, allyl alcohol, acetone and benzene was used by Kiesel [*AC* **52** 2230 *1988*]. Methanol (300ml) is added to 3L of acetonitrile fractionated at high reflux ratio until the boiling temperature rises from 64° to 80°, and the distillate becomes optically clear down to λ = 240nm. Add sodium hydride (1g) free from paraffin, to the liquid, reflux for 10min, and then distil rapidly until about 100ml of residue remains. Immediately pass the distillate through a column of acidic alumina, discarding the first 150ml of percolate. Add 5g of CaH_2 and distil the first 50ml at a high reflux ratio. Discard this fraction, and collect the following main fraction. The best way of detecting impurities is by gas chromatography.
Usual contaminants in commercial acetonitrile include H_2O, acetamide, NH_4OAc and NH_3. Anhydrous $CaSO_4$ and $CaCl_2$ are inefficient drying agents. Preliminary treatment of acetonitrile with cold, satd aq KOH is undesirable because of base-catalysed hydrolysis and the introduction of water. Drying by shaking with silica gel or Linde 4A molecular sieves removes most of the water in acetonitrile. Subsequent stirring with CaH_2 until no further hydrogen is evolved leaves only traces of water and removes acetic acid. The acetonitrile is then fractionally distd at high reflux, taking precaution to exclude moisture by refluxing over CaH_2 [Coetzee *PAC* **13** 429 *1966*]. Alternatively, 0.5-1% (w/v) P_2O_5 is often added to the distilling flask to remove most of the remaining water. Excess P_2O_5 should be avoided because it leads to the formation of an orange polymer. Traces of P_2O_5 can be removed by distilling from anhydrous K_2CO_3.
Kolthoff, Bruckenstein and Chantooni [*JACS* **83** 3297 *1961*] removed acetic acid from 3L of acetonitrile by shaking for 24h with 200g of freshly activated alumina (which had been reactivated by heating at 250° for 4h). The decanted solvent was again shaken with activated alumina, followed by five batches of 100-150g of anhydrous $CaCl_2$. (Water content of the solvent was then less than 0.2%). It was shaken for 1h with 10g of

P_2O_5, twice, and distd in a 1m x 2cm column, packed with stainless steel wool and protected from atmospheric moisture by $CaCl_2$ tubes. The middle fraction had a water content of 0.7 to 2mM.
Traces of unsaturated nitriles can be removed by an initial refluxing with a small amount of aq KOH (1ml of 1% solution per L). Acetonitrile can be dried by azeotropic distn with dichloromethane, benzene or trichloroethylene. Isonitrile impurities can be removed by treatment with conc HCl until the odour of isonitrile has gone, followed by drying with K_2CO_3 and distn.
Acetonitrile was refluxed with, and distd from alkaline $KMnO_4$ and $KHSO_4$, followed by fractional distn from CaH_2. (This was better than fractionation from molecular sieves or passage through a type H activated alumina column, or refluxing with KBH_4 for 24h and fractional distn)[Bell, Rodgers and Burrows *JCSFT 1* **73** 315 *1977*; Moore et al. *JACS* **108** 2257 *1986*].
Material suitable for polarography was obtained by refluxing over anhydrous $AlCl_3$ (15g/L) for 1h, distilling, refluxing over Li_2CO_3 (10g/L) for 1h and redistg. It was then refluxed over CaH_2 (2g/L) for 1h and fractionally distd, retaining the middle portion. The product was not suitable for UV spectroscopy use. A better purification used refluxing over anhydrous $AlCl_3$ (15g/L) for 1h, distg, refluxing over alkaline $KMnO_4$ (10g $KMnO_4$, 10g Li_2CO_3/L) for 15min, and distg. A further reflux for 1h over $KHSO_4$ (15g/L), then distn, was followed by refluxing over CaH_2 (2g/L) for 1h, and fractional distn. The product was protected from atmospheric moisture and stored under nitrogen [Walter and Ramalay *AC* **45** 165 *1973*].
Acetonitrile has been distd from $AgNO_3$, collecting the middle fraction over freshly activated Al_2O_3. After standing for two days, the liquid was distd from the activated Al_2O_3. Specific conductivity 0.8-1.0 x 10^{-8} mhos [Harkness and Daggett *Canad J Chem* **43** 1215 *1965*].
Acetonitrile ^{14}C was purified by gas chromatography and is water free and distd at 81°. [*J.Mol.Biol.* 1974, **87**, 541].

4-Acetophenetidine *[62-44-2]* **M 179.2, m 136°.** Crystd from H_2O or purified by soln in cold dilute alkali and reppted by addn of acid to neutralisation point. Air-dried.

Acetophenone *[98-86-2]* **M 120.2, m 19.6°, b 54°/2.5mm, 202°/760mm, d^{25} 1.0238, n^{25} 1.5322.** Dried by fractional distn or by standing with anhydrous $CaSO_4$ or $CaCl_2$ for several days, followed by fractional distn under reduced pressure (from P_2O_5, optional), and careful, slow and repeated partial crystns from the liquid at 0° excluding light and moisture. It can also be crystd at low temperatures from isopentane. Distn can be followed by purification using gas-liquid chromatography [Earls and Jones *JCSFT 1* **71** 2186 *1975*].

Acetoxime *[127-06-0]* **M 73.1, m 63°, b 135°/760mm.** Crystd from pet ether (b 40-60°). Can be sublimed.

Acetonylacetone (hexane-2,5-dione] *[110-13-4]* **M 114.2, m -9°, b 76-78°/13mm, 88°/25mm, 137°/150mm, 188°/atm, d_4^{20} 0.9440, n_D^{20} 1.423.** Purified by dissolving in Et_2O, stirred with K_2CO_3 (a quarter of its bulk), filtered, dried over anhydrous Na_2SO_4 (**not $CaCl_2$**), filtered, evapd and distd in a vacuum. It is then redistd through a 30cm Vigreux column (oil bath temp 150°). It is miscible with H_2O and EtOH. The *dioxime* has **m** 137° (plates from C_6H_6), *mono-oxime* has **b** 130°/11mm, and the *2,4-dinitrophenylhydrazone* has **m** 210-212° (red needles from EtOH). [*B* **22** 2100 *1989*; for enol content see *JOC* **19** 1960 *1954*].

Acetonyl triphenyl phosphonium chloride *[1235-21-8]* **M 354.8, m 237-238°, 244-246° (dec).** Recrystd from $CHCl_3$ + C_6H_6 + pet ether (b 60-80°) and by dissolving in $CHCl_3$ and running the soln into dry Et_2O. λ_{max}^{EtOH} nm(ε) 255(3,600), 262(3,700), 268(4,000) and 275(3,100). The *iodide salt* crystallises from H_2O and has **m** 207-209°. [*JOC* **22** 41 *1957*]. **IRRITANT and** *hygroscopic.* When shaken with a 10% aqueous soln of Na_2CO_3 (8h) it gives ***acetylmethylene triphenyl phosphorane*** which is recrystd from MeOH-H_2O and after drying at 70°/0.1mm has **m** 205-206°. UV: λmax nm(ε) 268 (6600), 275 (6500) and 288 (5700); IR:ν (cm^{-1}) 1529 (s), 1470 (m), 1425 (s), 1374 (m), 1105 (s) and 978 (s). [*JOC* **22** 41, 44 *1957*].

Aceto-*o*-toluidide *[120-66-1]* **M 149.2, m 110°, b 296°/760mm,**
Aceto-*m*-toluidide *[537-92-8]* **m 65.5°, b 182-183°/14mm, 307°/760mm.** Crystd from H_2O, EtOH or aqueous EtOH.

Aceto-*p*-toluidide *[103-89-9]* **M 149.2, m 146°, b 307°/760mm.** Crystd from aqueous EtOH.

Acetoxyacetone (acetol acetone] *[592-20-1]* **M 116.1, b 65°/11mm, 73-75°/17mm, 174-176°/atm, d_4^{20} 1.0757, n_D^{20} 1.4141.** Distil under reduced pressure, then redistil at atm pressure. It is miscible with H_2O but is slowly decomposed by it. Store in dry atmosphere. The *2,4-dinitrophenylhydrazone* has **m** 115-115.5° (from $CHCl_3$/hexane). [*JCS* **59** 789 *1891*; *JOC* **21** 68 *1956*; *A* **335** 260 *1904*].

4-Acetoxy-2-azetidinone *[28562-53-0]* **M 129.1, m 38-41°.** Dissolve in $CHCl_3$, dry ($MgSO_4$) concentrate at 40°/70mm, or better at room temperature to avoid decomposition. Wash and stir the residual oil with hexane by decantation and discard wash. Dry the oil at high vacuum when it should solidify, **m** 34°. It can be distd at high vacuum, 80-82°/10^{-3}mm, but this results in extensive losses. The purity can be checked by TLC using Merck Silica Gel F_{254} and eluting with EtOAc. The azetidinone has R_F 0.38 (typical impurities have R_F 0.67). The spots can be detected by the TDM spray. This is prepared from (A) 2.5g 4,4'-tetramethyldiaminodiphenylmethane (TDM) in 10ml AcOH and diluted with 50ml of H_2O, (B) 5g KI in 100ml of H_2O and (C) 0.3g ninhydrin in 10ml of AcOH and 90ml of H_2O. The spray is prepared by mixing (A) and (B) with 1.5ml of (C) and stored in a brown bottle. [*A* 539 *1974*; *Org Synth* **65** 135 *1987*].

1-Acetoxy-2-butoxyethane *[112-07-2]* **M 160.2, b 61-62°/0.2mm, 75-76°/12mm, 185.5°/740mm, 188-192°/atm, d_4^{20} 0.9425, n_D^{20} 1.4121.** Shake with anhydrous Na_2CO_3, filter and distil in a vacuum. Redistn can be then be carried out at atmospheric pressure. [*JOC* **21** 1041 *1956*].

3*R*,4*R*,1'*R*-4-Acetoxy-3-[1-(*tert*-butylmethylsilyloxy)ethyl]-2-azetinone see Chapter 4.

2-Acetoxy-ethanol *[542-59-6]* **M 104.1, b 187°/761mm, 187-189°/atm, d_4^{20} 1.108, n_D^{20} 1.42.** Dry over K_2CO_3 (**not $CaCl_2$**), and distil. [*JCS* 3061 1950; rate of hydrolysis: *JCS* 2706 *1951*].

1-Acetoxy-2-ethoxyethane *[111-15-9]* **M 132.2, b 156-159°, d_4^{20} 0.97, n_D^{20} 1.406.** Shake with anhydr Na_2CO_3, filter and distil in vac. Redistn can then be carried out at atm pressure. [*JOC* **21** 1041 *1956*].

1-Acetoxy-2-methoxyethane *[110-49-6]* **M 118.1, b 141°/732mm, 140144°/atm, d_4^{20} 1.009, n_D^{20} 1.4011.** Shake with anhydrous Na_2CO_3, filter and distil in a vacuum. Redistn can be then be carried out at atmospheric pressure. [*JOC* **21** 1041 *1956*].

***S*-(+)-α-Acetoxyphenylacetic acid** *[7322-88-5]* **M 194.2, m 80-81°, 95-97.5°, $[\alpha]_D^{27}$ +158° (c 1.78, Me_2CO), $[\alpha]_{546}^{20}$ +186° (c 2, Me_2CO).** Recryst from benzene-hexane and has characteristic NMR and IR spectra. [*A* **622** 10 *1959*; *JOC* **39** 1311 *1974*].

***R*-(-)-α-Acetoxyphenylacetic acid** *[51019-43-3]* **M 194.2, m 96-98°, $[\alpha]_D^{20}$ -153.7° (c 2.06, Me_2CO), $[\alpha]_{546}^{20}$ -194° (c 2.4, Me_2CO).** Recrysts from H_2O with 1mol of solvent which is removed on drying. [*JCS* 227 *1943*].

21-Acetoxypregnenolone M 374.5, m 184-185°. Crystd from Me_2CO.

***S*-(-)-2-Acetoxypropionyl chloride** *[36394-75-9]* **M 150.6, b 51-53°/11mm, d_4^{20} 1.19, n_D^{20} 1.423, $[\alpha]_D^{27}$ -33°, (c 4, $CHCl_3$), $[\alpha]_{546}^{20}$ -38° (c 4, $CHCl_3$).** It is moisture sensitive and is hydrolysed to the corresponding acid. Check the IR spectrum. It the OH band above 3000cm $^{-1}$ is too large and broad then the mixture should be refluxed with pure acetyl chloride for 1h, evapd and distd under reduced pressure.

***S*-Acetoxysuccinic anhydride** *[59025-03-5]* **M 158.1, m 58° (*RS* 81.5-82.5°, 86-87°), $[\alpha]_D^{20}$ -26.0° (c 19, Me_2CO), $[\alpha]_D^{20}$ -28.4° (c 13, Ac_2O).** Recrystd from Ac_2O and dry in a vacuum over KOH, or by washing with dry Et_2O due to its deliquescent nature. [*JCS* 788 *1933; SC* **16** 183 *1986*; *JOC* **52** 1040 *1988*; *RS* : *JACS* **88** 5306 *1966*].

Acetylacetone *[123-54-6]* **M 100.1, b 45°/30mm, $d^{30.2}$ 0.9630, $n^{18.5}$ 1.45178.** Small amounts of acetic acid were removed by shaking with small portions of 2M NaOH until the aqueous phase remained faintly

alkaline. The sample, after washing with water, was dried with anhydrous Na_2SO_4, and distd through a modified Vigreux column [Cartledge *JACS* **73** 4416 *1951*]. An additional purification step is fractional crystn from the liquid. Alternatively, there is less loss of acetylacetone if it is dissolved in four volumes of benzene and the soln is shaken three times with an equal volume of distd water (to extract acetic acid): the benzene is then removed by distn at 43-53° and 20-30mm through a helices-packed column. It is then refluxed over P_2O_5 (10g/L) and fractionally distd under reduced pressure. The distillate (sp conductivity 4 x 10^{-8} $ohm^{-1}cm^{-1}$) was suitable for polarography [Fujinaga and Lee *Talanta* **24** 395 *1977*]. To recover used acetylacetone, metal ions were stripped from the soln at pH 1 (using 100ml 0.1M H_2SO_4/L of acetylacetone). The acetylacetone was washed with (1:10) ammonia soln (100ml/L) and with distd water (100ml/L, twice), then treated as above.

***N*-Acetyl-L-alaninamide** *[15062-47-7]* **M 130.2, m 162°.** Crystd repeatedly from EtOH-ethyl ether.

***N*-Acetyl-ß-alanine** *[3025-95-4]* **M 127.2, m 78.3-80.3°.** Crystd from acetone.

***N*-Acetyl-L-alanyl-L-alaninamide** *[30802-37-0]* **M 201.2, m 250-251°.** Crystd repeatedly from EtOH/ethyl ether.

***N*-Acetyl-L-alanyl-L-alanyl-L-alaninamide** *[29428-34-0]* **M 272.3, m 295-300°.** Crystd from MeOH/ether.

***N*-Acetyl-L-alanylglycinamide** *[76571-64-7]* **M 187.2, m 148-149°.** Crystd repeatedly from EtOH/ethyl ether.

Acetyl-α-amino-*n*-butyric acid *[34271-24-4]* **M 145.2.** Crystd twice from water (charcoal) and air dried [King and King *JACS* **78** 1089 *1956*].

2-Acetylaminofluorene see ***N*-2-fluorenylacetamide.**

9-Acetylanthracene *[784-04-3]* **M 220.3, m 75-76°.** Crystd from EtOH. [Masnori et al. *JACS* **108** 1126 *1986*].

***N*-Acetylanthranilic acid** *[89-52-1]* **M 179.1, m 182-184°, 185-186°, 190°(dec).** Wash with distilled H_2O and recrystallise from aqueous AcOH, dry and recrystallise again from EtOAc. Also recryst from water or EtOH. Its pKa is 3.61 at 20°. [*JCS* 2495 *1931*; *JACS* **77** 6698 *1955*].

2-Acetylbenzoic acid *[577-56-0]* **M 164.2, m 115-116°, 116-118°.** Recrystallises from C_6H_6 and H_2O (15g/100ml). It has pKa in H_2O of 4.10 at 25°, and the *oxime* has **m** 156-157°, and the *2,4-dinitrophenylhydrazone* has **m** 185-186°(needles from EtOH). [*JACS* **69** 1547 *1947*].

4-Acetylbenzoic acid *[586-89-0]* **M 164.2, m 207.5-209.5°, 208.6-209.4°.** Dissolve in 5% aqueous NaOH, extract with Et_2O, and acidify the aqueous soln. Collect the ppte, and recrystallise from boiling H_2O (100 parts) using decolorising charcoal. It has a pKa of 3.70 in H_2O at 25°, and a pKa of 5.10 in 50% aq EtOH. [*JOC* **24** 504 *1959*; *JCS* 265 *1957*; *JACS* **72** 2882 *1050*, **74** 1058 *1952*].

Acetylbenzonitrile *[1443-80-7]* **M 145.2, m 57-58°.** Recrystd from EtOH [Wagner et al. *JACS* **108** 7727 *1986*].

4-Acetylbiphenyl *[92-91-1]* **M 196.3, m 120-121°, b 325-327°/760mm.** Crystd from EtOH or acetone.

Acetyl-5-bromosalicylic acid *[1503-53-3]* **M 168-169°.** Crystd from EtOH.

2-Acetylbutyrolactone *[517-23-7]* **M 128.1, b 105°/5mm, 120-123°/11mm, 142-143°/30mm, d_4^{20} 1.1846, n_D^{20} 1.459.** Purified by distillation, which will convert any free acid to the lactone, alternatively dissolve in Et_2O, wash well with 0.5N HCl, dry the organic layer and distil. The

solubility in H_2O is 20% v/v. The *2,4-dinitrophenylhydrazone* forms orange needles from MeOH, **m** 146°. The *dipropylamine salt* has **m** 68-70°, from which the lactone is formed on acidification. The liquid is a **skin irritant**. [*J Pharm Soc Japan* **62** 417(439) *1942*; *HCA* **35** 2401 *1952*].

Acetylcarnitine chloride *[R:5080-50-2][S:5061-35-8][RS:2504-11-2]* **M 239.7.** Recrystd from isopropanol. Dried over P_2O_5 under high vacuum.

Acetyl chloride *[75-36-5]* **M 78.5, b 52°, d 1.1051, n 1.38976.** Refluxed with PCl_5 for several hours to remove traces of acetic acid, then distd. Redistd from one-tenth volume of dimethylaniline or quinoline to remove free HCl. A.R. quality is freed from HCl by pumping it for 1h at -78° and distg into a trap at -196°.

Acetylcholine bromide *[66-23-9]* **M 226.1, m 146°.** Crystd from EtOH.

Acetylcyclohexane (cyclohexyl methylketone) *[823-76-7]* **M 126.2, b 64°/11mm, 76.2-77°/25mm, d_4^{20} 0.9178, n_D^{20} 1.4519.** Dissolve in Et_2O, shake with H_2O, dry, evaporate and fractionate under reduced pressure. [UV: *JACS* **74** 518 *1952*; enol content: *JOC* **19** 1960 *1954*]. The *semicarbazone* has **m** 174° and the *2,4-dinitrophenylhydrazone* has **m** 139-140° [*HCA* **39** 1290 *1956*].

2-Acetylcyclohexanone *[874-23-7]* **M 140.2, m -11°, b 62-64°/2.5mm, 95-98°/10mm, 111-112°/18mm, d_4^{20} 1.08, n_D^{20} 1.51.** Dissolve in ligroin (b 30-60°), wash with saturated aqueous $NaHCO_3$ dry over Drierite and fractionate in a vacuum. [*JACS* **75** 626, 5030 *1953*; **B 87** 108 *1954*]. It forms a *Cu salt* which crystallises in green leaflets from EtOH, **m** 162-163° [UV: *JCS* 4419 *1957*].

2-Acetylcyclopentanone *[1670-46-8]* **M 126.2, b. 72-75°/8mm, 82-86°/12mm, 88°/18mm, d_4^{20} 1.043, n_D^{20} 1.490.** Dissolve in pet ether (b 30-60°), wash with satd aq $NaHCO_3$, dry over Drierite and fractionate in a vacuum. It gives a violet colour with ethanolic $FeCl_3$ and is only slowly hydrolysed by 10% aq KOH but rapidly on boiling to yield 6-oxoheptanoic acid. [*JACS* **75** 5030 *1953*; *JCS* 4232 *1956*; UV: *JACS* **81** 2342 *1959*]. It gives a gray green *Cu salt* from Et_2O-pentane, **m** 237-238° [*JACS* **79** 1488 *1957*].

***N^4*-Acetylcytosine** *[14631-20-0]* **M 153.1, m >300°, 326-328°.** If TLC or paper chromatography show that it contains unacetylated cytosine then reflux in Ac_2O for 4h, cool at 3-4° for a few days, collect the crystals, wash with cold H_2O, then EtOH and dry at 100°. It is insoluble in EtOH and difficulty soluble in H_2O but crystallises in prisms from hot H_2O. It is hydrolysed by 80% aq AcOH at 100°/1h. [*Amer Chem J* **29** 500 *1903*; UV: *JCS* 2384 *1956*; *JACS* **80** 5164 *1958*]. It forms an Hg salt [*JACS* **79** 5060 *1957*].

Acetyldigitoxin-α M 807.0, m 217-221°, $[\alpha]_D^{20}$+5.0 (c 0.7, pyridine). Crystd from MeOH as plates.

Acetylene *[74-86-2]* **M 26.0, m -80.8°, b -84°.** Purified by successive passage through spiral wash bottles containing, in this order, satd aq $NaHSO_4$, H_2O, 0.2M iodine in aq KI (two bottles), sodium thiosulphate soln (two bottles), alkaline sodium hydrosulphite with sodium anthraquinone-2-sulphonate as indicator (two bottles), and 10% aqueous KOH soln (two bottles). The gas was then passed through a Dry-ice trap and two drying tubes, the first containing $CaCl_2$, and the second, Dehydrite [Conn, Kistiakowsky and Smith *JACS* **61** 1868 *1939*]. Acetone vapour can be removed from acetylene by passage through two traps at -65°.
Sometimes contains acetone and air. These can be removed by a series of bulb-to-bulb distns, e.g. a train consisting of a conc H_2SO_4 trap and a cold EtOH trap (-73°), or passage through H_2O and H_2SO_4, then over KOH and $CaCl_2$.

Acetylenedicarboxamide *[543-21-5]* **M 112.1, m 294°(dec).** Crystd from MeOH.

Acetylenedicarboxylic acid *[142-45-0]* **M 114.1, m 179°(anhydrous).** Crystd from aqueous ether as dipicrate.

Acetylenedicarboxylic acid monopotassium salt *[928-04-1]* **M 152.2.** Very soluble in H_2O, but can be crystd from small volume of H_2O in small crystals. These are washed with EtOH and dried over H_2SO_4 at 125°. [*B* **10** 841 *1877*; *A* **272** 133 *1893*].

***N*-Acetylethylenediamine** *[1001-53-2]* **M 102.1, m 50-51°, 51°, b 128°/3mm, 125-130°/5mm, 133-139°/27mm.** It has been fractionated under reduced pressure and fraction **b** 125-130°/5mm was refractionated; fraction **b** 132-135°/4mm was collected and solidified. It is a low melting *hygroscopic* solid which can be recrystd from dioxane-Et_2O. It is soluble in H_2O, Et_2O and C_6H_6. The *p-toluenesulphonate salt* can be recrystd from EtOH-EtOAc 1:8, has **m** 125-126° but the free base cannot be recovered from it by basifying and extracting with CH_2Cl_2.The *picrate* has **m** 175° (from EtOH). The pKa is 9.28 in H_2O at 25°. [*JACS* **63** 853 *1941*, **78** 2570 *1956*].

2-Acetylfluorene *[781-73-7]* **M 208.3, m 132°.** Crystd from EtOH.

Acetyl fluoride *[557-99-3]* **M 62.0, b 20.5°/760mm, d 1.032.** Purified by fractional distn.

***N*-Acetyl-D-galactosamine** *[14215-68-0]* **M 221.2, m 160-161°, $[\alpha]_{546}$ +102° (c 1, H_2O),**
***N*-Acetyl-D-glucosamine** *[7512-17-6]* **M 221.2, m *ca* 215°, $[\alpha]_{546}$ +49° after 2h (c 2,H_2O).** Crystd from MeOH/Et_2O.

***N*-Acetylglutamic acid** *[1188-37-0]* **M 189.2, m 185° (*RS*); 201° (*S*), $[\alpha]^{25}$ -16.6° (in H_2O).** Likely impurity is glutamic acid. Crystd from boiling water.

***N*-Acetylglycine** *[543-24-8]* **M 117.1, m 206-208°.** Treated with acid-washed charcoal and recrystd three times from water or EtOH/Et_2O and dried *in vacuo* over KOH [King and King *JACS* **78** 1089 *1956*].

***N*-Acetylglycyl-L-alaninamide** *[34017-20-4]* **M 175.2,**
***N*-Acetylglycinamide** [*2620-63-5*] **M 116.1, m 139-139.5°,**
***N*-Acetylglycylglycinamide** [*27440-00-2*] **M 173.2, m 207-208°,**
***N*-Acetylglycylglycylglycinamide** [*35455-24-4*] **M 230.2, m 253-255°.** Repeated crystn from EtOH/Et_2O. Dried in a vacuum desiccator over KOH.

***N*-Acetylhistidine (H_2O)** *[39145-52-3]* **M 171.2, m 148° (*RS*); 169° (*S*) $[\alpha]^{25}$ +46.2° (H_2O).** Likely impurity is histidine. Crystd from water, then 4:1 acetone:water.

***N*-Acetyl-*RS*-homocysteine thiolactone (CITIOLONE)** *[1195-16-0] [17896-21-8]* **M 159.2, m 110°, 109-111°, 111.5-112.5°.** Dry in a vacuum desiccator and recrystallise from toluene as needles. It is a ninhydrin -ve substance which gives a "slow" nitroprusside test. λ_{max} 238nm (ε 4,400 $M^{-1}cm^{-1}$); ν (nujol) 1789s and 851ms cm^{-1}. [*JACS* **78** 1597 *1956*; *JCS* 2758 *1963*].

***N*-Acetylimidazole** *[2466-76-4]* **M 110.1, m 101.5-102.5°.** Crystd from isopropenyl acetate. Dried in a vacuum over P_2O_5.

3-Acetylindole *[703-80-0]* **M 159.2, m 188-190°, 191-193°, 194°.** Recrystd from MeOH or C_6H_6 containing a little EtOH. The *phenylureido* derivative has **m** 154°. [*JCS* 461 *1946*].

Acetyl iodide *[507-02-8]* **M 170.0, b 108°/760mm.** Purified by fractional distn.

***N*-Acetyl-L-leucinamide** *[28529-34-2]* **M 177.2, m 133-134°.** Recrystd from $CHCl_3$ and pet ether (b 40-60°).

Acetyl mandelic acid (R-) *[51019-43-3]* **M 194.2, m 98-99° $[\alpha]_D$ -152.4° (c 2, acetone); (S+)** *[7322-88-5]* **m 97-99° $[\alpha]_D$ +150.4° (c 2, acetone).** Crystd from benzene or toluene.

***S*-β-(Acetylmercapto)isobutyric acid** *[7649-39-7]* **M 162.2, m 40-40.5°, b *ca* 120°/1.25mm.** Distil under vacuum and recrystd from C_6H_6. [*Chem Abs* **38** 3616 *1944*].

***N*-Acetyl-L-methionine** *[65-82-7]* **M 191.3, m 104°, $[\alpha]_{546}$ -24.5° (c 1, in H_2O).** Crystd from water or ethyl acetate. Dried in a vacuum over P_2O_5.

Acetylmethionine nitrile *[538-14-7]* **M 172.3, m 44-46°.** Crystd from ethyl ether.

5-Acetyl-2-methoxybenzaldehyde *[531-99-7]* **M 166.2 , m 144°.** Crystd from EtOH or Et_2O.

***N*-Acetyl-*N'*-methyl-L-alanimide** *[1901-83-8]* **M 144.2.** Crystd from EtOAc/Et_2O, then from EtOH and Et_2O.

Acetylmethylcarbinol see **3-hydroxy-2-butanone.**

4-Acetyl-1-methyl-1-cyclohexene *[6090-09-1]* **M 138.2, 73-75°/7.5mm, 85-86°/13mm, 94-94.7°/20mm, 204.5-206°/747mm, d_4^{20} 1.0238, n_D^{20} 1.469.** Purified by fractionation under reduced pressure *in vacuo*, and when almost pure it can be fractionated at atmospheric pressure, preferably in an inert atm. Forms two *semicarbazones* one of which is more soluble in C_6H_6, and both can be recryst from EtOH, more soluble has **m** 149°(151°), and the less soluble has **m** 172-175°(191°). *4-Nitrophenylhydrazone* has **m** 166-167° and the *2,4-dinitrophenylhydrazone* has **m** 114-115°. [*HCA* **17** 129, 140 *1934*; *A* **564** 109 *1949*].

***N*-Acetyl-6*N'*-methylglycinamide** *[7606-79-3]* **M 130.2.** Recrystd from EtOH/Et_2O mixture.

***N*-Acetyl-6*N'*-methyl-L-leucine amide** *[32483-15-1]* **M 186.3.** Recrystd from EtOH/hexane mixture.

4-Acetylmorpholine *[11696-20-4]* **M 129.2, m 13.8-14°, 14°, 14.5°, b 96-97°/6mm, 113-128°/22mm, 242-247°/760mm, d_4^{20} 1.0963, n_D^{20} 1.4830.** Distd through an 8inch Fenske column with a manual take-off head. Purified by fractional distn. The *hydrobromide* has **m** 172-175°. [*JACS* **75** 357 *1953*, *JOC* **21** 1072 *1956*].

1-Acetylnaphthalene *[941-98-0]* **M 170.1, m 10.5°, b 93-95°/0.1mm, 167°/12mm, 302°/atm, d_4^{20} 1.12.** If the NMR spectrum indicates the presence of impurities, probably 2-acetylnaphthalene, convert the substance to its picrate by dissolving in benzene or EtOH and adding excess of satd picric acid in these solvents until separation of picrates is complete. Recryst the picrate till **m** is 118°. Decompose the picrate with dil NaOH and extract with Et_2O. Dry the extract (Na_2SO_4), filter, evap and dist. The *2,4-dinitrophenylhydrazone* crysts from EtOH and has **m** 259°. [*A* **380** 95 *1911*; *JACS* **61** 3438 *1939*].

2-Acetylnaphthalene (2-acetonaphthenone) *[93-08-3]* **M 170.2, m 52-53°, 55°, 55.8°, b 164-166°/8mm, 171-173°/17mm, 301-303°/atm.** Separated from the 1-isomer by fractional crystn of the picrate in EtOH (see entry for the 1-isomer) **m** 82°. Decomposition of the picrate with dil NaOH and extraction with Et_2O and evaporation gives purer 2-acetylnaphthalene. If this residue solidifies it can be recrystd from pet ether. Purity should be checked by high field NMR spectroscopy. *Oxime* has **m** 145° dec, and the *semicarbazone* has **m** 235°. [*A* **380** 95 *1911*; *JACS* **72** 753 and 5626 *1950*, *JOC* **5** 512 *1940*].

***N*-Acetyl-D-penicillamine** *[15537-71-0]* **M 191.3, m 189-190° (dec), $[\alpha]_D$ +18° (c 1, in 50% EtOH).** Crystd from water.

***N*-Acetyl-L-phenylalanine** *[2018-61-3]* **M 207.2, m 170-171°, $[\alpha]_D$ +49.3, (DL) m 152.5-153°.** Crystd from $CHCl_3$ and stored in a desiccator at 4°. (DL)-isomer crystd from water or acetone.

***N*-Acetyl-L-phenylalanine ethyl ester** *[2361-96-8]* **M 235.3.** Crystd from water.

1-Acetyl-2-phenylhydrazine *[114-83-0]* **M 150.2, m 128.5°.** Crystd from aqueous EtOH.

1-Acetylpiperazine *[13889-98-0]* **M 128.2, m 32-34°, 52°.** Purified by recrystn from 40% aqueous EtOH or from EtOH-Et_2O. Its pKa in H_2O at 25° is 7.94. It is an **irritant,** and is *hygroscopic*. The *hydrochloride* has **m** 191° (from EtOH), and the *tosylate* has **m** 148-149° (from EtOH-EtOAc, 1:16). The free base, however, cannot be isolated by basifying the tosylate salt and extractn with CH_2Cl_2. [*B* **66** 113 *1933*; *JACS* **75** 4949 *1953*, 2570 **78** *1956*].

1-Acetyl-4-piperidone *[32161-06-1]* **M 141.2, b 124-128°/0.2mm, 218°/760mm, d_4^{25} 1.1444, n_D^{25} 1.5023.** Purified by fractional distn through a short Vigreux column (15mm). The *2,4-dinitrophenylhydrazone* has **m** 212-213° (from EtOH). It is freely soluble in H_2O but insoluble in Et_2O. [*JACS* 901 **71** *1949*].

3-Acetylpyridine *[350-03-8]* **M 121.1, m 13-14°, b 65-66°/1mm, 92-95°/8-9mm, 105°(113°)/16mm, 219-221°/760mm, d_4^{20} 1.1065, n_D^{20} 1.1065.** It is purified by dissolving in HCl, extracting with Et_2O to remove the possible impurity of nicotinic acid, basified with NaOH and extracted with Et_2O. The dried extract is filtered, evaporated and the residual oil distd. If the NMR spectrum indicates further impurities then convert to the *phenylhydrazone* (**m** 137°, yellow needles from EtOH). This is dec with HCl [*B* **22** 597 *1889*], the phenylhydrazine HCl is removed by filtration, $NaNO_2$ is added, the soln is basified with aq NaOH and extracted with Et_2O as before and distd at atmospheric pressure to give 3-acetylpyridine as a colourless oil. Purification can be achieved by shaking with 50% aq KOH, extracting with Et_2O, drying the extract and distilling at atmospheric pressure or in a vacuum. [*JACS* **79** 4226 *1957*]. The *hydrochloride* has **m** 180-181° (from MeOH-EtOH), the *picrate* has **m** 133.8-134.8° (from H_2O), and the *phenylhydrazone* has **m** 137° (129-130)° (from EtOH) [*JACS* **71** 2285 1949]. The *ketoxime* has **m** 112° (from EtOH or C_6H_6. [*JACS* **55** 816 *1933*, **63** 490 *1941*, **67** 1468 *1945*, **79** 4226 *1957*].

Acetylsalicylic acid *[50-78-2]* **M 180.2, m 133.5-135°.** Crystd twice from toluene, washed with cyclohexane and dried at 60° under vacuum for several hours [Davis and Hetzer *J Res Nat Bur Stand* **60** 569 *1958*]. Has also been recrystd from isopropanol and from ethyl ether/pet ether (b 40-60°).

***O*-Acetylsalicyloyl chloride** *[5538-51-2]* **M 198.6, m 45°, 46-49°, 48-52°, b 107-110°/0.1mm, 135°/12mm, n_D^{20} 1.536.** Check first the IR to see if an OH frequency is present. If so then some free acid is present. Then reflux with acetyl chloride for 2-3h and fractionate at high vac. The distillate should crystallise. It can be recryst from hexane. [*JCS* **89** 1318 *1906*].

***N*-Acetylsalicylsalicylic acid** *[530-75-6]* **M 300.3, m 159°.** Crystd from dilute acetic acid.

***N*-(4)-Acetylsulphanilamide** *[144-80-9]* **M 214.2, m 216°.** Crystd from aqueous EtOH.

***N*-Acetylsulphanilyl chloride** see ***p*-acetamidobenzenesulphonyl chloride.**

2-Acetylthiazole *[24295-03-2]* **M 127.2, b 89-91° (90-95°)/12mm, 95-105°/15mm, d_4^{20} 1.23, n_D^{20} 1.55.** Check NMR spectrum, if not too bad, distil through an efficient column in a vacuum. The *oxime* sublimes at 140-145°, **m** 159° (cryst from H_2O) has **m** 163-165.5°; *JACS* **79** 4524 *1957*; *HCA* **31** 1142 *1948*). [*HCA* ***40*** 554 *1957*].

2-Acetylthiophene (methyl 2-thienyl ketone) *[88-15-3]* **M 126.2, m 9.2-10.5°, 10.45°, 10-11°, b 77°/4mm, 89-91°/9mm, 94.5-96.5°/13mm, 213-214°/atm, d_4^{20} 1.17, n_D^{20} 1.5666.** Fractionally distd through a 12 plate column and fraction **b** 77°/4mm was collected. Also wet the acetylthiophene in order to remove and free thiophene which forms an azeotrope with H_2O, **b** 68°, Store in a brown bottle and the clear colourless liquid remains thus for extended periods. [*Org Synth* **28** 1 *1948*; *JACS* **69** 3093 *1947*]. The red *4-nitrophenylhydrazone* crysts from EtOH, **m** 181-182°.

3-Acetylthiophene (methyl 3-thienyl ketone) *[1468-83-3]* **M 126.2, m 57°, 60-63°, b 106-107°/25mm, 208-210°/748mm.** Recrystd from pet ether (b 30-60°) or EtOH. *2,4-dinitrophenylhydrazone* crystallises from $CHCl_3$, **m** 265°, and the *semicarbazone* crystallises from EtOH, **m** 174-175°. [*JACS* **70** 1555 *1948*].

1-*O*-Acetyl-2,3,5-tri-*O*-benzoyl-β-D-ribofuranose *[6974-32-9]* **M 504.5, m 128-130°, 130-131°, 131-132°, $[\alpha]_D^{20}$ +44.2° (c 1, $CHCl_3$).** Recrystd from EtOH or isoPrOH. [*HCA* **42** 1171 *1959*; NMR: *JOC* **33** 1799 *1968*; IR: *Chem Pharm Bull Japan* **11** 188 *1963*].

***N*-Acetyltryptophan M 246.3,** *[87-32-1]* **m 206° (RS); [*1218-34-4*] m 188° (S), $[\alpha]^{25}$ +30.1° (aq NaOH).** Likely impurity is tryptophan. Crystd from EtOH by adding water.

***N*-Acetyl-L-valine amide** *[37933-88-3]* **M 158.2, m 275°.** Recrystd from CH_3OH/Et_2O.

***N*-Acetylurea** *[591-08-2]* **M 118.2, m 164-165°, 165-168°.** Recrystd from AcOH, the solid is washed with Et_2O and dried in air then at 100°. [*Coll Czech Chem Comm* **24** 3678 *1959*].

***cis*-Aconitic acid** *[585-84-2]* **M 174.1, m 126-129°(dec).** Crystd from water by cooling (sol: 1g in 2ml of water at 25°). Dried in a vacuum desiccator.

***trans*-Aconitic acid (1,2,3-propenetriscarboxylic acid)** *[4023-65-8]* **M 174.1, m 195°(dec), m 198-199°(dec), 204-205°(dec).** Purified by dissolving in AcOH (77g/150ml), filtering and cooling. The acid separates (55g) as colourless needles. A further quantity (10g) can be obtained by reducing the vol of the filtrate. The acid is dried in air then in a vacuum desiccator over NaOH. The acid can be recrystd from Me_2CO-$CHCl_3$. The highest m is obtained with the very dry acid. The **m** (209°) is obtained on a Dennis bar [*JACS* **52** 3128 *1930*]. The acid has a pKa (H_2O) at 20° of 2.88. [*Org Synth* Coll Vol II 12 *1943*].

cis*-Aconitic anhydride** *[6318-55-4]* **M 156.1, m75°, 76-78°, 78-78.5°.** Reflux in xylene (7.5 parts) for 1h, then evaporate and recrystallise the residue from C_6H_6. Alternatively, reflux in Ac_2O, evaporate and recrystallise from C_6H_6. It is sensitive to moisture. [IR: *Acta Chem Scand* ***21 291 *1967*, ***B* 61** 2523 *1928*; NMR: *Biochemistry* **5** 2335 *1966*].

Aconitine *[302-27-2]* **M 645.8, m 204°, $[\alpha]_{546}$ +20° (c 1, $CHCl_3$).** Crystd from EtOH, $CHCl_3$ or toluene.

Aconitine hydrobromide M 726.7, m 207°. Crystd from water or EtOH/ether.

Acraldehyde see **acrolein**

Acridine *[260-94-6]* **M 179.2, m 111°, b 346°.** Crystd twice from benzene/cyclohexane, or from aqueous EtOH, then sublimed, removing and discarding the first 25% of the sublimate. The remainder was again crystd and sublimed, discarding the first 10-15% [Wolf and Anderson *JACS* **77** 1608 *1955*].
Acridine can also be purified by crystn from *n*-heptane and then from ethanol/water after pre-treatment with activated charcoal, or by chromatography on alumina with pet ether in a darkened room. Alternatively, acridine can be ppted as the hydrochloride from benzene soln by adding HCl, after which the base is regenerated, dried at 110°/50mm, and crystd to constant melting point from pet ether [Cumper, Ginman and Vogel *JCS* 4518 *1962*]. The regenerated free base may be recrystd, chromatographed on basic alumina, then vac-sublimed and zone-refined. [Williams and Clarke, *JCSFT 1* **73** 514 *1977*].

Acridine Orange *[494-38-2]* **M 349.94, m 181-182° (free base).** The double salt with $ZnCl_2$ (6g) was dissolved in water (200ml) and stirred with four successive portions (12g each) of Dowex-50 ion-exchange resin (K^+ form) to remove the zinc. The soln was then concentrated in vacuum to 20ml, and 100ml of ethanol was added to ppte KCl which was removed. Ether (160ml) was added to the soln from which, on chilling, the dye crystallises as its chloride. It was separated by centrifuging, washed with chilled ethanol and ether, and dried under vac, before being recryst from ethanol (100ml) by adding ether (50ml), and chilling. Yield 1g. [Pal and Schubert *JACS* **84** 4384 *1962*].
It was recrystd twice as the free base from ethanol or methanol/water by dropwise addition of NaOH (less than 0.1M). The ppte was washed with water and dried under vacuum. It was dissolved in $CHCl_3$ and chromatographed on alumina: the main sharp band was collected, concentrated and cooled to -20°. The ppte was

filtered, dried in air, then dried for 2h under vacuum at 70°. [Stone and Bradley *JACS* **83** 3627 *1961*; Blauer and Linschitz *JPC* **66** 453 *1962*].

Acridine Yellow *[135-49-9]* **M 237.8, m 325°.** Crystd from 1:1 benzene/methanol.

Acridinol see **4-hydroxyacridine.**

Acridone *[578-95-0]* **M 195.2, m >300°.** Dissolve in *ca* 1% NaOH (100ml), add 3M HCl to pH 4 when acridone separates as a pale yellow solid with **m** just above 350° (sharp). It can be recrystd from large vols of H_2O to give a few mg. It is soluble in 160 parts of boiling EtOH (540 parts at 22°) [*JCS* 1294 *1956*]. A few decigms are best crystallised as the 'HCl from 400 parts of 10N HCl (90% recovery) from which the free base is obtained by washing the salt with H_2O. A small quantity can be recrystd (as the neutral species) from boiling AcOH. Larger quantities are best recrystallised from a mixture of 5 parts of freshly distd aniline and 12.5 parts of glacial acetic acid. Acridone distills unchanged at atmospheric pressure, but the boiling point was not recorded, and some sublimation occurs below 350°. It has a basic pKa of -0.32 and an acidic pKa of 14. UV: λ_{max} 399nm. [see Albert, *The Acridines* Arnold Press p372, 201 *1966*].

***N*-(9-Acridinyl)maleimide (NAM)** *[49759-20-8]* **M 274.3, m 248°, 255-258°.** Purified by chromatography on silica gel using CH_2Cl_2 as eluant. Evaporation of pooled fractions that gave the correct NMR spectra gave a solid which was recrystd from Me_2CO as pale yellow prisms. IR ν (nujol): 1710 (imide); UV (MeOH): λ_{max} (nm), (ε $M^{-1}cm^{-1}$): 251 (159 500), 343 sh (7 700), 360 (12 400) and 382sh (47 000). [*Chem Pharm Bull, Japan* **26** 596 *1978*; *Eur J Biochem* **25** 64 *1972*].

Acriflavine *[8048-52-0]* **M 196.2.** Treated twice with freshly ppted AgOH to remove proflavine, then recrystd from absolute methanol [Wen and Hsu *JPC* **66** 1353 *1962*].

Acriflavin Mixture (Euflavin, 3,6-diamino-10-methylacridinium chloride) *[8048-52-0]* **M 259.7, m 179-181°.** Purified by dissolving in 50 parts of H_2O, shake with a small excess of freshly ppted and washed Ag_2O. The mixture is set aside overnight at 0° and filtered. The cake is not washed. The pH of the filtrate is adjusted to 7.0 with HCl and evaporated to dryness. The residue is then crystd twice from MeOH, twice from H_2O and dried at 120°. λ_{max} at 452nm has a logε value of 4.67. It is a red powder which readily absorbs H_2O. The solubility is increased in the presence of proflavin. The diHCl is a deep red crystn powder. It is available as a mixture of 3,6-diaminoacridinium chloride (35%) and its 10-metho chloride (65%). [see Albert, *The Acridines* Arnold Press p346 *1966*; *B 45* 1787 *1912*].

Acrolein *[107-02-8]* **M 56.1, b 52.1°, n 1.3992, d 0.839.** Purified by fractional distn. under nitrogen, drying with anhydrous $CaSO_4$ and then distilling under vac. Blacet, Young and Roof [*JACS* **59** 608 *1937*] distd under nitrogen through a 90cm column packed with glass rings. To avoid formation of diacryl, the vapour was passed through an ice-cooled condenser into a receiver cooled in an ice-salt mixture and containing 0.5g catechol. The acrolein was then distd twice from anhydrous $CuSO_4$ at low pressure, catechol being placed in the distilling flask and the receiver to avoid polymerization. [Alternatively, hydroquinone (1% of the final soln) can be used].

Acrolein diacetyl acetal (1,1-diacetoxy-2-propene). *[869-29-4]* **M 158.2, b 75°/10mm, 184°/atm, d_4^{20} 1.08, n_D^{20} 1.4203.** Check the NMR spectrum. If it is not satisfactory then add Ac_2O and a drop of conc H_2SO_4 and heat at 50° for 10min. Then add anhydrous NaOAc (*ca* 3g/ 100g of liquid) and fractionate. Note that it forms an azeoptrope with H_2O, so do not add H_2O at any time. It is a **highly flammable and TOXIC** liquid, keep away from the skin. [*JACS* **73** 5282 *1951*].

Acrolein diethyl acetal *[3054-95-3]* **M 130.2, b 120-125°/atm, n_4^{20} 1.398-1,407.** Add Na_2CO_3 (*ca* 3.5%) and distil using an efficient column, or better a spinning band column. [*Org Synth* **25** 1 *1945*].

Acrolein dimethyl acetal (1,1-dimethoxy-2-propene) *[6044-68-4]* **M 102.1, b 87.5-88°/750mm, 89-90°/760mm, d_4^{20} 0.86, n_D^{20} 1.3962.** Fractionally distil (after adding 0.5g of hydroquinone) under reduced press through an all glass column (40cm x 2.5 cm) packed with glass helices and provided with a heated jacket and a total reflux variable take-off head. Stainless steel Lessing rings (1/8 x 1/8

in) or gauze have been used as packing. It is a **highly flammable and TOXIC** liquid, keep away from the skin. [*JCS* 2657 *1955*].

Acrolein semicarbazone *[6055-71-6]* **M 113.1, m 171°.** Crystd from water.

Acrylamide *[79-06-1]* **M 71.1, m 84°, b 125°/25mm.** Crystd from acetone, chloroform, ethyl acetate, methanol or benzene/chloroform mixture, then vac dried and kept in the dark under vac. Recryst from $CHCl_3$ (200g dissolved in 1L heated to boiling and filtered without suction in a warmed funnel through Whatman 541 filter paper. Allowed to cool to room temp and kept at -15° overnight). Crystals were collected with suction in a cooled funnel and washed with 300ml of cold MeOH. Crystals were air-dried in a warm oven. [Dawson et al. *Data for Biochemical Research*, Oxford Press 1986 p 449].
CAUTION: *Acrylamide is extremely* **TOXIC** *and precautions must be taken to avoid skin contact or inhalation. Use gloves and handle in a well ventilated fume cupboard.*

Acrylic acid *[79-10-7]* **M 72.1, m 13°, b 30°/3mm, d 1.051.** Can be purified by steam distn, or vacuum distn through a column packed with copper gauze to inhibit polymerisation. (This treatment also removes inhibitors such as methylene blue that may be present.) Azeotropic distn of the water with benzene converts aqueous acrylic acid to the anhydrous material.

Acrylonitrile *[107-13-1]* **M 53.1, b 78°, d 0.806, n^{25} 1.3886.** Washed with dilute H_2SO_4 or dilute H_3PO_4, then with dilute Na_2CO_3 and water. Dried with Na_2SO_4, $CaCl_2$ or (better) by shaking with molecular sieves. Fractionally distd under nitrogen. Can be stabilised by adding 10ppm *tert*-butyl catechol. Immediately before use, the stabilizer can be removed by passage through a column of activated alumina (or by washing with 1% NaOH soln if traces of water are permissible in the final material), followed by distn. Alternatively, shaken with 10% (w/v) NaOH to extract inhibitor, and then washed in turn with 10% H_2SO_4, 20% Na_2CO_3 and distd water. Dried for 24h over $CaCl_2$ and fractionally distd under N_2 taking the fraction boiling at 75.0 to 75.5°C (at 734mm Hg). Stored with 10ppm *tert*-butyl catechol. Acrylonitrile is distilled off as required. [Burton *et al*, *JCSFT 1* **75** 1050 *1979*].

Acryloyl chloride *[814-68-6]* **M 90.5, b 72-74°/740mm, 74°/760mm, d_4^{20} 1.1127, n_D^{20} 1.4337.** Distil rapidly through an efficient 25cm column after adding 0.5g of hydroquinone/200g of chloride, and then redistil carefully at atmospheric pressure preferably in a stream of dry N_2. [*JACS* **72** 72, 2299 *1950*]. **The liquid is an irritant and is TOXIC.**

Actidione see **cycloheximide.**

Actinomycin D *[50-76-0]* **M 1255.5.** Crystd from ethyl acetate or from MeOH.

Adamantane *[281-23-2]* **M 136.2, m 269.6-270.8° (sublimes).** Crystd from acetone or cyclohexane, sublimed in a vacuum below its melting point. [Butler et al. *JCSFT 1* **82** 535 *1986*]. Adamantane was also purified by dissolving in *n*-heptane (*ca* 10ml/g of adamantane) on a hot plate, adding activated charcoal (2g/100g of adamantane), and boiling for 30min, filtering the hot soln through a filter paper, concentrating the filtrate until crystn just starts, adding one quarter of the original volume *n*-heptane and allowing to cool slowly over a period of hours. The supernatant was decanted off and the crystals were dried on a vacuum line at room temperature. [Walter et al. *JACS* **107** 793 *1985*].

1-Adamantane acetic acid *[4942-47-6]* **M 194.3, m 136°.** Dissolve in hot N NaOH, treat with charcoal, filter and acidify. Collect solid, wash with H_2O, dry and recryst from MeOH. [*B* **92** 1629 *1959*].

1-Adamantane carboxylic acid *[828-51-3]* **M 180.3, m 175-176.5°, 177°.** Possible impurities are trimethylacetic acid and C9 and C13 acids. Dissolve 15g of acid in CCl_4 (300ml) and shake with 110ml of 15N aqueous NH_3 and the ammonium salt separates and is collected. Acid impurities form soluble ammonium salts. The salt is washed with cold Me_2CO (20ml) and suspended in H_2O (250ml). This is treated with 12N HCl and extracted with $CHCl_3$ (100ml). The dried (Na_2SO_4) is evaporated and the residue recrystd from a mixture of

MeOH (30ml) and H_2O (*ca* 10ml) to give the pure acid (10-11g). [*Org Synth* Col.Vol.V 20 *1973*]. Also recrystd from absolute EtOH and dried under vacuum at 100°.
Alternatively, the acid (5g) is refluxed for 2h with 15ml of MeOH and 2ml of 98% H_2SO_4 (cool when mixing this soln). Pour into 10 volumes of H_2O and extract with the minimum volume of $CHCl_3$ to give clear separation of phases. The extract is washed with H_2O and dried ($CaCl_2$) and distd. The methyl ester is collected at 77-79°/1mm, **m** 38-39°. The ester is hydrolysed with the calculated amount of N KOH and refluxed until clear. Acidification with HCl provides the pure acid with 90% recovery. [*Org Synth* **4** 1 *1964*]. The *amide* crysts from cyclohexane, **m** 189°. [*B* **62** 1629 *1959*].

1,3-Adamantane diamine dihydrochloride *[26562-81-2]* **M 239.2, m >310°.** Dissolve in boiling conc HCl (400mg in 15ml) and evaporate to dryness. Dissolve in absolute EtOH and add dry Et_2O to crystallise the 'HCl. [*B* **93** 1366 *1960*].

1,3-Adamantane dicarboxylic acid *[39269-10-8]* **M 224.3, m 276°, 276-278°, 279°.** Dissolve in aq NaOH, treat with charcoal, filter and acidify with dilute HCl. Recryst from MeOH. [*B* **93** 1366 *1960*].

1-Adamantane methylamine *[17768-41-1]* **M 165.3, b 83-85°/0.3mm, d_4^{20} 0.93.** Dissolve in Et_2O, dry over KOH and distil. The *N-Tosyl* derivative has **m** 134-135° (from EtOH). [*B* **96** 550 *1963*].

1-Adamantanol *[768-95-6]* **M 152.4, m 288.5-290°.** If 2-adamantanol is a suspected impurity then dissolve substance (10g) in acetone (100ml) and Jone's reagent {CrO_3 (10.3g) in H_2O (30ml)} and conc H_2SO_4 (8.7ml) is added dropwise (turns green in colour) until excess reagent is present (slight red colour). Allow to stir overnight, decant the acetone soln from the Cr salts and adamantan-2-one, and dry (Na_2SO_4) and evaporate to dryness. The residue (*ca* 7g) is chromatographed through Al_2O_3 (250g) and washed with 50% benzene-pet ether (b 40-60°), then 100% Et_2O (to remove any adamantan-2-one present) and the 1-adamantanol is then eluted with 5% MeOH in Et_2O. The eluate is evaporated, and the residue is recrystd from pet ether (b 30-60°) at -70°, **m** 287.2-288.5°. It has characteristic IR, ν 3640, 1114, 1086, 982 and 930cm^{-1}. [*JACS* **83** 182 *1961*].
Alternatively, if free from the 2-isomer, dissolve in tetrahydrofuran, dilute with H_2O to ppte the alcohol. Collect, dry and sublime in a vacuum at 130°. [*B* **92** 1629 *1959*].

2-Adamantanol *[700-57-2]* **M 152.4, m 296.2-297.7°.** Can be purified by chromatogtaphy as for the 1-isomer. It crystallises from cyclohexane and has characteristic IR, ν 3600, 1053, 1029 and 992cm^{-1} [*JACS* **8** 182 *1961*].

2-Adamantanone *[700-58-3]* **M 150.2, m 256-258°(sublimes).** Purified by repeated sublimation *in vacuo*. [Butler et al. *JCSFT 1* **82** 535 *1986*].

***N*-(1-Adamantyl)acetamide** *[880-52-4]* **M 193.3, m 149°.** Wash well with H_2O, dry and recrystallise from cyclohexane. *It is an* **irritant**. [*B* **92** 1629 *1959*].

1-Adamantylamine *[768-94-5]* **M 151.2, m 160-190°, 208-210°.** Dissolve in Et_2O, dry over KOH, evaporate and sublime in a vacuum. [*B* **93** 226 *1960*].

1-Adamantylamine hydrochloride *[665-66-7]* **M 187.7, m 360° (dec).** Dissolve in dry EtOH, add a few drops of dry EtOH saturated with HCl gas, followed by dry Et_2O to crystallise the 'HCl. Dry the salt in vacuum. [*B* **93** 226 *1960*].

2-Adamantylamine hydrochloride *[10523-68-9]* **M 187.7, m >300°.** The free amine in Et_2O, liberated by the action of alkali in H_2O, is dried over KOH, filtered, evap and sublimed at 110°/12Torr, **m** 230-236°. The base is dissolved in EtOH and crystd by the addition of Et_2O, and dried in vac. [*A* **658** 151 *1962*].

1-Adamantyl bromide *[768-90-1]* **M 215.1, m 117-119°, 118°, 119.5-120°.** If coloured, dissolve in CCl_4, wash with H_2O, treat with charcoal, dry ($CaCl_2$), filter, evap to dryness. Dissolve in a small volume of MeOH and cool in a CO_2/trichloroethylene bath and collect the crystals. Sublime at 90-100°/water pump vacuum. [*B* **92** 1629 *1959*; *JACS* **83** 2700 *1961*].

1-Adamantyl bromomethylketone *[5122-82-7]* **M 257.2, m 76-79°, m 78-79°.** Dissolve in Et_2O, wash with H_2O, dry ($MgSO_4$), evaporate and crystallise residue from small volumes of MeOH. **LACHRYMATORY.** [*B* **93** 2054 *1960*].

1-Adamantyl chloride *[935-56-8]* **M 170.7, m 164.3-165.6°.** Crystd from aqueous MeOH and sublimed at 100°/12Torr. Also crystd from MeOH at -70°. [*B* **92** 1629 *1959*; *JACS* **83** 2700 *1961*].

1-Adamantyl fluoride *[768-92-3]* **M 154.2, m 210-212° (dec), 259-260° (dec).** Dissolve in Et_2O, dry over Na_2SO_4, evaporate to dryness and sublime the residue at 90-100°/12mm. Recryst sublimate from MeOH, **m** 259-260°. [*ZOK* **30** 1609 *1965*]. To remove 1-hydroxyadamantane impurity, dissolve in cyclohexane cool for many hours, filter off the hydroxyadamantane, and evaporate to dryness. Recrystallise the residue from pet ether at -77° and sublime in vacuum, **m** 210-212° dec (sealed tube). [*JOC* **30** 789 *1965*].

1-Adamantyl fluoroformate *[62087-82-5]* **M 198.2, m 31-32°.** Dissolve in *n*-hexane (*ca* 10g in 150 ml) and keep at 0° for 24h. Any 1-adamantanol present will separate. Filter and evaporate to dryness. Crystalline residue has **m** 31-32° (ν 1242, 1824 and 2340 cm^{-1}). There should be no OH str band above 2500 cm^{-1}. [*ZPC* **357** 1647 *1976*; *JACS* **88** 1988 *1966*].

1-Adamantyl iodide *[768-93-4]* **M 262.1, m 75.3-76.4°.** Dissolve in Et_2O, shake with aqueous $NaHSO_3$, aqueous K_2CO_3, and H_2O, dry (Na_2SO_4), evaporate and recrystallise from MeOH at -70° (to avoid alcoholysis) giving white crystals. [*JACS* **83** 2700 *1961*; lit **m** of 151-152.5° is incorrect]. Also purified by recrystn from pet ether (40-60°C) followed by rigorous drying and repeated sublimation.

1-Adamantyl isocyanate *[4411-25-0]* **M 177.3, m 144-145°.** Recryst from *n*-hexane and sublime. **Irritant.** [*B* **95** 2302 *1962*].

1-Adamantyl isothiocyanate *[4411-26-1]* **M 193.3, m 168-169°.** Dissolve in Et_2O, wash with H_2O, dry (Na_2SO_4), evaporate and sublime the residue in a vacuum at 140°, and recryst from MeOH. **Irritant.** [*B* **95** 2302 *1962*].

1-Adamantylmethanol see **1-hydroxymethyladamantane.**

***N*-(1-Adamantyl)urea** *[13072-69-01]* **M 194.2, m >250° (dec), 268-272° (dec).** Wash with H_2O and dioxane and recryst from EtOH. [*B* **95** 2302 *1962*].

Adenine *[73-24-5]* **M 135.1, m 360-365° (dec rapid heating).** Crystd from distd water.

Adenosine *[58-61-7]* **M 267.3, m 234-236°, $[\alpha]_{546}$ -85° (c 2, 5% NaOH).** Crystd from distilled water.

Adenosine-3'-phosphoric acid *[84-21-9]* **M 365.2, m 210°(dec), $[\alpha]_{546}$ -50° (c 0.5, 0.5M Na_2HPO_4).** Crystd from a large volume of distilled water, as the monohydrate.

Adenosine-5'-phosphoric acid monohydrate *[18422-05-4]* **M 365.2, m 196-200°(dec), $[\alpha]_{546}$ -56° (c 2, 2% NaOH).** Crystd from H_2O by addition of acetone. Purified by chromatography on Dowex 1 (in formate form), eluting with 0.25M formic acid. It was then adsorbed onto charcoal (which had been boiled for 15min with M HCl, washed free of chloride and dried at 100°), and recovered by stirring three times with isoamyl alcohol/H_2O (1:9 v/v). The aqueous layer from the combined extracts was evaporated to dryness under reduced pressure, and the product was crystallised twice from hot H_2O. [Morrison and Doherty *BJ* **79** 433 *1961*]. See entry in Chapter 5.

Adenosine-5'-triphosphate *[56-65-5]* **M 507.2, $[\alpha]_{546}$ -35.5 (c 1, 0.5 M Na_2HPO_4).** Ppted as its barium salt when excess barium acetate soln was added to a 5% soln of ATP in water. After filtering off, the ppte was washed with distd water, redissolved in 0.2M HNO_3, and again pptd with barium acetate. The ppte, after several washings with distd water, was dissolved in 0.2M HNO_3 and slightly more 0.2M H_2SO_4 than was

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needed to ppte all the barium as $BaSO_4$, was added. After filtering off the $BaSO_4$, the ATP was ppted by addition of a large excess of 95% ethanol, filtered off, washed several times with 100% EtOH and finally with dry ethyl ether. [Kashiwagi and Rabinovitch *JPC* **59** 498 *1955*].

3'-Adenylic acid see **adenosine-3'-phosphoric acid**

Adipic acid *[124-04-9]* **M 146.1, m. 154°.** For use as a volumetric standard, adipic acid was crystd once from hot water with the addition of a little animal charcoal, dried at 120° for 2h, then recrystd from acetone and again dried at 120° for 2h. Other purification procedures include crystn from ethyl acetate and from acetone/petroleum ether, fusion followed by filtration and crystn from the melt, and preliminary distn under vac.

Adiponitrile (1,4-dicyanobutane) *[111-69-3]* **M 108.14, m 2.4°, 123°/0.5mm, 153°/6mm, 175°/26mm, 184°/30mm, 295°/atm, d_4^{20} 0.9396, n_D^{20} 1.4371.** Reflux over P_2O_5 and $POCl_3$, and fractionally distil, then fractionate through an efficient column. **The liquid is TOXIC and is an irritant.** [*B* **67** 1770 *1934*; *A* **596** 127 *1955*; *Canad J Chem* **34** 1662 *1956*; *JACS* **62** 228 *1940*].

Adonitol (Ribitol) *[488-81-3]* **M 152.2, m 102°.** Crystallise from EtOH by addition of ethyl ether.

Adrenalin see **epinephrine.**

Adrenochrome *[382-45-6]* **M 179.2, m 125-130°.** Crystd from MeOH/formic acid, as hemihydrate, and stored in a vacuum desiccator.

Adrenosterone (Reichstein's G) *[382-45-6]* **M 300.4, m 220-224°.** Crystd from EtOH. Can be sublimed under high vacuum.

Agaricic acid *[666-99-9]* **M 416.6, m 142°(dec), $[\alpha]_D$ -9.8° (in NaOH).** Crystd from EtOH.

Agmatine sulphate *[2482-00-0]* **M 228.3, m 231°.** Crystd from aqueous MeOH.

Agroclavin *[548-42-5]* **M 238.3, m 198-203°(dec), $[\alpha]^{30}$ -242°.** Crystd from ethyl ether.

Ajmalicine *[483-04-5]* **M 352.4, m 250-252°(dec), $[\alpha]_{546}$ -76° (c 0.5, $CHCl_3$).** Crystd from MeOH.

Ajmalicine hydrochloride *[4373-34-6]* **M 388.9, m 290°(dec), $[\alpha]_D$ -17° (c 0.5, MeOH).** Crystd from EtOH.

Ajmaline *[4360-12-7]* **M 326.4, m 160°.** Crystd from MeOH.

Ajmaline hydrochloride *[4373-34-6]* **M 388.9, m 140°.** Crystd from water.

Alanine (*RS*) *[302-72-7]* **M 89.1, m 295-296°,** (S) *[56-41-7]* **m 297°(dec), $[\alpha]_D^{15}$ +14.7° (in 1M HCl).** Crystd from water or aqueous EtOH, e.g. crystd from 25% EtOH in water, recrystd from 62.5% EtOH, washed with EtOH and dried to constant weight in a vacuum desiccator over P_2O_5. [Gutter and Kegeles *JACS* **75** 3893 *1953*]. 2,2'-Iminodipropionic acid is a likely impurity.

ß-Alanine *[107-95-9]* **M 89.1, m 205°(dec).** Crystd from filtered hot saturated aqueous soln by adding four volumes of absolute EtOH and cooling in an ice-bath. Recrystd in the same way and then finally, crystd from a warm saturated soln in 50% EtOH by adding four volumes of absolute EtOH cooled in an ice bath. Crystals were dried in a vacuum desiccator over P_2O_5. [Donovan and Kegeles *JACS* **83** 255 *1961*].

***S*-Alaninol** see ***S*-2-Amino-3-methyl-1-butanol**.

Albumin (bovine serum) see entry in Chapter 5.

Aldol *[107-89-1]* **M 88.1, b 80-81°/20mm.** An ethereal soln was washed with a saturated aqueous soln of $NaHCO_3$, then with water. The non-aqueous layer was dried with anhydrous $CaCl_2$ and distd immediately before use. The fraction, **b** 80-81°/20mm, was collected, [Mason, Wade and Pouncy *JACS* **76** 2255 *1954*].

Aldosterone *[52-39-1]* **360.5, m 108-112°(hydrate), 164°(anhydr).** Crystd from aqueous acetone.

Aldrin *[309-00-2]* **M 354.9, m 103-104.5°.** Crystd from MeOH.

Aleuritic acid *[533-87-3]* **M 304.4, m 100-101°.** Crystd from aqueous EtOH.

Alginic acid *[9005-32-7]* **M 48,000-186000.** To 5g in 550ml water containing 2.8g $KHCO_3$, were added 0.3ml acetic acid and 5g potassium acetate. EtOH to make the soln 25% (v/v) in EtOH was added and any insoluble material was discarded. Further addition of EtOH, to 37% (v/v), ppted alginic acid. [Pal and Schubert *JACS* **84** 4384 *1962*].

Aliquat 336 *[5137-55-3]* **M 404.2, d 0.884.** A 30% (v/v) soln in benzene was washed twice with an equal volume of 1.5M HBr. [Petrow and Allen, *AC* **33** 1303 *1961*]. Purified by dissolving 50g in $CHCl_3$ (100ml) and shaking with 20% NaOH soln (200ml) for 10min, and then with 20% NaCl (200ml) for 10min. Washed with small amount of H_2O and filtered through a dry filter paper [Adam and Pribil *Talanta* **18** 733 *1971*].

Alizarin *[72-48-0]* **M 240.2, d 0.884.** Crystd from glacial acetic acid or 95% EtOH. Can also be sublimed.

Alizarin Complexone ($2H_2O$) *[3952-78-1]* **M 421.4, m 189°(dec).** Purified by suspending in 0.1M NaOH (1g in 50ml), filtering the solution and extracting alizarin with 5 successive portions of CH_2Cl_2. Then add HCl dropwise to precipitate the reagent, stirring the solution in a bath. Filter ppte on glass filter, wash with cold water and dry in a vacuum desiccator over KOH [Ingman *Talanta* **20** 135 *1973*].

Alizarin Yellow R [5-(4-nitrophenylazosalicylic acid), Mordant Orange I] *[2243-76-7]* **M 287-2, m 253-254°(dec), >300°.** The free acid is ppted by adding HCl to an aq soln of the Na salt. After 2 recrystns from aq AcOH, it has **m** 255°(dec); [m 253-254° dec was reported *JCS* **79** 49 *1901*]. The free acid can be recrystd from dilute AcOH as orange brown needles. The Na salt changes colour from yellow to red when the pH is decreased from 10.2 to 12.0. It has a pKa (H_2O) at 25° of 11.17. [*JACS* **75** 5838 *1953*].

Alizarin Orange see **3-nitroalizarin.**

Alizarin Red S [3,4-dihydroxy-9,10-dioxo-2-anthracene sulphonic acid, Na salt. H_2O] *[130-22-3]* **M 342.3.** Dissolve in EtOH and ppte with Et_2O several times. It has pKa values (H_2O) at 19° are 5.54 and 11.01. [*JPC* **54** 829 *1950* ; polarography *JACS* **70** 3055 *1948*].

***n*-Alkylammonium chloride n=2,4,6.** Recrystd from EtOH or an EtOH/Et_2O mixture. [Hashimoto and Thomas *JACS* **107** 4655 *1985;* Chu and Thomas *JACS* **108** 6270 *1986*].

***n*-Alkyltrimethylammonium bromide n=10,12,16.** Recrystd from an EtOH/Et_2O mixture. [Hashimoto and Thomas *JACS* **107** 4655 *1985*].

Allantoin *[97-59-6]* **M158.1, m 238°(dec).** Crystd from water or EtOH.

Allene *[463-49-0]* **M 40.1, m -146°, b -32°.** Frozen in liquid nitrogen, evacuated, then thawed out. This cycle was repeated several times, then the allene was frozen in a methyl cyclohexane-liquid nitrogen bath and pumped for some time. Also purified by HPLC.

(-)-Alloaromadendrene *[25246-27-9]* **M 204.4, b 96°/2mm, 265-267°/atm, $[\alpha]_D^{25}$ -22° (neat), d_4^{20} 0.923, n_D^{23} 1.501.** Fractionally distd from Na. IR has bands at 6.06 and 11.27μ due to C=CH_2. [*JCS* 715 *1953*; *cf JACS* **91** 6473 *1969*].

***neo*-Allocimene** **(*tc*-2,6-dimethyl-2,4,6-octatriene)** *[7216-56-0]* **M 136.2, b 80°/13mm,196-198°/atm, d_4^{20} 0.8161, n_D^{20} 1.5437.** Fractionally distd through an efficient column and stabilised with ca 0.1% of hydroquinone. UV: λ_{max} nm(ε $M^{-1}cm^{-1}$) 290 (32 500), 279 (41 900) and 270 (32 600). [*A* **609** 1 *1957*; *AC* **26** 1726 *1954*].

Allopregnane-3α, 20α-diol *[566-58-5]* **M 320.5, m 248-248.5°, $[\alpha]_D$+17° (c 0.15, EtOH).** Crystd from EtOH.

D-Allothreonine [2R,3R(-)] *[24830-94-2]* **M 119.1, m 272-273°(dec), 276°(dec), $[\alpha]_D^{25}$ -9.1° (c 3.9, H_2O).** Recrystd from aqueous EtOH or 50% EtOH. [*JCS* 62 *1950*; *JACS* **194** 455 *1952*; IR: Greenstein & Winitz *The Chemistry of the Amino Acids* J. Wiley, Vol 3, *1961*].

Alloxan *[50-71-5]* **M 142.0, m ~170°(dec).** Crystn from water gives the tetrahydrate. Anhydrous crystals are obtained by crystn from acetone, glacial acetic acid or by sublimation *in vacuo*.

Alloxan monohydrate [2,4,5,6(1*H*,3*H*]pyrimidine, tetrone] *[2244-11-3]* **M 160.1, m 255°(dec).** Recryst from H_2O as the *tetrahydtrate* in large prisms or rhombs. On heating at 100°, or on exposure to air, this is converted to the *monohydrate*. Dissolve it in its own weight of boiling H_2O and cool for several days below 0° [the *tetrahydrate* crystallises from soln much more slowly when free from HNO_3. It is less sol in HCO_3 solns than in H_2O]. Drying the solid over H_2SO_4 yields the *monohydrate*. The *anhydrous* crystals can be obtained by recrystn from dry Me_2CO or AcOH followed by washing with dry Et_2O or by sublimation in a vacuum. On heating it turns pink at 230° and decomposes at *ca* 256°. It is acidic to litmus and has a pKa value in H_2O of 6.64. [*Org Synth* Coll Vol III 37 *1955*]. It forms a compound with urea which crystallises from H_2O in yellow needles that become red at 170° and dec at 185-186°.

Alloxantin *[76-24-4]* **M 286.2, m 253-255°(dec) (yellow at 225°).** Crystd from water or EtOH and kept under nitrogen. Turns red in air.

Allyl acetate *[591-87-7]* **M 100.1, b 103°, d 0.928, n_4 1.40488, n_D^{27} 1.4004.** Freed from peroxides by standing with crystalline ferrous ammonium sulphate, then washed with 5% $NaHCO_3$, followed by saturated $CaCl_2$ soln. Dried with Na_2SO_4 and fractionally distd in an all-glass apparatus.

Allylacetic acid (pent-4-enoic acid) *[591-80-0]* **M 100.1, -22.5°, b 83-84°/12mm, 90°/15mm, d_4^{20} 0.9877, n_D^{20} 1.4280.** Distil through an efficient column (allyl alcohol has **b** 95-97°). It is characterised as the S-*benzyl isothiouronium salt* **m** 155-158° (96% EtOH, aq EtOH) [*Acta Chem Scand* **9** 1425 *1955*], *4-bromophenacyl ester* **m** 59.5-60.5° (from 90% EtOH). Solubility at 18°: in pyridine (57%), AcOH (7.3%), MeOH (5.4%), Me_2CO (3.2%), MeOAc (2.8%), EtOH (5.4%), H_2O (1.8%), PrOH (1.6%), ISOPrOH (0.27%). [*JACS* **74** 1894 *1952*].

Allyl alcohol *[107-18-6]* **M 58.1, b 98°, d_4 0.857, n_D 1.4134.** Can be dried with K_2CO_3 or $CaSO_4$, or by azeotropic distn with benzene followed by distn under nitrogen. It is difficult to obtain peroxide free. Also reflux with magnesium and fractionally distd [Hands and Norman *Industrial Chemist* **21** 307 *1945*].

Allylamine *[107-11-9]* **M 57.1, b 52.9°, d 0.761, n 1.42051.** Purified by fractional distn from calcium chloride.

1-Allyl-6-amino-3-ethyluracil *[642-44-4]* **M 195.2, m 143-144° (anhydr).** Crystd from water (as monohydrate).

Allyl bromide *[106-95-6]* **M 121, b 70°, d 1.398, n 1.46924.** Washed with $NaHCO_3$ soln then distd water. Dried with $CaCl_2$ or $MgSO_4$, and fractionally distd. Protect from strong light.

Allyl butyl ether *[3739-64-8]* **M 114.2, b 64-65°/120mm, 117.8-118°/763mm, d_4^{20} 1.4057, n_D^{20} 0.7829.** Check the IR for the presence of OH str vibrations, if so then wash well with H_2O, dry with $CaCl_2$ and distil through a good fractionating column. **The liquid is an irritant.** [*JOC* **23** 1666 *1958*; *JACS* **73** 3528 *1951*].

Allyl chloride *[107-05-1]* **M 76.5, b 45.1°, d 0.939, n 1.4130.** Likely impurities include 2-chloropropene, propyl chloride, iso-propyl chloride, 3,3-dichloropropane, 1,2-dichloropropane and 1,3-dichloropropane. Purified by washing with conc HCl, then with Na_2CO_3 soln, drying with $CaCl_2$, and distn through an efficient column [Oae and Vanderwerf *JACS* **75** 2724 *1953*].

Allyl chloroformate *[2937-50-0]* **M 120.5, b. 56°/97mm, 109-110°/atm, d_4^{20} 1.14, n_D^{20} 1.4223.** Wash several times with cold H_2O to remove alcohol and HCl and dry over $CaCl_2$. It is **important** to dry well before distilling *in vacuo*. Note that the receiver should be cooled in ice to avoid loss of distillate into the trap and vacuum pump. The liquid is **highly TOXIC and flammable.** [*JACS* **72** 1254 *1950*].

Allyl cyanide (3-butene nitrile) *[109-75-1]* **M 67.1, b -19.6°/1.0mm, 2.9°/5mm, 14.1°/5mm, 26.6°/20mm, 48.8°/60mm, 60.2°/100mm, 98°/400mm, 119°/760mm, d_4^{20} 0.8341, n_D^{20} 1.406.** It should be distd first at atmospheric pressure then under a vacuum to remove final traces from the residue. Note that the residue is difficult to remove from the flask and should be treated with conc HNO_3 then H_2O and finally hot EtOH. It has an onion-like odour and is stable to heat. It forms a complex with $AlCl_3$ (2:2) **m** 41°, and (3:2) **m** 120°. **All operations should be done in an efficient fume hood as the liquid is flammable and TOXIC.** [*Org Synth* Coll Vol I 46 *1941*].

Allyl disulphide (diallyl disulphide) *[2179-57-9]* **M 146.3, 58-59°/5mm, b 79-81°/20mm, 138-139°/atm, d_4^{20} 1.01, n_D^{20} 1.541.** Purified by fractional distn until their molar refractivities are in uniformly good agreement with the calculated values [*JACS* **69** 1710 *1947*]. Also purified by gas chromatography [retention times: *JOC* **24** 175 *1959*; UV: *JCS* 395 *1949*].

DL-C-Allylglycine (2-aminopent-4-enoic acid). *[7685-44-1]* **M 115.1, m 250-255°(dec).** Dissolve in absolute EtOH and ppte with pyridine, then recrystallise from aqueous EtOH [R_F in BuOH:EtOH:NH_3:H_2O (4:4:1:1:) 0.37]. The *hydrobromide* has **m** 136-140° (from EtOAc) and the *phenylureido* derivative has **m** 159-161°. [*M* **89** 377 *1958*].

1-*N*-Allyl-3-hydroxymorphinan *[152-02-3]* **M 283.4, m 180-182°.** Crystd from aqueous EtOH.

Allyl iodide *[556-56-9]* **M 167.7, b 103°, d^{12} 1.848.** Purified in a dark room by washing with aq Na_2SO_3 to remove free iodine, then drying with $MgSO_4$ and distilling at 21mm pressure, to give a very pale yellow liquid. (This material, dissolved in hexane, was stored in a light-tight container at -5° for up to three months before free iodine could be detected, by its colour in the soln) [Sibbett and Noyes *JACS* **75** 761 *1953*].

5-Allyl-5-*iso*butylbarbituric acid *[77-26-9]* **M 224.3, m 139°, 139-140°, 140-142°.** It can be recrystallised from H_2O or dilute EtOH, and sublimes at 100-120°/8-12mm. It is soluble in C_6H_6, cyclohexane, tetralin and pet ether at 20° and has a pKa of 12.36 at 38°. [*JACS* **77** 1486 *1955*].

Allylisocyanate *[1476-23-9]* **M 83.1, b 84°/atm, 87-89°/atm, d_4^{20} 0.94, n_D^{20} 1.417.** Purify as for allylisothiocyanate.

Allylisothiocyanate *[57-06-7]* **M 99.2, m -80°, b 84-85°/80mm, 150°/760mm, 151°/atm, d_4^{20} 1.017, n_D^{20} 1.5268.** Fractionate using an efficient column, preferably in a vacuum. It is a yellow **pungent irritating and TOXIC (suspected CARCINOGEN) liquid.** Store in a sealed tube under N_2. The *N'-benzylthiourea* derivative has **m** 94.5° (from aq EtOH) [*JACS* **74** 1104 *1952*].

Allyl Phenyl sulphide *[5296-64-0]* **M 150.2, b 59-60°/1.5mm, 79-80°/3mm, 114-114.3°/23.5mm, 225-226°/740mm, 215-218°/750mm, d_4^{20} 1.0275, n_D^{20} 1.5760.** Dissolve in

Et_2O, wash with alkali, H_2O, dry over $CaCl_2$, evaporate and fractionally distil, preferably under vacuum. It should not give a ppte with an alcoholic soln of $Pb(OAc)_2$. [*JACS* **52** 3356 *1930*, **74** 48 *1952*].

***N*-Allylthiourea (thiosinamine)** *[109-57-9]* **M 116.2, m 70-73°, 78°.** Recrystd from H_2O. Soluble in 30 parts of cold H_2O, soluble in EtOH but insoluble in C_6H_6. Also recrystd from acetone, EtOH or ethyl acetate, after decolorizing with charcoal. The white crystals have a bitter taste with a slight garlic odour and are **TOXIC**. [*AC* **21** 421 *1949*].

***N*-Allylurea** *[557-11-9]* **M 100.1, m 85°.** Crystd from EtOH, EtOH/ether, EtOH/chloroform or EtOH/toluene.

Aloin (10-glucopyranosyl-1,8-dihydroxy-3-(hydroxymethyl)-9(10*H*)anthracenone, Barbaloin) *[8015-61-0]* **M 418.4, m 148-148.5°, 148-150°.** Lemon yellow crystals from H_2O (450g/1.5L) as the *monohydrate* which has a lower **m** (70-80°). [*JCS* 2573 *1932*, 3141 *1956*].

D-Altrose *[1990-29-0]* **M 180.2, m 103-105°, $[\alpha]_{546}$ +35° (c 7.6, H_2O).** Crystd fom aq EtOH.

Amberlite IRA-904 Anion-exchange resin (Rohm and Haas). Washed with 1M HCl, CH_3OH (1:10) and then rinsed with distilled water until the washings were neutral to litmus paper. Finally extracted successively for 24h in a Soxhlet apparatus with MeOH, benzene and cyclohexane [Shue and Yan *AC* **53** 2081 *1981*].

Amethopterin (H_2O) *[59-05-2]* **M 454.5, m 185-204° (dec), $[\alpha]_D$ -19.4° (c 2, 0.1 M NaOH).** Crystd from water.

Aminoacetaldehyde dimethyl acetal (2,2-dimethoxy ethylamine) *[22483-09-6]* **M 105.1, m <-78°, b 139.5°/768mm, 137-139°/atm, d_4^{20} 0.9676 n_D^{20} 1.4144.** Dry over KOH pellets and distil through a 30cm vac jacketed Vigreux column. [*JACS* **75** 3398 *1953*, **77** 6640 *1955*].

***p*-Aminoacetanilide** *[122-80-5]* **M 150.2, m 162-163°.** Crystd from water.

Aminoacetic acid (Glycine) *[56-40-6]* **M 75.1, m 262° (dec, goes brown at 226°, sublimes at 200°/0.1mm).** Crystd from distilled water by dissolving at 90-95°, filtering, cooling to about -5°, and draining the crystals centrifugally. Alternatively, crystd from distilled water by addition of MeOH or EtOH (e.g. 50g dissolved in 100ml of warm water, and 400ml of MeOH added). The crystals can be washed with MeOH or EtOH, then with ethyl ether. Likely impurities are ammonium glycinate, iminodiacetic acid, nitrilotriacetic acid, ammonium chloride.

Aminoacetonitrile bisulphate *[151-63-3]* **M 154.1, m 188°(dec)** Crystd from aqueous EtOH.

Aminoacetonitrile hydrochloride *[6011-14-9]* **M 92.5, m 166-167°, 172-174°.** Recrystd from dil EtOH *hygroscopic* leaflets. Best to crystallise from absolute EtOH-Et_2O (1:1) and then recryst from absolute EtOH. The **m** recorded range from 144° to 174°. The free base has **b** 58°/15mm with partial decomposition. [*J Prakt Chem* **[2] 65** 189 *1902*; *JACS* **56** 2197 *1934*; *JCS* 1371 *1947*].

ω-Aminoacetophenone hydrochloride *[5468-37-1]* **M 171.6, m 188°(dec), 194°[dec].** Crystd from acetone/EtOH.

***m*-Aminoacetophenone** *[99-03-6]* **M 135.2, m 98-99°.** Crystd from EtOH.

4-Aminoacetophenone *[99-92-3]* **M 135.2, m 104-106° 105-107°, b 293°/atm.** Recryst from $CHCl_3$, C_6H_6 or H_2O. Soluble in hot H_2O. UV (EtOH) has λ_{max} 403nm (logε 4.42) [*JACS* **75** 2720 *1953*]. The pKa (H_2O) at 25° is 2.19 [*AC* **26** 726 *1954*]. The *2,4-dinitrophenylhydrazone* has **m** 266-267° (from $CHCl_3$ or EtOH), and the *semicarbazone* has **m** 193-194°(dec)(from MeOH) and the *hydrochloride* has **m** 98°(dec)(from H_2O).

9-Aminoacridine [9-acridineamine] *[90-45-9]* **M 194.2, m 241°.** Crystd from EtOH or acetone and sublimes at 170-180°/0.04mm [Albert and Ritchie *JOC* Coll Vol III 53 *1955*; for hydrochloride see Chapter 5].

***dl*-α-Aminoadipic acid (hydrate)** *[542-32-5]* **M 161.2, m 196-198°.** Crystd from water.

2-Amino-4-anilino-*s*-triazine *[537-17-7]* **M 168.2, m 235-236°.** Crystd from dioxane or 50% aqueous EtOH.

1-Aminoanthraquinone-2-carboxylic acid *[82-24-6]* **M 276.2, m 295-296°.** Crystd from nitrobenzene.

4-Aminoantipyrine *[83-07-8]* **M 203.3, m 109°.** Crystd from EtOH or EtOH/ether.

***p*-Aminoazobenzene** *[60-09-3]* **M 197.2, m 126°.** Crystd from EtOH, CCl_4, pet ether/benzene, or a MeOH/water mixture.

***o*-Aminoazotoluene (Fast Garnet GBC base)** *[614-63-1]* **M 225.3, m 101.4-102.6°.** Crystd twice from EtOH, once from benzene, then dried in an Abderhalden drying apparatus [Cilento *JACS* **74** 968 *1952*]. **CARCINOGENIC.**

5-Aminobarbituric acid see **uramil.**

2-Aminobenzaldehyde *[529-23-7]* **M 121.1, m 39-40°.** Distd in steam and crystd from water or EtOH/ether.

2-Aminobenzaldehyde phenylhydrazone (Nitrin) *[63363-93-9]* **M 211.3, 227-229°.** Crystd from acetone. [Knöpfer *M* **31** 97 *1910*].

3-Aminobenzaldehyde *[29159-23-7]* **M 121.1, m 28-30°.** Crystd from ethyl acetate.

4-Amidobenzamide hydrochloride *[59855-11-7]* **M 199.6, m 284-285°.** Recrystd from EtOH.

***p*-Aminobenzeneazodimethylaniline** *[539-17-3]* **M 240.3, m 182-183°.** Crystd from aqueous EtOH.

***p*-Aminobenzenesulphonamide** see **sulphanilamide.**

***m*-Aminobenzenesulphonic acid** see **metanilic acid.**

***p*-Aminobenzenesulphonic acid** see **sulphanilic acid.**

***o*-Aminobenzoic acid (anthranilic acid)** *[118-92-3]* **M 137.1, m 145°.** Crystd from water (charcoal). Has also been crystd from 50% aqueous acetic acid. Can be vacuum sublimed.

***m*-Aminobenzoic acid** *[99-05-8]* **M.137.1, m 174°.** Crystd from water.

***p*-Aminobenzoic acid** *[150-13-0]* **M 137.1, m 187-188°.** Purified by dissolving in 4-5% aqueous HCl at 50-60°, decolorizing with charcoal and carefully precipitating with 30% Na_2CO_3 to pH 3.5-4 in the presence of ascorbic acid. It can be crystd from water, EtOH or EtOH/water mixtures.

***p*-Aminobenzonitrile** *[873-74-5]* **M 118.1, m 86-86.5°.** Crystd from water, 5% aqueous EtOH or EtOH and dried over P_2O_5 or dried *in vacuo* for 6h at 40°. [Moore et al. *JACS* **108** 2257 *1986*].

4-Aminobenzophenone *[1137-41-3]* **M 197.2, m 123-124°.** Dissolved in aq acetic acid, filtered and ppted with ammonia. Process repeated several times, then recrystd from aqueous EtOH.

2-Aminobenzothiazole *[136-95-8]* **M 150.2, m 132°,**
6-Aminobenzothiazole *[533-30-2]* **M 150.2, m 87°.** Crystd from aqueous EtOH.

***N*-(*p*-Aminobenzoyl)-L-glutamic acid** *[4271-30-1]* **M 266.3, m 173° (L-form), $[\alpha]_{546}$ -17.5° (c 2, 0.1m HCl); 197° (DL).** Crystd from H_2O.

3-*o*-Aminobenzyl-4-methylthiazolium chloride hydrochloride *[534-94-1]* **M 277.4, m 213°(dec).** Crystd from aqueous EtOH.

***o*-Aminobiphenyl** *[90-41-5]* **M 169.2, m 49.0°.** Crystd from aqueous EtOH (charcoal).

***p*-Aminobiphenyl** *[92-67-1]* **M 169.2, m 53°, b 191°/16mm.** Crystd from water or EtOH. **CARCINOGENIC.**

2-Amino-5-bromotoluene *[583-75-5]* **M 186.1, m 59°.** Steam distd, and crystd from EtOH.

***S*-α-Aminobutyric acid** *[1492-24-6]* **M 103.1, m 292°(dec), $[\alpha]_D$ + 20.4° (c 2, 2.5N HCl).** Crystd from aqueous EtOH.

***RS*-α-Aminobutyric acid** *[2835-81-6]* **M 103.1, m 303°(dec).** Crystd from water.

ß-Aminobutyric acid *[2835-82-7]* **M 103.1, m 193-194°,**
α-Aminobutyric acid *[56-12-2]* **M 103.1, m 202°(dec).** Crystd form aqueous EtOH.

***RS*-α-Amino-*n*-caproic acid** see ***RS*-norleucine**

2-Amino-5-chlorobenzoic acid *[635-21-1]* **M 171.6, m 100°.** Crystd from water, EtOH or chloroform.

3-Amino-4-chlorobenzoic acid *[2840-28-0]* **M 171.6, m 216-217°.** Crystd from water.

4-Amino-4'-chlorobiphenyl *[135-68-2]* **M 203.5, m 134°.** Crystd from pet ether.

2-Amino-4-chloro-6-methylpyrimidine *[5600-21-5]* **M 143.6, m 184-186°.** Crystd from EtOH.

2-Amino-5-chloropyridine *[1072-98-6]* **M 128.6, m 135-136°.** Crystd from pet ether, sublimes at 50°/0.5mm.

1-Amino-1-cyclopentanecarboxylic acid *[52-52-8]* **M 129.2, m 330°(dec).** Crystd from aq EtOH.

2-Amino-3,5-dibromopyridine *[35486-42-1]* **M 251.9, m 103-104°.** Steam distd and crystd from aqueous EtOH or pet ether.

2-Amino-4,6-dichlorophenol *[527-62-8]* **M 175.0, m 95-96°.** Crystd from CS_2 or benzene.

3-Amino-2,6-dichloropyridine *[62476-56-6]* **M 164.0, m 119°, b 110°/0.3mm.** Crystd from water.

4-Amino-*N*,*N*-diethylaniline hydrochloride *[16713-15-8]* **M 200.7, m 233.5°.** Crystd from EtOH.

4-Amino-3,5-diiodobenzoic acid *[2122-61-4]* **M 388.9, m >350°.** Purified by soln in dilute NaOH and pptn with dilute HCl. Air dried.

2-Amino-4,6-dimethylpyridine *[5407-87-4]* **M 122.2, m 69-70.5°.** Crystd from hexane, ether/pet ether or benzene. Residual benzene was removed over paraffin-wax chips in an evacuated desiccator.

2-Amino-4,6-dimethylpyrimidine *[767-15-7]* **M 123.2, m 152-153°.** Crystn from water gives **m** 197°, and crystn from acetone gives **m** 153°.

2-Aminodiphenylamine *[534-85-0]* **M 184.2, m 79-80°.** Crystd from H_2O.

4-Aminodiphenylamine *[101-54-2]* **M 184.2, b 155°/0.026mm.** Crystn from EtOH gives **m** 66°, and crystn from ligroin gives **m** 75°.

2-Amino-1,2-diphenylethanol *[530-36-9]* **M 213.3, m 165°.** Crystd from EtOH.

2-Aminodiphenylmethane *[28059-64-5]* **M 183.3, m 52°, b 172°/12mm and 190°/22mm.** Crystd from ether.

2-Aminoethanethiol *[60-23-1]* **M 77.2, m 97-98.5°.** Sublimed under vacuum. [Barkowski and Hedberg *JACS* **109** 6989 *1987*].

2-Aminoethanol *[141-43-5]* **M 61.1, f 10.5°, b 72-73°/12mm, 171.1°/760mm, d 1.012, n 1.14539.** Decomposes slightly when distd at atmospheric pressure, with the formation of conducting impurities. Fractional distn at about 12mm pressure is satisfactory. After distn, 2-aminoethanol was further purified by repeated washing with ether and crystn from EtOH (at low temperature). After fractional distn in the absence of CO_2, it was twice crystd by cooling, followed by distn. *Hygroscopic.* [Reitmeier, Silvertz and Tartar *JACS* **62** 1943 *1940*]. It can be dried by azeotropic distn with dry benzene.

2-Aminoethanol hydrochloride *[2002-24-6]* **M 97.6, m 75-77°.** Crystd from EtOH. It is deliquescent.

2-Aminoethanol hydrogen sulphate *[926-39-6]* **M 125.2, m 285-287° (chars at 275°).** Crystd from water or dissolved in water and EtOH added.

2-(2-Aminoethylamino)ethanol see **hydroxyethyl-ethylenediamine.**

S-(2-Aminoethyl)isothiouronium bromide hydrobromide *[56-10-0]* **M 281.0, m 194-195°.** Crystd from absolute EtOH/ethyl acetate. It is *hygroscopic.*

2-Amino-4-(ethylthio)butyric acid see **ethionine.**

(2-Aminoethyl)trimethylammonium chloride hydrochloride (chloramine chloride hydrochloride) *[3399-67-5]* **M 175.1, m 260°(dec).** Crystd from EtOH. (Material is very soluble in H_2O).

2-Aminofluorene *[153-78-6]* **M 181.2, m.127.8-128.8°.** Wash well with H_2O and recrystd from 50% aqueous EtOH (25g with 400ml), and dry in a vacuum. Store in the dark. [*Org Synth* Col.Vol. II 447 *1943*; Col.Vol. V 30 *1973*].

***RS*-α-Aminohexanoic acid** see ***RS*-methionine.**

4-Amino hippuric acid *[61-78-9]* **M 194.2, m 198-199°.** Crystd from H_2O.

1-Amino-4-hydroxyanthraquinone *[116-85-8]* **M 293.2, m 207-208°.** Purified by TLC on SiO_2 gel plates using toluene/acetone (9:1) as eluent. The main band was scraped off and extracted with MeOH. The solvent was evaporated and the dye was dried in a drying pistol [Land, McAlpine, Sinclair and Truscott *JCSFT 1* **72** 2091 *1976*]. Crystd from aq EtOH.

2-Amino-4-hydroxybutyric acid see **homoserine.**

***dl*-4-Amino-3-hydroxybutyric acid** *[924-49-2]* **M 119.1, m 225°(dec).** Crystd from H_2O or aqueous EtOH.

2-Amino-2-hydroxymethyl-1,3-propanediol see **tris(hydroxymethyl)aminomethane.**

5-Amino-8-hydroxyquinoline hydrochloride *[3881-33-2]* **M 196.7.** Dissolved in minimum of MeOH, then Et_2O was added to initiate pptn. Ppte was filtered off and dried [Lovell et al. *JPC* **88** 1885 *1984*].

3-Amino-4-hydroxytoluene *[95-84-1]* **M 123.2, m 137-138°.** Crystd from H_2O or toluene.

4-Amino-5-hydroxytoluene *[2835-98-5]* **M 123.2, m 159°,**
6-Amino-3-hydroxytoluene *[2835-99-6]* **M 123.2, m 162°(dec).** Crystd from 50% EtOH.

4-Aminoimidazole-5-carboxamide hydrochloride (AICAR HCl) *[72-40-2]* **M 162.6, m 255-256°(dec).** Recrystd from EtOH.

5-Aminoindane *[24425-40-9]* **M 133.2, m 37-38°, b 131°/15mm, 146-147°/25mm, 247-249°/745mm.** Distd and then crystd from pet ether.

6-Aminoindazole *[6967-12-0]* **M 133.2, m 210°.** Crystd from H_2O or EtOH and sublimed in a vacuum.

2-Amino-5-iodotoluene *[13194-68-8]* **M 233.0, m 87°.** Crystd from 50% EtOH.

α-Aminoisobutyric acid *[62-57-7]* **M 103.1, sublimes at 280°.** Crystd from aqueous EtOH and dried at 110°.

D-4-Amino-3-isoxazolidone (D-cycloserine) *[68-14-7]* **M 102.1, m 154-155°(dec), $[\alpha]_{546}$ +139° (c 2, H_2O).** Crystd from aqueous ammoniacal soln at pH 10.5 (100mg/ml) by diluting with 5 volumes of isopropanol and then adjusting to pH 6 with acetic acid.

5-Aminolaevulinic acid hydrochloride *[5451-09-2]* **M 167.6, m 156-158°(dec).** Dried in a vacuum desiccator over P_2O_5 overnight then crystd by dissolving in cold EtOH and adding dry Et_2O.

8-Amino-6-methoxyquinoline *[90-52-8]* **M 174.1, m 41-42°.** Distd under N_2 at *ca* 50 microns, then recrystd several times from MeOH (0.4ml/g).

1-Amino-4-methylaminoanthraquinone *[1220-94-6]* **M 252.3.** Purified by TLC on silica gel plates using toluene/acetone (3:1) as eluent. The main band was scraped off and extracted with MeOH. The solvent was evaporated and the residue dried in a drying pistol [Land, McAlpine, Sinclair and Truscott *JCSFT 1* **72** 2091 *1976*].

4-Aminomethylbenzenesulphonamide hydrochloride *[138-37-4]* **M 222.3, m 265-267°.** Crystd from dilute HCl and dried in a vacuum at 100°.

***S*-2-Amino-3-methyl-1-butanol** *[2026-48-4]* **M 103.2, m 31-32°, b 88°/11mm, d 0.92, $[\alpha]_{546}$ + 16.5° (c 6.32, *l* = 2 H_2O], $[\alpha]_D$ + 15.6° (EtOH).** Purified by vacuum distn using short Vigreux column. Alternatively it is purified by steam distn. The steam distillate is acidified with HCl, the aq layer is collected and evapd. The residue is dissolved in butan-1-ol, filtered and dry Et_2O added to cryst the hydrochloride salt (*hygroscopic*), **m** 113°. The free base can be obtained by suspending the salt in Et_2O adding small vols of satd K_2CO_3 until effervescence is complete and the mixture is distinctly alkaline. At this stage the aq layer should appear as a white sludge. The mixture is heated to boiling and refluxed for 30 min (more Et_2O is added if necessary). The Et_2O is decanted from the white sludge, the sludge is extracted twice with Et_2O (by boiling for a few minutes), the combined organic layers are dried (KOH pellets), evapd and the residue distd in a vacuum.

7-Amino-4-methylcoumarin *[26093-31-2]* **M 175.2, 221-442°(dec).** Dissolved in 5% HCl, filtered and basified with 2M ammonia. The ppte is dried in a vacuum, and crystd from dilute EtOH. It yields a blue soln and is light sensitive.

4-Amino-2-methyl-1-naphthol hydrochloride *[130-24-5]* **M 209.6, m 283°(dec).** Crystd from dilute HCl.

2-Amino-2-methyl-1,3-propanediol *[115-69-5]* **M 105.1, m 111°, b 151-152°/10mm.** Crystd three times from MeOH, dried in a stream of dry N_2 at room temp, then in a vacuum oven at 55°. Stored over $CaCl_2$ [Hetzer and Bates *JPC* **66** 308 *1962*].

2-Amino-2-methyl-1-propanol *[124-68-5]* **M 89.4, m 31°, b 164-166°/760mm, d 0.935.** Purified by distn and fractional freezing.

2-Amino-3-methylpyridine *[1603-40-3]* **M 108.1, m 33.2°, b 221-222°.** Crystd three times from benzene, most of the residual benzene being removed from the crystals over paraffin wax chips in an evacuated desiccator. The amine, transferred to a separating funnel under N_2, was left in contact with NaOH pellets for 3h with occasional shaking. It was then placed in a vacuum distilling flask where it was refluxed gently in a stream of dry N_2 before being fractionally distd [Mod, Magne and Skau *JPC* **60** 1651 *1956*].

2-Amino-4-methylpyridine *[695-34-1]* **M 108.1, m 99.2°, b 230°.** Crystd from EtOH or a 2:1 benzene/acetone mixture, and dried under vacuum.

2-Amino-5-methylpyridine *[1603-41-4]* **M 108.1, m 76.5°, b 227°.** Crystd from acetone.

2-Amino-6-methylpyridine *[1824-81-3]* **M 108.1, m 44.2°, b 208-209°.** Crystd three times from acetone, dried under vacuum at *ca* 45°. After leaving in contact with NaOH pellets for 3h, with occasional shaking, it was decanted and fractionally distd [Mod, Magne and Skau *JPC* **60** 1651 *1956*]. Also recrystd from CH_2Cl_2 by addition of pet ether. [Marzilli et al. *JACS* **108** 4830 *1986*].

2-Amino-5-methylpyrimidine *[50840-23-8]* **M 109.1, m 193.5°.** Crystd from water and benzene. Sublimes at 50°/0.5mm.

4-Amino-2-methylquinoline *[6628-04-2]* **M 158.2, m 168°, b 333°/760mm.** Crystd from benzene/pet ether.

2-Amino-4-(methylsulphoxyl)butyric acid see **methionine sulphoxide.**

2-Aminonaphthalene (ß-naphthylamine) *[91-59-8]* **M 143.2, m 111-113°.** Crystd from water (charcoal). **CARCINOGENIC.**

3-Amino-2-naphthoic acid *[5959-52-4]* **M 187.2, m 214°(dec).** Crystd from aqueous EtOH.

4-Amino-5-naphthol-2,7-disulphonic acid *[90-20-0]* **M 320.3.** Sufficient Na_2CO_3 (*ca* 22g) to make the soln slightly alkaline to litmus was added to a soln of 100g of the dry acid in 750ml of hot distd water, followed by 5g of activated charcoal and 5g of Celite. The suspension was stirred for 10min and filtered by suction. The acid was ppted by adding *ca* 40ml of conc HCl (soln blue to Congo Red), then filtered by suction through sharkskin filter paper and washed with 100ml of distd water. The purification process was repeated. The acid was dried overnight in an oven at 60° and stored in a dark bottle [Post and Moore *AC* **31** 1872 *1959*].

1-Amino-2-naphthol hydrochloride *[1198-27-2]* **M 195.7, m 250°(dec).** Crystd from the minimum volume of hot water containing a few drops of stannous chloride in an equal weight of hydrochloric acid (to reduce atmospheric oxidation).

1-Amino-2-naphthol-4-sulphonic acid *[116-63-2]* **M 239.3, m 295°(dec).** Purified by warming 15g of the acid, 150g of $NaHSO_3$ and 5g of Na_2SO_3 (anhydrous) with 1L of water to *ca* 90°, shaking until most of the solid had dissolved, then filtering hot. The precipitate obtained by adding 10ml of conc HCl to the cooled filtrate was collected, washed with 95% EtOH until the washings were colourless, and dried under vacuum over $CaCl_2$. It was stored in a dark coloured bottle, in the cold [Chanley, Gindler and Sobotka *JACS* **74** 4347 *1952*].

6-Aminonicotinic acid *[3167-49-5]* **M 138.1, m 312°(dec).** Crystd from aq acetic acid.

2-Amino-4-nitrobenzoic acid *[619-17-0]* **M 182.1, m 269°(dec).** Crystd from water or aq EtOH.

5-Amino-2-nitrobenzoic acid *[13280-60-9]* **M 182.1, m 235°(dec).** Crystd from water.

1-Amino-4-nitronaphthalene *[776-34-1]* **M 188.2, m 195°.** Crystd from EtOH or ethyl acetate.

2-Amino-4-nitrophenol *[99-57-0]* **M 154.1, m 80-90° (hydrate), 142-143° (anhydr),**
2-Amino-5-nitrophenol *[121-88-0]* **M 154.1, m 207-208°,**
6-Aminopenicillanic acid *[551-16-6]* **M 216.2, m 208-209°, $[\alpha]_{546}$ +327° (in 0.1M HCl)** Crystd from water.

2-Aminoperimidine hydrobromide *[40835-96-9]* **M 264.1, m 299°.** Purified by boiling a saturated aqueous soln with charcoal, filtering and leaving the salt to crystallise. Stored in a cool, dark place.

2-Aminophenol *[95-55-6]* **M 109.1, m 175-176°.** Purified by soln in hot water, decolorised with activated charcoal, filtered and cooled to induce crystn. Maintain an atmosphere of N_2 over the hot phenol soln to prevent its oxidation [Charles and Freiser *JACS* **74** 1385 *1952*]. Can also be crystd from EtOH.

3-Aminophenol *[591-27-5]* **M 109.1, m 122-123°.** Crystd from hot water or toluene.

4-Aminophenol *[123-30-8]* **M 109.1, m 190° (under N_2).** Crystd from EtOH, then water, excluding oxygen. Can be sublimed at 110°/0.3mm. Has been purified by chromatography on alumina with a 1:4 (v/v) mixture of absolute EtOH/benzene as eluent.

4-Aminophenol hydrochloride *[51-78-5]* **M 145.6, m 306°(dec).** Purified by treating an aqueous soln with saturated $Na_2S_2O_3$, filtering under an inert atmosphere, then recrystd from 50% EtOH twice and once from absolute EtOH [Livingston and Ke *JACS* **72** 909 *1950*].

4-Aminophenylacetic acid *[1197-55-3]* **M 151.2, m 199-200°(dec).** Crystd from hot water (60-70ml/g).

***S*-(-)-2-Amino-3-phenyl-1-propanol (L-phenylalaninol)** *[3182-95-4]* **M 151.2, m 95°, $[\alpha]_D^{24}$ -25.7° (c 3.3, EtOH).** Crystd from benzene or toluene.

***N*-Aminophthalimide** *[1875-48-5]* **M 162.2, m 200-202°.** It has been recrystd from 96% EtOH (1 part in 44 at b.p.) to form a yellow solution. It sublimes *in vacuo* at *ca* 150°. Resolidifies after melting, and remelts at 338-341°.

4-Aminopropiophenone *[70-69-9]* **M 163.1, m 140°.** Crystd from water or EtOH.

α-(α-Aminopropyl)benzyl alcohol *[5053-63-4]* **M 165.1, m 79-80°.** Crystd from benzene/pet ether.

4-(2-Aminopropyl)phenol *[103-86-6]* **M 151.2, m 125-126°.** Crystd from benzene.

1-Aminopyrene *[1606-67-3]* **M 217.3, m 117-118°.** Crystd from hexane.

2-Aminopyridine *[504-29-0]* **M 94.1, m 58°, b 204-210°.** Crystd from benzene/pet ether (b 40-60°) or $CHCl_3$ /pet ether.

3-Aminopyridine *[462-08-8]* **M 94.1, m 64°, b 248°.** Crystd from benzene, $CHCl_3$/pet ether (b 60-70°), or benzene/pet ether (4:1).

4-Aminopyridine *[504-24-5]* **M 94.1, m 160°, b 180°/12-13mm.** Crystd from benzene/EtOH, then recrystd twice from water, crushed and dried for 4h at 105° [Bates and Hetzer *J Res Nat Bur Stand* **64A** 427 *1960*]. Has also been crystd from EtOH, benzene, benzene/pet ether, toluene and sublimes in vacuum.

2-Aminopyrimidine *[109-12-6]* **M 95.1, m 126-127.5°.** Crystd from C_6H_6, EtOH or H_2O.

Aminopyrine (4-dimethylaminoantipyrene) *[58-15-1]* **M 231.3, m 107-109°.** Crystd from pet ether.

3-Aminoquinoline *[580-17-6]* **M 144.2, m 93.5°.** Crystd from C_6H_6.

4-Aminoquinoline *[578-68-7]* **M 144.2, m 158°.** Purified by zone refining.

5-Aminoquinoline *[611-34-7]* **M 144.2, m 110°, b 184°/10mm, 310°/760mm.** Crystd from pentane, then from benzene or EtOH.

6-Aminoquinoline *[580-15-4]* **M 144.2, m 117-119°.** Purified by column chromatography on a SiO_2 column using $CHCl_3$/MeOH (4:1) as eluent. It is an **irritant**.

8-Aminoquinoline *[578-66-5]* **M 144.2, m 70°.** Crystd from EtOH or ligroin.

***p*-Aminosalicylic acid** *[65-49-6]* **M 153.1, m 150-151°(dec),**
2-Amino-5-sulphanilylthiazole *[473-30-3]* **M 238.3, m 219-221°(dec).** Crystd from EtOH.

4-Amino-2-sulphobenzoic acid *[527-76-4]* **M 217.1.** Crystd from water.

2-Aminothiazole *[96-50-4]* **M 108.1, m 93°, b 140°/11mm.** Crystd from pet ether (b 100-120°), or EtOH.

2-Amino-1,2,4-triazole *[244994-60-3]* **M 84.1, m 91-93°.** Crystd from water. [Barszez et al. *JCSDT* 2025 *1986*].

3-Amino-1,2,4-triazole *[61-82-5]* **M 84.1, m 159°.** Crystd from EtOH (charcoal), then three times from dioxane [Williams, McEwan and Henry *JPC* **61** 261 *1957*].

4-Amino-1,2,4-triazole *[584-13-4]* **M 84.1, m 80-81°.** Crystd from water. [Barszez et al. *JCSDT* 2025 *1986*].

7-Amino-4-(trifluoromethyl)coumarin, m 222°. Purified by column chromatography on a C18 column, eluted with acetonitrile/0.01M aq HCl (1:1), and crystd from isopropanol. Alternatively, it is eluted from a silica gel column with CH_2Cl_2, or by extracting a CH_2Cl_2 solution (4g/L) with 1M aq NaOH (3 x 0.1L), followed by drying ($MgSO_4$), filtration and evaporation. [Bissell *JOC* **45** 2283 *1980*].

9-Aminotriptycene *[793-41-9]* **M 269.3, m 223.5-224.5°.** Recrystd from ligroin [Imashiro et al. *JACS* **109** 729 *1987*].

DL-α-Amino-*n*-valeric acid see **norvaline.**

5-Amino-*n*-valeric acid *[660-88-8]* **M 117.2, m 157-158°.** Crystd by dissolving in H_2O and adding EtOH.

5-Amino-*n*-valeric acid hydrochloride *[627-95-2]* **M 153.6, m 103-104°.** Crystd from $CHCl_3$.

Ammonium benzoate *[1863-63-4]* **M 139.2, m 200°(dec).** Crystd from EtOH.

Ammonium *d*-α-bromocamphor-π-sulphonate *[14575-84-9]* **M 328.2, m 284-285°(dec), $[\alpha]_D^{25}$ +84.8° (c 4, H_2O).** Passage of a hot aqueous soln through an alumina column removed water-soluble coloured impurities which remained on the column when the ammonium salt was eluted with hot water. The salt was crystd from water and dried over $CaCl_2$ [Craddock and Jones *JACS* **84** 1098 *1962*].

Ammonium dodecylsulphate *[2235-54-3]* **M 283.4.** Recrystd first from 90% EtOH and then twice from abs EtOH, finally dried in a vacuum.

Ammonium nitrosophenylhydroxylamine see **cupferron** entry in Chapter 4.

Ammonium peroxydisulphate *[7727-54-0]* **M 228.2.** Recrystd at room temperature from EtOH/water.

Ammonium picrate *[131-74-8]* **M 246.1, EXPLODES above 200°.** Crystd from EtOH and acetone.

Amodiaquin [4-(3-aminomethyl-4-hydroxyanilino)-7-chloroquinoline] *[86-42-0]* **M 287.5, m 208°.** Crystd from 2-ethoxyethanol.

D-Amygdalin *[29883-15-6]* **M 457.4, m 214-216°, $[\alpha]_D^{22}$ -38° (c 1.2, H_2O).** Crystd from water.

***n*-Amyl acetate** *[628-63-7]* **M 130.2, b 149.2°, d 0.876, n 1.40228.** Shaken with saturated $NaHCO_3$ soln until neutral, washed with water, dried with $MgSO_4$ and distd.

***n*-Amyl alcohol** *[71-41-0]* **M 88.2, b 138.1°, d^{15} 0.818, n 1.4100.** Dried with anhydrous K_2CO_3 or $CaSO_4$, filtered and fractionally distd. Has also been treated with 1-2% of sodium and heated at reflux for 15h to remove water and chlorides. Traces of water can be removed from the near-dry alcohol by refluxing with a small amount of sodium in the presence of 2-3% *n*-amyl phthalate or succinate followed by distn (see *ethanol*). Small amounts of amyl alcohol have been purified by esterifying with *p*-hydroxybenzoic acid, recrystallising the ester from CS_2, saponifying with ethanolic-KOH, drying with $CaSO_4$ and fractionally distilling [Olivier *Rec Trav chim Pays-Bas* **55** 1027 *1936*].

***tert*-Amyl alcohol** *[75-85-4]* **M 88.2, b 102.3°, d^{15} 0.8135, n 1.4058.** Refluxed with anhydrous K_2CO_3, CaH_2, CaO or sodium, then fractionally distd. Near-dry alcohol can be further dried by refluxing with magnesium activated with iodine, as described for *ethanol*. Further purification is possible using fractional crystn, zone refining or preparative gas chromatography.

***n*-Amylamine** *[110-58-7]* **M 87.2, b 105°, d 0.752.** Dried by prolonged shaking with NaOH pellets, then distd.

***n*-Amyl bromide (*n*-pentylbromide)** *[110-53-2]* **M 151.1, b 129.7°, d 1.218, n 1.445.** Washed with conc H_2SO_4, then water, 10% Na_2CO_3 soln, again with water, dried with $CaCl_2$ or K_2CO_3, and fractionally distd just before use.

***n*-Amyl chloride** *[543-59-9]* **M 106.6, b 107.8°, d 0.882, n 1.41177,**
***sec*-Amyl chloride (1-chloro-2-methylbutane)** *[616-13-7]* **M 106.6, b 96-97°.** Purified by stirring vigorously with 95% H_2SO_4, replacing the acid when it became coloured, until the layer remained colourless after 12h stirring. The amyl chloride was then washed with satd Na_2CO_3 soln, then distd water, and dried with anhydrous $MgSO_4$, followed by filtration, and distn through a 10-in Vigreux column. Alternatively a stream of oxygen containing 5% ozone was passed through the amyl chloride for three times as long as it took

to cause the first coloration of starch iodide paper by the exit gas. Washing the liquid with $NaHCO_3$ soln hydrolyzed ozonides and removed organic acids prior to drying and fractional distn [Chien and Willard *JACS* **75** 6160 *1953*].

***tert*-Amyl chloride** *[594-36-5]* **M 106.6, b 86°, d 0.866.** Methods of purification commonly used for other alkyl chlorides lead to decomposition. Unsatd materials were removed by chlorination with a small amount of chlorine in bright light, followed by distn [Chien and Willard *JACS* **75** 6160 *1953*].

Amyl ether *[693-65-2]* **M 158.3, b 186.8°, d 0.785, n 1.41195.** Repeatedly refluxed over sodium and distd.

***n*-Amyl mercaptan** see **1-pentanethiol.**

Amylose see entry in Chapter 5.

***p-tert*-Amylphenol** *[80-46-6]* **M 146.3, m 93.5-94.2°.** Purified *via* its benzoate, as for phenol. After evaporating the solvent from its soln in ether, the material was crystd (from the melt) to constant melting point [Berliner, Berliner and Nelidow *JACS* **76** 507 *1954*].

2-*n*-Amylpyridine *[2294-76-0]* **M 149.2, b 63.0°/2mm, n^{26} 1.4861,**
4-*n*-Amylpyridine *[2961-50-4]* **M 149.2, b 78.0°/2.5mm, n 1.4908.** Dried with NaOH for several days, then distd from CaO under reduced pressure, taking the middle fraction and redistilling it.

α-Amyrin *[638-95-9]* **M 426.7, m 186°.** Crystd from EtOH.

ß-Amyrin *[508-04-3]* **M 426.7, m 197-197.5°.** Crystd from pet ether or EtOH.

Androstane *[24887-75-0]* **M 260.5, m 50-50.5°.** Crystd from acetone/MeOH.

***epi*-Androsterone** *[481-29-8]* **M 290.4, m 172-173°, $[\alpha]_{546}$ +115° (c 1, MeOH).** Crystd from aq EtOH.

***cis*-Androsterone** *[53-41-8]* **M 290.4. m 185-185.5°.** Crystd from acetone/Et_2O.

Angelic acid *[565-63-9]* **M 100.1, m 45°.** Steam distd, then crystd from H_2O.

Aniline *[62-53-3]* **M 93.1, f.p. -6.0°, b 68.3/10mm, 184.4°/760mm, d 1.0220, n 1.585, n^{25} 1.5832.** Aniline is *hygroscopic*. It can be dried with KOH or CaH_2, and distd at reduced pressure. Treatment with stannous chloride removes sulphur-containing impurities, reducing the tendency to become coloured by aerial oxidn. Can be crystd from Et_2O at low temps. More extensive purifications involve preparation of derivatives, such as the double salt of aniline hydrochloride and cuprous chloride or zinc chloride, or *N*-acetylaniline (m 114°) which can be recrystd from water.
Recrystd aniline was dropped slowly into an aqueous soln of recrystd oxalic acid. Aniline oxalate was filtered off, washed several times with water and recrystd three times from 95% EtOH. Treatment with satd Na_2CO_3 soln, regenerated aniline which was distd from the soln, dried and redistd under reduced pressure [Knowles *Ind Eng Chem* **12** 881 *1920*].
After refluxing with 10% acetone for 10h, aniline was acidified with HCl (Congo Red as indicator) and extracted with Et_2O until colourless. The hydrochloride was purified by repeated crystn before aniline was liberated by addition of alkali, then dried with solid KOH, and distd. The product was sulphur-free and remained colourless in air [Hantzsch and Freese *Ber* **27** 2529, 2966 *1894*].
Non-basic materials, including nitro compounds were removed from aniline in 40% H_2SO_4 by passing steam through the soln for 1h. Pellets of KOH were added to liberate the aniline which was steam distd, dried with KOH, distd twice from zinc dust at 20mm, dried with freshly prepared BaO, and finally distd from BaO in an all-glass apparatus [Few and Smith *JCS* 753 *1949*].

Aniline hydrobromide *[542-11-0]* **M 174.0, m 286°,**
Aniline hydrochloride *[142-04-1]* **M 129.6, m 200.5-201°,**
Aniline hydriodide *[45497-73-2]* **M 220.0.** Crystd from water or EtOH and dried at 5mm over P_2O_5. Crystd four times from MeOH containing a few drops of conc HCl by addition of pet ether (b 60-70°), then dried to constant weight over paraffin chips, under vacuum [Gutbezahl and Grunwald *JACS* **75** 559 *1953*]. It was ppted from EtOH soln by addition of Et_2O, and the filtered solid was recrystd from EtOH and dried *in vacuo.* [Buchanan et al. *JACS* **108** 1537 *1986*].

p-**Anilinophenol** see *p*-**hydroxydiphenylamine.**

m-**Anisaldehyde** *[591-31-1]* **M 136.2, b 143°/50mm, d 1.119.** Washed with $NaHCO_3$, then H_2O, dried with anhydrous $MgSO_4$ and distd under reduced pressure under N_2. Stored under N_2 in sealed glass ampoules.

Anisic acid see *p*-**methoxybenzoic acid.**

p-**Anisidine** *[104-94-9]* **M 123.2, m 57°.** Crystd from H_2O or aqueous EtOH. Dried in a vacuum oven at 40° for 6h and stored in a dry box. [More et al. *JACS* **108** 2257 *1986*]. Purified by vacuum sublimation [Guarr et al. *JACS* **107** 5104 *1985*].

Anisole *[100-66-3]* **M 108.1, f.p. -37.5°, b 43°/11mm, 153.8°/760mm, d^{15} 0.9988, n^{25} 1.5143.** Shaken with half volume of 2M NaOH, and emulsion allowed to separate. Repeated 3 times, then washed twice with water, dried over $CaCl_2$, filtered, dried over sodium wire and finally distd from fresh sodium under N_2, using a Dean-Stark trap, samples in the trap being rejected until free from turbidity [Caldin, Parbov, Walker and Wilson *JCSFT 1* **72** 1856 *1976*].
Dried with $CaSO_4$ or $CaCl_2$, or by refluxing with sodium or BaO with crystalline $FeSO_4$ or by passage through an alumina column. Traces of phenols have been removed by prior shaking with 2M NaOH, followed by washing with water. Can be purified by zone refining.

2-*p*-**Anisyl-1,3-indanone** *[117-37-3]* **M 252.3, m 156-157°.** Crystd from acetic acid or EtOH.

Anserine *[584-85-0]* **M 240.3, m 238-239°, $[\alpha]_D$ +11.3° (H_2O).** Crystd from aqueous EtOH. It is *hygroscopic.*

S-**Anserine nitrate** *[5937-77-9]* **M 303.3, m 225°(dec), $[\alpha]_D^{30}$ +12.2°.** Likely impurities: 1-methylimidazole-5-alanine, histidine. Crystd from aqueous MeOH.

Antheraxanthin *[68831-78-7]* **M 584.8, m 205°, λ_{max} 460.5, 490.5nm, in $CHCl_3$.** Likely impurities: violaxanthin and mutatoxanthin. Purified by chromatography on columns of $Ca(OH)_2$ and of $ZnCO_3$. Crystd from C_6H_6/MeOH as needles or thin plates. Stored in the dark, in an inert atmosphere, at -20°.

Anthracene *[120-12-7]* **M 178.2, m 218°.** Likely impurities are anthraquinone, anthrone, carbazole, fluorene, 9,10-dihydroanthracene, tetracene and bianthryl. Carbazole is removed by continuous-adsorption chromatography [see Sangster and Irvine *JPC* **24** 670 *1956*] using a neutral alumina column and passing *n*-hexane. [Sherwood in *Purification of Inorganic and Organic Materials*, Zief (ed), Marcel Dekker, New York, 1969]. The solvent is evaporated and anthracene is sublimed under vacuum, then purified by zone refining, under N_2 in darkness or non-actinic light.
Has been purified by co-distillation with ethylene glycol (boils at 197.5°), from which it can be recovered by additn of water, followed by crystn from 95% EtOH, benzene, toluene, a mixture of benzene/xylene (4:1), or Et_2O. It has also been chromatographed on alumina with pet ether in a dark room (to avoid photo-oxidation of adsorbed anthracene to anthraquinone). Other purification methods include sublimation in a N_2 atmosphere (in some cases after refluxing with sodium), and recrystd from toluene [Gorman et al. *JACS* **107** 4404 *1985*].
Anthracene has also been crystd from EtOH, chromatographed through alumina in hot benzene (*fume hood)* and then vac sublimed in a pyrex tube that has been cleaned and baked at 100°. (For further details see Craig and

Rajikan *JCSFT 1* **74** 292 *1978*; and Williams and Zboinski *JCSFT 1* **74** 611 *1978*.) More recently it has been chromatographed on alumina, recrystd from *n*-hexane and sublimed under reduced pressure. [Saltiel *JACS* **108** 2674 *1986*; Masnori et al. *JACS* **108** 1126 *1986*]. Alternatively, it was recrystd from cyclohexane, chromatographed on alumina with *n*-hexane as eluent, and recrystd two more times [Saltiel et al. *JACS* **109** 1209 *1987*].

Anthracene-9-carbonitrile see **9-cyanoanthracene.**

Anthracene-9-carboxylic acid *[723-62-6]* **M 222.2, m 214°(dec).** Crystd from EtOH.

9-Anthraldehyde *[642-31-9]* **M 206.2, m 104-105°.** Crystd from acetic acid or EtOH. [Masnori et al. *JACS* **108** 1126 *1986*].

Anthranilic acid see ***o*-aminobenzoic acid.**

Anthranol *[529-86-2]* **M 196.2, m 160-170°(dec).** Crystd from glacial acetic acid or aqueous EtOH.

Anthranthrone *[641-13-4]* **M 306.3, m 300°.** Crystd from chlorobenzene or nitrobenzene.

Anthraquinone *[84-65-1]* **M 208.2, m 286°.** Crystd from $CHCl_3$ (38ml/g), benzene, or boiling acetic acid, washing with a little EtOH and drying under vacuum over P_2O_5.

Anthraquinone Blue B *[2861-02-1]* **M 476.4,**
Anthraquinone Blue RXO *[4403-89-8]* **M 445.5,**
Anthraquinone Green G *[4403-90-1]* **M 624.6.** Purified by salting out three times with sodium acetate, followed by repeated extraction with EtOH [McGrew and Schneider *JACS* **72** 2547 *1950*].

Anthrarufin *[117-12-4]* **M 240.1, m 280°(dec).** Purified by column chromatography on silica gel with $CHCl_3/Et_2O$ as eluent, followed by recrystn from acetone. Alternatively recrystd from glacial acetic acid [Flom and Barbara *JPC* **89** 4489 *1985*].

1,8,9-Anthratriol *[480-22-8]* **M 226.2, m 176-181°.** Crystd from pet ether.

Anthrimide *[82-22-4]* **M 429.4.** Crystd from chlorobenzene or nitrobenzene.

Anthrone *[90-44-8]* **M 194.2, m 155°.** Crystd from a 3:1 mixture of benzene/pet ether (b 60-80°) (10-12ml/g), or successively from benzene then EtOH. Dried under vacuum.

Antipyrine *[60-80-0]* **M 188.2, m 114°, b 319°.** Crystd from EtOH/water mixture, benzene, benzene/pet ether or hot water (charcoal), and dried under vacuum.

ß-Apo-4'-carotenal, ß-Apo-8'-carotenal, ß-Apo-8'-carotenoic acid ethyl ester, and **ß-Apo-8'-carotenoic acid methyl ester** see entries in Chapter 5.

Apocodeine and **Apomorphine** see entries in Chapter 5.

ß-L-Arabinose (natural) *[87-72-9]* **M 150.1, m 158°, $[\alpha]_D$ +104° (c 4, H_2O after 24h).** Crystd slowly twice from 80% aq EtOH, then dried under vacuum over P_2O_5.

D-Arabinose *[28697-53-6]* **M 150.1, m 164°, $[\alpha]_{546}$ -123° (c 10, H_2O after 24h).** Crystd three times from EtOH, vacuum dried at 60° for 24h and stored in a vacuum desiccator.

L-Arabitol *[7643-75-6]* **M 152.2, m 102°, $[\alpha]_{546}$ -16° (c 5, 8% borax soln),**
DL-Arabitol *[2152-56-9]* **M 152.2, m 105-106°.** Crystd from 90% EtOH.

Araboascorbic acid see **isoascorbic acid.**

Arachidic acid *[506-30-9]* **M 312.5, m 77°.** Crystd from absolute EtOH.

Arachidic alcohol (1-eicosanol) *[629-96-9]* **M 298.6, m 65.5° (71°), b 200°/3mm.** Crystd from benzene or benzene/pet ether.

p-**Arbutin** *[497-76-7]* **M 272.3, m 163-164°.** Crystd from water.

S-**Arginine** *[74-79-3]* **M 174.2, m 207°(dec), $[\alpha]_D$ +26.5° (c 5, in 5M HCl), $[\alpha]_{546}$ +32° (c 5, in 5M HCl).** Crystd from 66% EtOH.

S-**Arginine hydrochloride** *[1119-34-2]* **M 210.7, m 217°(dec), $[\alpha]_D^{20}$ +26.9° (c 6, M HCl).** Likely impurity is ornithine. Crystd from water at pH 5-7, by adding EtOH to 80% (v/v).

S-**Argininosuccinic acid** *[2387-71-5]* **M 290.3, $[\alpha]_D^{24}$ +16.4° (H_2O).** Likely impurity is fumaric acid. In neutral or alkaline soln it readily undergoes ring closure. Crystd from water by adding 1.5 vols of EtOH. Barium salt is stable at 0-5° if dry.

S-**Argininosuccinic anhydride** *[28643-94-9]* **M 272.3, $[\alpha]_D^{23}$ -10° (H_2O for anhydride formed at neutral pH).** Crystd from water by adding two volumes of EtOH. An isomeric anhydride is formed if the free acid is allowed to stand at acid pH. In soln, the mixture of anhydrides and free acid is formed.

Ascorbic acid *[50-81-7]* **M 176.1, m 193°(dec), $[\alpha]_{546}$ +23° (c 10, H_2O).** Crystd from MeOH/Et_2O/pet ether [Herbert et al. *JCS* 1270 *1933*].

S-**Asparagine** *[70-47-3]* **M 150.1, m 234-235°, (monohydrate)** *[5794-13-8]* **$[\alpha]_D$ +32.6° (0.1M HCl).** Likely impurities are aspartic acid and tyrosine. Crystd from H_2O or aqueous EtOH. Slowly effloresces in dry air.

Aspartic acid M 133.1, m 338-339° (*RS, [617-45-8]*); m 271° (*S*, requires heating in a sealed tube *[56-84-8]*), **$[\alpha]_D^{25}$ +25.4° (3M HCl).** Likely impurities are glutamic acid, cystine and asparagine. Crystd from water by adding 4 volumess of EtOH and dried at 110°.

L-Aspartic acid ß-methyl ester hydrochloride *[16856-13-6]* **M 183.6, m 194°.** Recrystd from MeOH by using anhydrous ethyl ether [Bach et al. *Biochemical Preparations* **13** 20 *1971*].

DL-Aspartic acid dimethyl ester hydrochloride *[14358-33-9]* **M 197.7.** Crystd from absolute MeOH. [Kovach et al. *JACS* **107** 7360 *1985*].

Aspergillic acid *[490-02-8]* **M 224.3, m 97-99°.** Sublimed at 80°/10^{-3}mm. Crystd from MeOH.

Astacin *[514-76-1]* **M 592.8, $\varepsilon_{1cm}^{1\%}$ $10^{5.5}$ at 498mm (pyridine).** Probable impurity is astaxanthin. Purified by chromatography on alumina/fibrous clay (1:4) or sucrose, or by partition between pet ether and MeOH (alkaline). Crystd from pyridine/water. Stored in the dark under N_2 at -20°.

Atrolactic acid ($0.5H_2O$) *[515-30-0]* **M 166.2, m 94.5° (anhydr), 88-91° ($0.5H_2O$).** Crystd from water and dried at 55°/0.5mm.

Atropine *[51-55-8]* **M 289.4, m 114-116°.** Crystd from acetone or hot water.

Auramine O *[2465-27-2]* **M 321.9.** Crystd from EtOH as hydrochloride, very slightly soluble in $CHCl_3$, UV: λ_{max} 434 (370) nm, pKa 10.71 (free base), 9.78 (carbinolamine). The free base has **m** 136° after crystn from benzene. [*JCS* 1724 *1949*; *BC* **9** 1540 *1970*].

Aureomycin and hydrochloride see entry in Chapter 5.

Aurin tricarboxylic acid *[4431-00-9]* **M 422.4, m 300°.** The acid is dissolved in aqueous NaOH, $NaHSO_3$ solution is added until the colour is discharged and then the tricarboxylic acid is ppted with HCl [*Org Synth* Col Vol I 54 *1947*]. Do not extract the acid with hot water because it softens forming a viscous mass. Make a solution by dissolving in aqueous NH_3. See **Aluminon** for the ammonium salt.

8-Azaadenine *[1123-54-2]* **M 136.1, m 345°(dec).** Crystd from H_2O.

2-Azacyclotridecanone *[947-04-6]* **M 197.3, m 152°.** Crystd from $CHCl_3$, stored over P_2O_5 in a vacuum desiccator.

8-Azaguanine *[134-58-7]* **M 152.1, m >300°.** Dissolved in hot M NH_4OH, filtered, and cooled; recrystd, and washed with water.

7-Azaindole *[271-63-6]* **M 118.1, m 105-106°.** Repeatedly recrystd from EtOH, then vacuum sublimed [Tokumura et al. *JACS* **109** 1346 *1987*].

1-Azaindolizine *[274-76-0]* **M 118.1, b 72-73°/1mm.** Purified by distn or gas chromatography.

Azaserine *[115-02-6]* **M 173.1, m 146-162°(dec), $[\alpha]_D^{27.5}$ -0.5° (c 8.5, H_2O, pH 5.2).** Crystd from 90% EtOH.

Azelaic acid *[123-99-9]* **M 188.2, m 105-106°.** Crystd from H_2O (charcoal) or thiophene-free benzene. The material cryst from H_2O was dried by azeotropic distn in toluene, the residual toluene soln was cooled and filtered, the ppte being dried in a vacuum oven. Also purified by zone refining or by sublimation onto a cold finger at 10^{-3} torr.

Azobenzene *[103-33-3]* **M 182.2, m 68°.** Ordinary azobenzene is nearly all in the *trans*-form. It is partly converted into the *cis*-form on exposure to light [for isolation see Hartley *JCS* 633 *1938*, and for spectra of *cis*- and *trans*-azobenzenes, see Winkel and Siebert *B* **74B** 670*1941*]. *trans*-Azobenzene is obtained by chromatography on alumina using 1:4 benzene/heptane or pet ether, and crystd from EtOH (after refluxing for several hours) or hexane. All operations should be carried out in diffuse red light or in the dark.

1,1'-Azobis(cyclohexane carbonitrile) *[2094-98-6]* **M 244.3, m 114-114.5°, ε_{350nm} 16.0.** Crystd from EtOH.

Azobis(isobutyramidinium) chloride M 179.7. Crystd from H_2O.

α,α'-Azobis(isobutyronitrile) *[78-61-1]* **M 164.2, m 103°(dec).** Crystd from acetone, Et_2O, $CHCl_3$, aq EtOH or MeOH. Has also been crystd from abs EtOH below 40° in subdued light. Dried under vacuum at room temp over P_2O_5 and stored under vacuum in the dark at <-10° until used. Also crystd from $CHCl_3$ soln by addn of pet ether (b <40°). [Askham et al. *JACS* **107** 7423 *1985*; Ennis et al. *JCSDT* 2485 *1986*; Inoue and Anson *JPC* **91** 1519 *1987*; Tanner *JOC* **52** 2142 *1987*].

Azolitmin B *[1395-18-2]*. Crystd from water,

Azomethane *[503-28-6]* **M 58.1, m -78°, b 1.5°.** Purified by vacuum distn and stored in the dark at -80°. Can be **EXPLOSIVE.**

***p,p'*-Azoxyanisole** *[1562-94-3]* **M 258.3, transition temps: 118.1-118.8°, 135.6-136.0°.** Crystd from absolute EtOH or acetone, and dried by heating under vacuum.

Azoxybenzene *[495-48-7]* **M 198.2, m 36°.** Crystd from EtOH or MeOH, and dried for 4h at 25° and 10^{-3}mm. Sublimed before use.

***p,p*-Azoxyphenetole** *[1562-94-3]* **M 258.3, m 137-138° (turbid liquid clarifies at 167°).** Crystd from toluene or EtOH.

Azulene *[275-51-4]* **M 128.2, m 98.5-99°.** Crystd from EtOH.

Azuleno(1,2-b)thiophene *[25043-00-9]* **M 184.2,**
Azuleno(2,1-b)thiophene *[248-13-5]* **M 184.2.** Crystd from cyclohexane, then sublimed *in vacuo*.

Azure A *[531-53-3]* **M 291.8, CI 52005, m > 290°(dec), λ_{max} 633nm,**
Azure B *[531-55-3]* **M 305.8, CI 52010, m > 201°(dec), λ_{max} 648nm,**
Azure C *[531-57-7]* **M 277.8, λ_{max} 616nm.** Twice recrystd from H_2O, and dried at 100°/1h in an oven.

B.A.L. see 1,2-dimercapto-3-propanol.

BAO [2,5-bis(4-aminophenyl)-1,3,4-oxadiazole] *[2425-95-8]* **M 252.3, m 252-255°, 254-255°.** Recrystd from EtOH using charcoal and under N_2 to avoid oxidation.

Barbituric acid *[67-52-7]* **M 128.1, m 250°(dec).** Crystd twice from H_2O, then dried for 2 days at 100°.

Bathophenanthroline (4,7-diphenyl-1,10-phenanthroline) *[1662-01-7]* **M 332.4, m 215-216°, 218-220°.** Best purified by recrystn from C_6H_6 or toluene. Its solubility (per L): H_2O (1mg), M HCl (20mg), heptane (110mg), Et_2O (530mg), Me_2CO (2.3g), dioxane (3.4g), MeOH (6.0g), EtOH (10.5g), isoPrOH (10.0g), *n*-pentanol (18.7g), C_6H_6 (12.2g), pyridine (33g), nitrobenzene (44.7g), $CHCl_3$ (78g) and AcOH (450.4g). [UV: *Bull Soc Chim France* 371 *1972*].

Bathophenanthroline disulphonic acid disodium salt (disodium 4,7-diphenyl-1,10-phenanthroline disulphonate) *[52746-49-3]* **M 590.55.** It forms a dark red complex with Fe^{2+} with λ_{max} 535nm (ε 2.23 x $10^4 mol^{-1} cm^{-1}$) [*ACA* **115** 407 *1980*]. Prepared by sulphonating bathophenanthroline with $ClSO_3H$: to 100g of bathophenanthroline was added 0.5ml of Fe free $ClSO_3H$ and heated over a flame for 30sec. Cool and carefully add 10ml of pure distd H_2O and warm on a water bath with stirring till all solid dissolved. A stock soln is made by diluting 3ml of this reagent to 100ml with 45% aq NaOAc, filter off the solid and store in a dark bottle. In this way it is stable for several months. [*Am J Clinical Pathology* **29** 590 *1958*].

Batyl alcohol *[544-62-7]* **M 344.6, m 70.5-71°.** Crystd from aq Me_2CO, EtOH or pet ether (b 40-60°).

Behenic acid see **docosanoic acid.**

Behenoyl chloride (docosanoyl chloride) *[21132-76-3]* **M 359.0, m 40°.** If the IR shows OH bands then it should be dissolved in oxalyl chloride in C_6H_6 soln and warmed at 35° for 24h in the absence of moisture, evaporated and distd in a vacuum of 10^{-5}mm. It is sol in C_6H_6 and Et_2O. It is moisture sensitive and is **LACHRYMATORY**. [*JCS* 1001 *1937*; *JBC* **59** 905 *1924*].

Behenyl alcohol see **1-docosanol.**

Benzalacetone *[122-57-6]* **M 146.2, m 42°.** Crystd from pet ether (b 40-60°), or distd (**b** 137-142° /16mm).

Benzalacetophenone (Chalcone) *[94-41-6]* **M 208.3, m 56-58°.** Crystd from EtOH warmed to 50° (about 5ml/g), iso-octane, or toluene/pet ether, or recrystd from MeOH, and then twice from hexane.

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Azure C *[531-57-7]* **M 277.8,** λ_{max} **616nm.** Twice recrystd from H_2O, and dried at 100°/1h in an oven.

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Benzalacetophenone (Chalcone) *[94-41-6]* **M 208.3, m 56-58°.** Crystd from EtOH warmed to 50° (about 5ml/g), iso-octane, or toluene/pet ether, or recrystd from MeOH, and then twice from hexane.

Benzaldehyde *[100-52-7]* **M 106.1, f -26°, b 62°/10mm, 179.0°/760mm, d 1.044, n 1.5455.** To diminish its rate of oxidation, benzaldehyde usually contains additives such as hydroquinone or catechol. It can be purified *via* its bisulphite addition compound but usually distn (under nitrogen at reduced pressure) is sufficient. Prior to distn it is washed with NaOH or 10% Na_2CO_3 (until no more CO_2 is evolved), then with satd Na_2SO_3 and H_2O, followed by drying with $CaSO_4$, $MgSO_4$ or $CaCl_2$.

Benzaldehyde-2-sulphonic acid sodium salt *[1008-72-6]* **M 208.2.** Forms prisms or plates by extracting with boiling EtOH, filtering, evaporate to dryness and recrystallise the Na salt from a small volume of H_2O. The *N-phenylhydrazone sodium salt* recrysts from H_2O, **m** 174.5°. [*A* **299** 363 *1898*].

***anti*-Benzaldoxime** *[932-90-1]* **M 121.1, m 130°.** Crystd from ethyl ether by adding pet ether (b 60-80°).

Benzamide *[55-21-0]* **M 121.1, m 129.5°.** Crystd from hot water (about 5ml/g), EtOH or 1,2-dichloroethane, and air dried. Crystd from dilute aqueous ammonia, water, acetone and then benzene (using a Soxhlet extractor). Dried in an oven at 110° for 8h and stored in a desiccator over 99% H_2SO_4. [Bates and Hobbs *JACS* **73** 2151 *1951*].

Benzamidine *[618-39-3]* **M 120.2, m 64-66°.** Liberated from chloride by treatment with 5M NaOH. Extracted into ethyl ether. Sublimed *in vacuo*.

Benzanilide *[93-98-1]* **M 197.2, m, 164°.** Crystd from pet ether (b 70-90°) using a Soxhlet extractor, and dried overnight at 120°. Also crystd from EtOH.

Benz[a]anthracene *[56-55-3]* **M 228.3, m 159-160°.** Crystd from MeOH, EtOH or benzene (charcoal), then chromatographed on alumina from sodium-dried benzene (twice), using vacuum distn to remove benzene. Final purification was by vacuum sublimation.

Benz[b]anthracene see **naphthacene**.

Benz[a]anthracene-7,12-dione *[2498-66-0]* **M 258.3, m 169.5-170.5°.** Crystd from MeOH (charcoal).

Benzanthrone *[82-05-3]* **M 230.3, m 170°.** Crystd from EtOH or xylene.

Benzene *[71-43-2]* **M 78.1, f 5.5°, b 80.1°, d 0.874, n 1.50110, n^{25} 1.49790.** For most purposes, benzene can be purified sufficiently by shaking with conc H_2SO_4 until free from thiophene, then with H_2O, dilute NaOH and water, followed by drying (with P_2O_5, sodium, $LiAlH_4$, CaH_2, 4X Linde molecular sieve, or $CaSO_4$, or by passage through a column of silica gel, for a preliminary drying, $CaCl_2$ is suitable), and distn. A further purification step to remove thiophene, acetic acid and propionic acid, is crystn by partial freezing. The usual contaminants in dry thiophene-free benzene are non-benzenoid hydrocarbons such as cyclohexane, methylcyclohexane, and heptanes, together with naphthenic hydrocarbons and traces of toluene. Carbonyl-containing impurities can be removed by percolation through a Celite column impregnated with 2,4-dinitrophenylhydrazine, phosphoric acid and H_2O. (Prepared by dissolving 0.5g DNPH in 6ml of 85% H_3PO_4 by grinding together, then adding and mixing 4ml of distd H_2O and 10g Celite.) [Schwartz and Parker *AC* **33** 1396 *1961*]. Benzene has been freed from thiophene by refluxing with 10% (w/v) of Raney nickel for 15min, after which the nickel was removed by filtration or centrifugation.
Mair et al. [*J Res Nat Bur Stand* **37** 229 *1946*] cooled a mixture of 200ml of benzene and 50ml of EtOH in a cylindrical brass container (5cm dia x 20cm) in an ice-salt cooling bath at *ca* -10° The slurry which was produced on vigorous stirring was transferred to a centrifuge cooled to near -10°. After 5min the benzene crystals were removed from the basket of the centrifuge, allowed to melt, washed three times with distd H_2O, and filtered through silica gel to remove any alcohol and H_2O before distn.
Dry benzene was obtained by doubly distilling high purity benzene from a soln containing the blue ketyl formed by the reaction of sodium-potassium alloy with a small amount of benzophenone.

Thiophene has been removed from benzene (absence of bluish-green coloration when 3ml of benzene is shaken with a soln of 10mg of isatin in 10ml of conc H_2SO_4) by refluxing the benzene (1Kg) for several hours with 40g HgO (freshly pptd) dissolved in 40ml glacial acetic acid and 300ml of water. The ppte was filtered off, the aq phase was removed and the benzene was washed twice with H_2O, dried and distd. Alternatively, benzene dried with $CaCl_2$ has been shaken vigorously for half an hour with anhydrous $AlCl_3$ (12g/L) at 25-35°, then decanted, washed with 10% NaOH, and water, dried and distd. The process was repeated, giving thiophene-free benzene. [Holmes and Beeman *Ind Eng Chem* **26** 172 *1934*].
After shaking successively for about an hour with conc H_2SO_4, distd water (twice), 6M NaOH, and distd water (twice), benzene was distd through a 3-ft glass column to remove most of the water. Abs EtOH was added and the benzene-alcohol azeotrope was distd. (This low-boiling distn leaves any non-azeotrope-forming impurities behind.) The middle fraction was shaken with distd water to remove EtOH, and again redistd. Final slow and very careful fractional distn from sodium, then $LiAlH_4$ under N_2, removed traces of water and peroxides. [Peebles, Clarke and Stockmayer *JACS* **82** 2780 *1960*]. *Benzene liquid and vapour are very* **TOXIC** *and* **HIGHLY FLAMMABLE**, *and all operations should be carried out in an efficient fumecupboard and in the absence of naked flames in the vicinity.*

[$^2H_6$]Benzene (***benzene-d*$_6$**) *[1076-43-3]* **M 84.2, b 80°/773.6mm, 70°/562mm, 60°/399mm, 40°/186.3mm, 20°/77.1mm, 10°/49.9mm, 0°/27.5mm, d 0.9488, d^{40} 0.9257, n 1.4991, n^{40} 1.4865.** Hexadeuteriobenzene of 99.5% purity is refluxed over and distd from CaH_2 onto Linde type 5A sieves under N_2.

Benzeneazodiphenylamine *[28110-26-1]* **M 273.3, m 82°.** Purified by chromatography on neutral alumina using anhydrous C_6H_6 with 1% anhydrous MeOH. The major component, which gave a stationary band, was cut out and eluted with EtOH or MeOH. [Högfeldt and Bigeleisen *JACS* **82** 15 *1960*]. Crystd from pet ether or EtOH.

1-Benzeneazo-2-naphthol *[842-07-9]* **M 248.3, m 134°.** Crystd from EtOH.

1-Benzeneazo-2-naphthylamine *[85-84-7]* **M 247.3, m 102-104°.** Crystd from acetic acid/water.

1,2-Benzenedimethanol (1,2-bishydroxymethylbenzene) *[612-14-6]* **M 138.2, m 61-64°, 63-64°, 64-65°, 65-66.5°, b 145°/3mm.** Recrystd from C_6H_6, H_2O, pet ether or pentane. It has been extracted in a Soxhlet with Et_2O, evaporated and recrystd from hot pet ether. Also dissolve in Et_2O, allow to evaporate till crystals are formed, filter off and wash the colourless crystals with warm pet ether or pentane. The *diacetate* has **m** 35°, 35-36°. [*JACS* **69** 1197 *1947*, IR and UV: *JACS* **74** 441 *1952*].

***m*-Benzenedisulphonic acid** *[98-48-6]* **M 238.2.** Freed from H_2SO_4 by conversion to the calcium or barium salts (using $Ca(OH)_2$ or $Ba(OH)_2$, and filtering). The calcium salt was then converted to the potassium salt, using K_2CO_3. Both the potassium and the barium salts were recrystd from H_2O, and the acid was regenerated by passing through the H^+ form of a strong cation exchange resin. The acid was recrystd twice from conductivity water and dried over $CaCl_2$ at 25°. [Atkinson, Yokoi and Hallada *JACS* **83** 1570 *1961*]. It has also been crystd from Et_2O and dried in a vacuum oven.

***m*-Benzenedisulphonyl chloride** *[585-47-7]* **M 275.1, m 63°.** Crystd from $CHCl_3$ and dried at 20mm pressure.

Benzene-1,2-dithiol *[17534-15-5]* **M 142.2, m 24-25°, 27-28°, b 110-112°.** Likely impurities are the oxidation products, the disulphides which could be polymeric. Dissolve in aq NaOH until the soln is alkaline. Extract with Et_2O and discard the extract. Acidify with cold HCl (diluted 1:1 by vol with H_2O) to Congo Red paper under N_2 and extract three times with Et_2O. Dry the Et_2O with Na_2SO_4, filter, evaporate and distil residue under reduced press in an atmosphere of N_2. The distillate solidifies on cooling. [UV: *JCS* 3076 *1958*; *JACS* **81** 4939 *1951*; *Org Synth* Col Vol V 419 *1973*].

Benzenephosphinic acid,
Benzeneseleninic acid see entries in Chapter 4.

Benzenesulphonic anhydride *[512-35-6]* **M 298.3, m 88-91°.** Crystd from Et_2O.

Benzenesulphonyl chloride *[98-09-9]* **M 176.6, m 14.5°, b 120°/10mm, 251.2°/760mm(dec), d 1.384.** Distd, then treated with 3mole % each of toluene and $AlCl_3$, and allowed to stand overnight. The free benzenesulphonyl chloride was distd off at 1mm pressure, and then carefully fractionally distd at 10mm in an all-glass column. [Jensen and Brown *JACS* **80** 4042 *1958*].

Benzene-1,2,4,5-tetracarboxylic acid *[89-05-4]* **M 254.2, m 281-284°.** Crystd from H_2O.

Benzenethiol (thiophenol) *[108-98-5]* **M 110.2, f.p. -14.9°, b 46.4°/10mm, 168.0°/760mm, d 1.073, n 1.58973.** Dried with $CaCl_2$ or $CaSO_4$, and distd at 10mm pressure or at 100mm (**b** 103.5°) in a stream of N_2.

Benzene-1,2,3-tricarboxylic acid (H_2O) *[36362-97-7]* **M 210.1, m 190°(dec),**
Benzene-1,3,5-tricarboxylic acid (trimesic acid) *[554-95-0]* **M 210.1, m 360°(dec).** Crystd from water.

1,2,4-Benzenetriol *[533-73-3]* **M 126.1, m 141°.** Crystd from Et_2O.

Benzethonium chloride *[121-54-0]* **M 448.1, m 164-166°.** Crystd from 1:9 MeOH/Et_2O mixture.

Benzhydrol *[91-01-0]* **M 184.2, m 69°, b 297°/748mm, 180°/20mm.** Crystd from hot H_2O or pet ether (b 60-70°), pet ether containing a little benzene, from CCl_4, or EtOH (1ml/g). An additional purification step is passage of a benzene soln through an activated alumina column. Sublimes in a vacuum. Also crystd three times from MeOH/H_2O [Naguib *JACS* **108** 128 *1986*].

Benzidine *[92-87-5]* **M 184.2, m 128-129°.** Its soln in benzene was decolorized by percolation through two 2-cm columns of activated alumina, then concentrated until benzidine crystd on cooling. Recrystd alternatively from EtOH and benzene to constant absorption spectrum [Carlin, Nelb and Odioso *JACS* **73** 1002 *1951*]. Has also been crystd from hot water (charcoal) and from ethyl ether. Dried under vac in an Abderhalden pistol. Stored in the dark in a stoppered container. **CARCINOGENIC.**

Benzidine dihydrochloride *[531-85-1]* **M 257.2.** Crystd by soln in hot H_2O, with addition of conc HCl to the slightly cooled soln. **CARCINOGENIC.**

Benzil *[134-81-6]* **M 210.2, m 96-96.5°.** Crystd from benzene after washing with alkali. (Crystn from EtOH did not free benzil from material reacting with alkali.) [Hine and Howarth *JACS* **80** 2274 *1958*]. Has also been crystd from CCl_4, diethyl ether or EtOH [Inoue et al. *JCSFT 1* **82** 523 *1986*].

Benzilic acid *[76-93-7]* **M 228.3, m 150°.** Crystd from benzene (*ca* 6ml/g), or hot H_2O.

Benzil monohydrazone *[5433-88-7]* **M 224.3, m 151°.** Crystd from EtOH.

α-Benzil monoxime *[14090-77-8], [E, 574-15-2], [Z, 574-16-3]* **M 105.1, m 140°.** Crystd from C_6H_6 (must not use animal charcoal).

Benzimidazole *[51-17-2]* **M 118.1, m 172-173°.** Crystd from water or aqueous EtOH (charcoal), and dried at 100° for 12h.

2-Benzimidazolylacetonitrile *[4414-88-4]* **M 157.2, m 200-205° dec 209.7-210.7°(corrected), 210°.** Recrystd from aqueous EtOH. It has been recrystd from hot H_2O using charcoal, and finally from aqueous EtOH. [*JACS* **65** 1072 *1943*].

Benzo[*b*]biphenylene *[259-56-3]* **M 202.2.** Purified by sublimation under reduced pressure.

Benzo-15-crown-5 *[14098-44-3]* **M 268.3.** Recrystd from *n*-heptane.

Benzo-18-crown-6 *[14098-24-9]* **M 312.2, m 42-45°, 43-43.5°.** Purified by passage through a DEAE cellulose column in cyclohexane. Recryst from *n*-hexane. Its complex with thiourea has **m** 127° [5-6 mol of urea to ether, *JOC* **36** 1690 *1971*]. The stability constants of Na^+, K^+, Rb^+, Cs^+, Tl^+ and Ba^{++} are in *Inorg Chim Acta* **28** 73 *1978*] [NMR: *JACS* **98** 3769 *1976*].

Benzo[3,4]cyclobuta[1,2-*b*]quinoxaline *[259-57-3]* **M 204.2.** Purified by sublimation under reduced pressure.

Benzofuran (coumarone) *[271-89-6]* **M 118.1, b 62-63°/15mm, 97.5-99.0°/80mm. 170-173°/atm, 173-175°(169)/760mm, d_4^{20} 1.0945, n_D^{20} 1.565.** Steam distil, dissolve in Et_2O, wash with 5% aqueous NaOH, saturated NaCl, dry (Na_2SO_4), evaporate and distil. UV: λ_{max} 245, 275, 282nm (log ε 4.08, 3.45, 3.48). The *picrate* has **m** 102-103°. [*Org Synth* Coll Vol V 251 *1973*; NMR: Black and Heffernan *Australian J Chem* **18** 353 *1965*].

2-Benzofurancarboxylic acid *[496-41-3]* **M 162.1, m 192-193°.** Crystd from water.

Benzofurazan *[273-09-6]* **M 20.1, m 55°.** Purified by crystn from EtOH and sublimed.

Benzoic acid *[65-85-0]* **M 122.1, m 122.6-123.1°.** For use as a volumetric standard, analytical reagent grade benzoic acid should be carefully fused to *ca* 130° (to dry it) in a platinum crucible, and then powdered in an agate mortar. Benzoic acid has been crystd from boiling water (charcoal), aq acetic acid, glacial acetic acid, C_6H_6, aq EtOH, pet ether (b 60-80°), and from EtOH soln by adding water. It is readily purified by fractional crystn from its melt and by sublimation in a vacuum at 80°. It has a pKa^{25} of 4.12 in water.

***o*-Benzoic acid sulphimide (saccharin, 1,1-dioxo-1λ⁶-benz[d]isothiazol-3-one)** *[81-07-2]* **M 183.2, m 227-229°, 229°, 228.8-229.7°.** Purified by recrystn from Me_2CO [solubility 7.14% at 0°, 14.4% at 50°], or aqueous isoPrOH to give fluorescent soln. It has pKa (H_2O) values of 2.1 and 12.8. [*J Am Pharm Soc* **41** 17 *1952*].

Benzoic anhydride *[93-97-0]* **M 226.2, m 42°.** Freed from benzoic acid by washing with $NaHCO_3$, then water, and drying. Crystd from benzene (0.5ml/g) by adding just enough pet ether (b 40-60°), to cause cloudiness, then cooling in ice. Can be distd at 210-220°/20mm.

(±)-Benzoin *[119-53-9]* **M 212.3, m 137°.** Crystd from CCl_4, hot EtOH (8ml/g), or 50% acetic acid. Crystd from high purity benzene, then twice from high purity MeOH, to remove fluorescent impurities [Elliott and Radley *AC* **33** 1623 *1961*].

(±)-α-Benzoinoxime *[441-38-3]* **M 227.3, m 151°.** Crystd from ethyl ether.

Benzonitrile *[100-47-0]* **M 103.1, f.p. -12.9°, b 191.1°, d 1.010, n 1.52823.** Dried with $CaSO_4$, $CaCl_2$, $MgSO_4$ or K_2CO_3, and distd from P_2O_5 in an all-glass apparatus, under reduced pressure (**b** 69°/10mm), collecting the middle fraction. Distn from CaH_2 causes some decomposition of solvent. Isonitriles can be removed by preliminary treatment with conc HCl until the smell of isonitrile has gone, followed by preliminary drying with K_2CO_3. (This treatment also removes amines).
Steam distd (to remove small quantities of carbylamine). The distillate was extracted into ether, washed with dil Na_2CO_3, dried overnight with $CaCl_2$, and the ether removed by evaporation. The residue was distd at 40mm (**b** 96°) [Kice, Perham and Simons *JACS* **82** 834 *1960*].
Conductivity grade benzonitrile (specific conductance 2 x 10^{-8} mho) was obtained by treatment with anhydrous $AlCl_3$, followed by rapid distn at 40-50° under vacuum. After washing with alkali and drying with $CaCl_2$, the distillate was vac distd several times at 35° before being fractionally crystd several times by partial freezing. It was dried over finely divided activated alumina from which it was withdrawn as required [Van Dyke and Harrison *JACS* **73** 402 *1951*].

Benzo[ghi]perylene (1,12-benzoperylene) *[191-24-2]* **M 276.3, m 273°, 277-278.5°, 278-280°.** Purified as light green crystals by recrystn from C_6H_6 or xylene and sublimes at 320-340° and 0.05mm [UV *HCA* **42** 2315 *1959*; *B* **65** 846 *1932*; Fluoresc. Spectrum: *JCS* 3875 *1954*]. *1,3,5-Trinitrobenzene complex* **m** 310-313° (deep red crystals from C_6H_6); *picrate* **m** 267-270° (dark red crystals from C_6H_6); *styphnate* **m** 234° (wine red crystals from C_6H_6). It recrystallises from propan-1-ol [*JCS* 466 *1959*].

3,4-Benzophenanthrene *[195-19-7]* **M 228.3, m 68°.** Crystd from EtOH, pet ether, or EtOH/Me_2CO.

Benzophenone *[119-61-9]* **M 182.2, m 48.5-49°.** Crystd from MeOH, EtOH, cyclohexane, benzene or pet ether, then dried in a current of warm air and stored over BaO or P_2O_5. Also purified by zone melting and by sublimation [Itoh *JPC* **89** 3949 *1985*; Naguib et al. *JACS* **108** 128 *1986*; Gorman and Rodgers *JACS* **108** 5074 *1986*; Ohamoto and Teranishi *JACS* **108** 6378 *1986*; Naguib et al. *JPC* **91** 3033 *1987*].

Benzophenone oxime *[574-66-3]* **M 197.2, m 142°.** Crystd from MeOH (4ml/g).

Benzopinacol *[464-72-2]* **M 366.5, m 170-180° (depends on heating rate).** Crystd from EtOH.

Benzopurpurin 4B *[992-59-6]* **M 724.7.** Crystd from H_2O.

Benzo[a]pyrene *[50-32-8]* **M 252.3, m 179.0-179.5°.** Chromatographed on activated alumina, eluted with a cyclohexane-benzene mixture containing up to 8% benzene, and the solvent evapd under reduced pressure [Cahnmann *AC* **27** 1235 *1955*]. It can be recrystd from EtOH [Nithipatikom and McGown *AC* **58** 3145 *1986*].

Benzo[e]pyrene (1,2-benzpyrene) *[192-97-2]* **M 252.3, m 178-179°, 178-180°.** Purified by passage through an Al_2O_3 column (Woelm, basic, activity I) and eluted with C_6H_6 and recrystd from 2 volumes of EtOH-C_6H_6 (4:1). Forms colourless or light yellow prisms or needles. [*JCS* 3659 *1954*; *A* **705** 190 *1967*]. *1,3,5-Trinitrobenzene complex* **m** 253-254° (orange needles from EtOH); the *picrate* prepared by mixing 20mg in 1ml of C_6H_6 with 20mg of picric acid in 2ml C_6H_6, collecting the deep red crystals, and recrystallising from C_6H_6 **m** 228-229° [Synth *JCS* 398 *1967*; NMR: *JCP* **47** 2020 *1967*].

2,3-Benzoquinoline (acridine) *[260-94-6]* **M 179.2, m 111° (sublimes),**
3,4-Benzoquinoline (phenanthridines) *[229-87-8]* **M 179.2, m 102.5-103.5°,**
5,6-Benzoquinoline *[85-02-9]* **M 179.0, m 85.5-86°,**
7,8-Benzoquinoline *[230-27-3]* **M 179.0, m 52.0-52.5°.** Chromatographed on activated alumina from benzene soln, with ethyl ether as eluent. Evapn of ether gave crystalline material which was freed from residual solvent under vacuum, then further purified by fractional crystn under N_2, from its melt [Slough and Ubbelhode *JCS* 911 *1957*].

***p*-Benzoquinone** *[106-51-4]* **M 108.1, m 115.7°.** Usually purified in one or more of the following ways: steam distn, followed by filtration and drying (e.g. in a desiccator over $CaCl_2$); crystn from pet ether (b 80-100°), benzene (with, then without, charcoal), water or 95% EtOH; sublimation under vacuum (e.g. from room temperature to liquid N_2). It slowly decomposes, and should be stored, refrigerated, in an evacuated or sealed glass vessel in the dark. It should be resublimed before use. [Wolfenden et al. *JACS* **109** 463 *1987*].

1-Benzosuberone (6,7,8,9-tetrahydrobenzocyclohepten-5-one) *[826-73-3]* **M 160.2, b 80-85°/0.5mm, 90-93°/1mm, 138-139°/12mm, 154°/15mm, 175-175°/40mm, d_4^{20} 1.086, n_D^{20} 1.5638.** Purified by dissolving in toluene, washing with aqueous 5% NaOH, then brine, dried ($MgSO_4$), and distd. *2,4-Dinitrophenylhydrazone* has **m** 210.5°, 207-208° (from $CHCl_3$ + MeOH). *Z-O-Picryloxime* has **m** 156-157° (from Me_2CO+MeOH); the *E-O-picryloxime* has **m** 107°. The *oxime* has **m** 106.5-107.5°. [UV *JACS* **73** 1411 *1951*, **75** 3744 *1953*; *B* **90** 1844 *1957*].

1,2,3-Benzothiadiazole *[273-77-8]* **M 136.2, m 35°,**
2,1,3-Benzothiadiazole *[272-13-2]* **M 136.2, m 44°, b 206°/760mm.** Crystd from pet ether.

1-Benzothiophene (benzo[b]thiophene, thianaphthene) *[95-15-8]* **M 134.2, m 29-32°, 30°, 31-32°, 32°, b 100°/16mm, 103-105°/20mm, 221-222°/760mm, $d_4^{32.2}$ 1.1484, n_D^{39} 1.6306.** It has the odour of naphthalene. If the IR spectrum is not very good then suspend in a faintly alkaline aqueous soln and steam distil. Extract the distillate with Et_2O, dry the extract with $CaCl_2$, filter, evaporate the solvent and fractionate the residue. Distillate sets solid . The *sulphoxide* has **m** 142°, the *picrate* has **m** 148-149° (yellow crystals from EtOH) and the *styphnate* has **m** 136-137°. [*JOC* **10**, 381 *1945*; *B* 52B 1249 *1919*, **53** 1551 *1920*; *The Chemistry of Heterocyclic Compounds* Hartough and Weisel eds, Interscience Publ, NY, p23, 28, *1954*].

1,2,3-Benzotriazole *[95-14-7]* **M 119.1, m 96-97°, 98.5°, 100°, b 159°/0.2mm, 204°/15mm.** Crystd from toluene, $CHCl_3$, Me_2NCHO or satd aq soln, and dried at room temperature or in a vacuum oven at 65°. Losses are less if material is distd in a vacuum. **CAUTION: may EXPLODE during vac distn, necessary precautions must be taken.** [*Org Synth* Coll Vol III 106 *1955*].

Benzotrifluoride see **α,α,α-trifluorotoluene.**

Benzoylacetone *[93-91-4]* **M 162.2, m 58.5-59.0°.** Crystd from Et_2O or MeOH and dried under vacuum at 40°.

Benzoylauramine G m 178-179°. Crystd from chlorobenzene.

2-Benzoylbenzoic acid *[85-52-9]* **M 226.2, m 126-129°, 129.2, 130°, 130°.** Recrystd from C_6H_6 or cyclohexane, but is best recrystallised by dissolving in a small volume of hot toluene and then adding just enough pet ether to cause pptn and cool. Dry in a low vacuum at 80°. It can be sublimed at 230-240°/0.3mm. It has a pKa^{25} (H_2O) of 3.54 [*JCS* 265 *1957*]. The *S-benzylthiouronium salt* has **m** 177-178° (from EtOH). [*JACS* **75** 4087 *1953*; *B* **90** 1208 *1957*].

4-Benzoylbenzoic acid *[611-95-0]* **M 226.2, m 196.5-198°, 197-200°.** Dissolve in hot H_2O by adding enough aqueous KOH soln till distinctly alkaline, filter and then acidify with drops of conc HCl. Filter off, wash solid with cold H_2O, dry at 100°, and recrystallise from EtOH. [*JACS* **55** 2540 *1933*].

(*S* +) and (*R* -) 1-Benzoyl-2-*tert*-butyl-3-methyl-4-imidazolinone *[101055-56-5]* **M 260.3, m 142-143°, 145.6-146.6°, 145-147°, $[\alpha]_{546}^{20}$ + or - 155°, $[\alpha]_D^{20}$ + or - 133° (c 1, $CHCl_3$).** Recrystd from boiling EtOH (sol 1.43g/ml) or better by dissolving in CH_2Cl_2 and adding pentane, filter and dry for at least 12h at 60°/0.1mm and sublimed at 135°/0.01mm. It has also been purified by flash column chromatography with Merck silica gel at 0.04-0.063mm and using Et_2O/pet ether/MeOH (60:35:5) as eluent. It is then recrystd from EtOH/pet ether. [IR, NMR: *HCA* **70** 237 *1987*; *Angew Chem, Engl Edn* **25** 345 *1986*]. The *racemate* is purified in a similar manner and has **m** 104-105° [NMR: *HCA* **68** 949 *1985*].

Benzoyl chloride *[98-88-4]* **M 140.6, b 56°/4mm, 196.8°/745mm, d 1.2120, n^{10} 1.5537.** A soln of benzoyl chloride (300ml) in C_6H_6 (200ml) was washed with two 100ml portions of cold 5% $NaHCO_3$ soln, separated, dried with $CaCl_2$ and distd [Oakwood and Weisgerber *Org Synth* **III** 113 *1955*]. Repeated fractional distn at 4mm through a glass helices-packed column (avoiding porous porcelain or silicon-carbide boiling chips, and hydrocarbon or silicon greases on the ground joints) gave benzoyl chloride that did not darken on addition of $AlCl_3$. Further purification was achieved by adding 3 mole% each of $AlCl_3$ and toluene, standing overnight, and distilling off the benzoyl chloride at 1-2mm [Brown and Jenzen *JACS* **80** 2291 *1958*]. Refluxing for 2h with an equal weight of thionyl chloride before distn, has also been used. *Strong* **irritant**. *Use in a fume cupboard.*

Benzoylformic acid (phenylglyoxylic acid) *[611-73-4]* **M 150.14, m 62-65°, 64.5-65.5°, 67°, b 84°/0.1mm, 163-167°/15mm.** If the sample is oily then it may contain H_2O. In this case dry in a vacuum desiccator over P_2O_5 or KOH until crisp. For further purification dissolve 5.5g in hot CCl_4 (750ml), add charcoal (2g, this is necessary otherwise the acid may separate as an oil), filter, cool in ice-water until crystallisation is complete. Filter the acid, and the solvent on the crystals is removed by keeping the acid (4.5g) in a vacuum desiccator for 2 days. Slightly yellow crystals are obtained. It can be recrystd also from C_6H_6/pet

ether, and can be distilled in vacuum. The acid is estimated by titration with standard NaOH. It has pKa^{25} values of 1.39, 1.79. The *phenylhydrazone* is recrystallised form EtOH, **m** 163-164°; the *semicarbazone acid* has **m** 259°(dec) (from EtOH). The *methyl ester* distils at 137°/14mm, 110-111°/2mm, n_D^{20} 1.5850. [*JACS* **67** 1482 *1945*; *JOC* **24** 1825 *1959*].

Benzoyl glycine *[495-69-2]* **M 179.2, m 188°.** Crystd from boiling H_2O.

Benzoyl isothiocyanate *[532-55-8]* **M 163.2, m 25.5-26°, b 72.5-73°/6mm, 88-91°/20mm, 94-96°/21mm, 202.5-204°/724mm, 250-255°/atm, d_4^{20} 1.213, n_D^{20} 1.637.** Distil over a small amount of P_2O_5, whereby the distillate crystallises in prisms. It is readily hydrolysed by H_2O to give benzamide and benzoylurea, but with NH_3 it gives *benzoylurea* **m** 210° which can be recrystd from EtOH. [*JACS* **62** 1595 *1940*, **76** 580 *1954*; *Org Synth* Coll Vol III 735 *1955*].

Benzoyl peroxide *[94-36-0]* **M 242.2, m 95°(dec).** Dissolved in $CHCl_3$ at room temperature and ppted by adding an equal volume of MeOH or pet ether. Similarly ppted from acetone by adding two volumes of distilled water. Has also been crystd from 50% MeOH, and from ethyl ether. Dried under vacuum at room temperature for 24h. Stored in a desiccator in the dark at 0°. When purifying in the absence of water it can be **EXPLOSIVE** and it should be done on a very small scale with adequate protection. Large amounts should be kept moist with water and stored in a refrigerator. [Kim et al. *JOC* **52** 3691 *1987*].

p-**Benzoylphenol** *[1137-42-4]* **M 198.2, m 133.4-134.8°.** Dissolved in hot EtOH (charcoal), crystd once from EtOH/H_2O and twice from benzene [Grunwald *JACS* **73** 4934 *1951*].

N-**Benzoyl-*N*-phenylhydroxylamine** *[304-88-1]* **M 213.2, m 121-122°.** Recrystd from hot water, benzene or acetic acid.

2-Benzoylpyridine *[91-02-1]* **M 183.2, m 41-43°, 48-50°, 72°/0.02mm, 104-105°/0.01, n_D^{24} 1.6032.** Dissolve in Et_2O, shake with aqueous $NaHCO_3$, H_2O, dry over $MgSO_4$, it solidifies on cooling. The solid can be recrystd from pet ether. Its *hydrochloride* crystallises from Me_2CO, **m** 126-127°, and the *2,4-dinitrophenylhydrazone* has **m** 193-195°. [*J Organometal Chem* **24** 623 *1970*].

Benzoyl sulphide *[644-32-6]* **M 174.4, m 131.2-132.3°.** About 300ml of solvent was blown off from a filtered soln of benzoyl disulphide (25g) in acetone (350ml). The remaining acetone was decanted from the solid which was recrystd first from 300ml of 1:1 (v/v) EtOH/ethyl acetate, then from 300ml of EtOH, and finally from 240ml of 1:1 (v/v) EtOH/ethyl acetate. Yield about 40% [Pryor and Pickering *JACS* **84** 2705 *1962*]. *Handle in a fume cupboard because of* **TOXICITY** *and obnoxious odour.*

2,1-Benzoxathiol-3-one-1,1-dioxide (sulphobenzoic acid anhydride) *[81-08-3]* **M 184.2, m 116-124°, 126-127°, b 184-186°/18mm.** Purified by distn in a vacuum and readily solidifies to a crystalline mass on cooling. [*JACS* **34** 1594 *1912*]. Alternatively purified by dissolving in the minimum vol of toluene and reflux for 2h using a Dean-Stark trap. Evaporate under reduced pressure and distil the anhydride at 18mm. It can then be recrystd three times from its own weight of dry C_6H_6. It is sensitive to moisture and should be stored in the dark in a dry atmosphere. The *O-methyloxime* has **m** 110-112° [*TET LETT* 3289 *1972*]. [*Org Synth* Coll Vol I 495 *1941*].

Benzoxazolinone *[59-49-4]* **M 135.1, m 137-139°, 142-143°(corrected), b 121-213°/17mm, 335-337°/760mm.** It can be purified by recrystn from aqueous Me_2CO then by distn at atm pressure then in a vacuum. The *methyl mercury salt* recrystallises from aq EtOH, **m** 156-158°. [*JACS* **67** 905 *1945*].

N-**Benzoyl-*o*-tolylhydroxylamine** *[1143-94-4]* **M 227.3, m 104°.** Recrystd from aqueous EtOH.

3,4-Benzpyrene *[50-32-8]* **M 252.3, m 177.5-178°.** A soln of 250mg in 100ml of benzene was diluted with an equal volume of hexane, then passed through a column of alumina, $Ca(OH)_2$ and Celite (3:1:1). The adsorbed material was developed with a 2:3 benzene/hexane mixture. (It showed as an intensely fluorescent zone.) The main zone was eluted with 3:1 acetone/EtOH, and was transferred into 1:1 benzene-hexane by

addding H_2O. The soln was washed, dried with Na_2SO_4, evaporated and crystd from benzene by the addition of MeOH [Lijinsky and Zechmeister *JACS* **75** 5495 *1953*]. **CARCINOGENIC.**

Benzyl-2-acetamido-4,6-*O*-benzylidene-2-deoxy-α-D-glucopyranoside *[13343-63-0]* **M 399.4, m 256-261°, 263-264°, $[\alpha]_D^{26}$ +120° (c 1, pyridine).** Wash with cold isoPrOH and crystallise from dioxane/isoPrOH. [*JOC* **32** 2759 *1967*].

Benzyl acetate *[140-11-4]* **M 150.2, m -51°, b 92-93°/10mm, 134°/102mm, 214.9°/760mm, d_4^{20} 1.0562, n_D^{25} 1.4994.** Purified by fractional distn, preferably in a good vacuum. Values of n^{25} of 1.5232-1.5242 seem too high and should be 1.4994. [*JOC* **26** 5180 *1961*].

Benzyl acetoacetate *[5396-89-4]* **M 192.2, b 130°/2mm, 156-157°/10mm, 162-167°/15mm, 275-277°/atm, d_4^{20} 1.114, n_D^{20} 1.514.** Fractionate and collect fractions of expected physical properties. Otherwise add *ca* 10% by weight of benzyl alcohol and heat in an oil bath (160-170°, open vessel) for 30min during which time excess of benzyl alcohol will have distd off, then fractionate. [*JOC* **17** 77 *1952*].

4'-Benzylacetophenone *[782-92-3]* **M 210.3, m 73°.** Crystd from EtOH (*ca* 1ml/g).

Benzyl alcohol *[100-51-6]* **M 107.2, f.p. -15.3°, b 205.5°, 93°/10mm, d 0.981, n 1.54033.** Usually purified by careful fractional distn at reduced pressure in the absence of air. Benzaldehyde, if present, can be detected by UV absorption at 283nm. Also purified by shaking with aq KOH and extracting with peroxide-free ethyl ether. After washing with water, the extract was treated with satd NaHS sol, filtered, washed and dried with CaO and distd under reduced pressure [Mathews *JACS* **48** 562 *1926*]. Peroxy compounds can be removed by shaking with a soln of Fe(II) followed by washing the alcohol layer with distd water and fractionally distd.

Benzylamine *[100-46-9]* **M 107.2, b 178°/742mm, 185°/768mm, d 0.981, n 1.5392.** Dried with NaOH or KOH, then distd from Na, under N_2, through a column packed with glass helices, taking the middle fraction. Has also been distd from zinc dust under reduced pressure.

Benzylamine hydrochloride *[3287-99-8]* **M 143.6, m 248° (rapid heating).** Crystd from water.

***N*-Benzylaniline** *[103-32-2]* **M 183.4, m 36°, b 306-307°, d 1.061.** Crystd from pet ether (b 60-80°) (*ca* 0.5ml/g).

1-Benzyl-1-aza-12-crown-4 *[84227-47-4]* **M 265.4, 122-125°/0.03mm, 140-143°/0.05mm, d_4^{20} 1.09, n_D^{20} 1.52.** Dissolve in CH_2Cl_2 or CCl_4 (1g in 30ml) wash with H_2O (30ml), brine (30ml), H_2O (30 ml) again, dry over $MgSO_4$ or Na_2SO_4 and evaporate. The residue in CH_2Cl_2 is chromatographed through Al_2O_3 (eluting with 10% EtOAc in hexane), evaporate, collect the correct fractions and distil (kugelrohr). Log K_s in dry MeOH at 25° for Na^+ complex is 2.08. [*TET LETT* **26** 151 *1985*; *JOC* **53** 5652 *1988*].

Benzyl bromide *[100-39-0]* **M 171.0, m -4°, b 85°/12mm, 192°/760mm, d 1.438, n 1.575.** Washed with conc H_2SO_4, water, 10% Na_2CO_3 or $NaHCO_3$ soln, and again with water. Dried with $CaCl_2$, Na_2CO_3 or $MgSO_4$ and fractionally distd in the dark, under reduced pressure. It has also been thoroughly degassed at 10^{-6} mm and redistd in the dark. This gave material with λ_{max} (MeCN): 226nm (ε 8200) [Mohammed and Kosower *JACS* **93** 2709 *1971*]. *Handle in a fume cupboard, extremely* **LACHRYMATORY.**

Benzyl bromoacetate *[5437-45-6]* **M 229.1, b 96-98°/0.1mm, 146°/12mm, 166-170°/22mm, d_4^{20} 1.444, n_D^{25} 1.5412.** Dilute with Et_2O, wash with 10% aqueous $NaHCO_3$, H_2O, dry ($MgSO_4$) and fractionate using a Fenske column. [*JCS* 1521 *1956*]. **LACHRYMATORY**

***N*-Benzyl-*tert*-butylamine** *[3378-72-1]* **M 163.3, b 91°/12mm, 109-110°/25mm, 218-220°/atm, d_4^{20} 0.899, n_D^{25} 1.4942.** Dissolve in Et_2O, dry over KOH pellets, filter and fractionate in a N_2 atmosphere to avoid reaction with CO_2 from the air. The *hydrochloride* has **m** 245-246°(dec) (from MeOH + Me_2CO) and the *perchlorate* has **m** 200-201°. [*JACS* **80** 4320 *1958*].

Benzyl carbamate *[621-84-1]* **M 151.2, m 86°, 86-88°, 86-87°, 90-91°.** If it smells of NH_3 then dry in a vac desiccator and recryst from 2 vols of toluene and dry in a vac desiccator again. It forms glistening plates from toluene, and can be recrystd from H_2O. [*JOC* **6** 878 *1941*; *Org Synth* Coll Vol III 168 *1955*].

Benzyl chloride *[100-44-7]* **M 126.6, m 139°, b 63°/8mm, d 1.100, n 1.538.** Dried with $MgSO_4$ or $CaSO_4$, or refluxed with fresh Ca turnings, then fractionally distd under reduced pressure, collecting the middle fraction and storing with CaH_2 or P_2O_5. Has also been purified by passage through a column of alumina. Alternatively it is dried over $MgSO_4$ and distd in a vacuum. The middle fraction is degassed by several freeze-thaw cycles and then fractionated in an 'isolated fractionating column' (which has been evacuated and sealed off at ~10^{-6} mm) over a steam bath. The middle fraction is retained. The final samples were vacuum distd from this sample and again retaining the middle fraction. The purity is >99.9% (no other peaks are visible on GLC and the NMR spectrum is consistent with the structure. [Mohammed and Kosower *JACS* **93** 1709 *1971*]. **irritant** and *strongly* **LACHRYMATORY.**

Benzyl chloroformate see **benzyloxycarbonyl chloride.**

***N*-Benzyl-ß-chloropropionamide** *[24752-66-7]* **M 197.7, m 94°.** Crystd from MeOH.

***N*-Benzylcinchonidium chloride,**
***N*-Benzylcinchoninium chloride** see entries in Chapter 5.

Benzyl cinnamate *[103-41-3]* **M 238.3, m 34-35°, 39°, b 154-157°/0.5mm, 228-230°/22mm.** Recrystd to constant melting point from 95% EtOH and has the odour of balsam. Alternatively dissolve in Et_2O, wash with 10% aqueous Na_2CO_3, H_2O, dry (Na_2SO_4), evaporate and fractionate under reduced press using a short Vigreux column. It decomposes when boiled at atm press. [*JACS* **74** 547 *1952*; **84** 2550 *1962*].

Benzyl cyanide *[140-29-4]* **M 117.1, b 100°/8mm, 233.5°/760mm, d 1.015, n 1.52327.** Benzyl isocyanide can be removed by shaking vigorously with an equal volume of 50% H_2SO_4 at 60°, washing with satd aq $NaHCO_3$, then half-saturated NaCl soln, drying and fractionally distilling under reduced pressure. Distn from CaH_2 causes some decomposition of this compound: it is better to use P_2O_5. Other purification procedures include passage through a column of highly activated alumina, and distn from Raney nickel. *Precautions should be taken because of possible formation of free* **TOXIC** *cyanide; use a fume cupboard.*

***N*-Benzyl dimethylamine** *[103-83-3]* **M 135.2, b 66-67°/15mm, 83-84°/30mm, 98-99°/24mm, d_4^{20} 0.898, n_D^{20} 1.5157.** Dry over KOH pellets and fractionate in a CO_2—free atmosphere. It has a pKa^{25} of 8.25 in 45% aq EtOH. The *picrate* has **m** 94-95°, and the *picrolonate* has **m** 151° (from EtOH). [*B* **63** 34 *1930*; *JACS* **55** 3001 *1933*; *JCS* 2845 *1957*]. The *tetraphenyl borate salt* has **m** 182-185°. [*AC* **28** 1794 *1956*].

Benzyldimethyloctadecylammonium chloride *[122-19-0]* **M 442.2, m 63°.** Crystd from acetone.

2-Benzyl-1,3-dioxalane *[101-49-5]* **M 164.2, b 98-99°/1mm, 110°/5mm, 137-138°/34mm, 240-242°/atm, d_4^{20} 1.087, n_D^{20} 1.532.** Dissolve in CH_2Cl_2, wash well with 1M NaOH, dry over K_2CO_3, filter, evaporate and distil through a short path still (kugelrohr). It has also been purified by preparative gas chromatography. [*S* 808 *1974*; *JOC* **34** 3949 *1969*].

Benzyl disulphide see **dibenzyl disulphide.**

Benzyl ether *[103-50-4]* **M 198.3, b 298°, 158-160°/0.1mm, d 1.043, n 1.54057.** Refluxed over sodium, then distd under reduced pressure. Also purified by fractional freezing.

***N*-Benzyl-*N*-ethylaniline** *[92-59-1]* **M 221.3, b 212-222°/54mm, 285-286°/710mm, 312-313°/atm (dec), d_4^{20} 1.029, n_D^{20} 1.5950.** Dry over KOH pellets and fractionate. The *picrate* crystallises from C_6H_6 as yellow lemon crystals **m** 126-128° (softening at 120°). [*JCS* 303 *1951*; IR: *JCS* 760 *1958*].

Benzyl ethyl ether *[539-30-0]* **M 136.2, b 186°, 65°/10mm, d 0.949, n 14955.** Dried with $CaCl_2$ or NaOH, then fractionally distd. [*JACS* **78** 6079 *1956*].

Benzyl ethyl ketone (1-phenylbutan-2-one) *[1007-32-5]* **M 1468.2, b 49-49.5°/0.01mm, 66-69°/1mm, 83-85°/5mm, 101-102°/10mm, 229-233°/atm, d_4^{20} 0.989, n_D^{25} 1.5015.** Purified by fractionation using an efficient column. It can be converted into the *oxime* and distd, **b** 117-118°/2mm, 145-146°/15mm, d_{25}^{25} 1.036, n_D^{25} 1.5363, decompose oxime and the ketone is redistilled. It can also be purified *via* the *semicarbazone* which has **m** 154 155°. [*JACS* **77** 5655 *1955*; *JOC* **15** 8 *1950*].

(+)- Benzyl-(*S*)-glycidyl ether (1-benzyloxy-oxirane) *[S:14618-80-5]* **M 164.2, b 68°/10^{-4} mm, 105°/0.4mm, d_4^{20} 1.072, n_D^{20} 1.517, $[\alpha]_{546}^{20}$ +5.5°, $[\alpha]_D^{20}$ +5.1° (c 5, toluene), $[\alpha]_D^{20}$+1.79° (c 5.02, $CHCl_3$), $[\alpha]_D^{21}$ -15.3° (neat),**
(-)- Benzyl-(*R*)-glycidyl ether (1-benzyloxy-oxirane) *[R:16495-13-9]* **M 164.2, b 68°/10^{-4} mm, 105°/0.4mm, d_4^{20} 1.072, n_D^{20} 1.517, $[\alpha]_{546}^{20}$ -5.5°, $[\alpha]_D^{20}$ -5.1° (c 5, toluene), $[\alpha]_D^{20}$-1.79° (c 5.02, $CHCl_3$), $[\alpha]_D^{21}$ +15.3° (neat).** The ether in EtOAc is dried (Na_2SO_4) then purified by flash chromatography using pet ether/EtOAc (5:1) as eluent. The ether is then distd through a short path dist apparatus (Kugelrohr) as a colourless liquid. Alternatively, dissolve in $CHCl_3$, wash with H_2O, dry (Na_2SO_4), evaporate and purify through silica gel chromatography. [*JCS* 1021 *1967*; *Heterocycles* **16** 381 *1981* ; *Org Synth* **69** 82 *1990*; *S* 539 *1989*; *Chem Pharm Bull Japan* **39** 1385 *1991*].

3-Benzyl-5-(2-hydroxyethyl)-4-methylthiazolinium chloride *[4568-71-2]* **M 269.8, m 142-144°, 145-147°.** Purified by recrystn from EtOH or H_2O. If placed in a bath at 125° and heated at 2°/min the **m** is 140.5-141.4°. [*JBC* **167** 699 *1947*, JACS **79** 4386 *1957*].

***O*-Benzylhydroxylamine hydrochloride** *[2687-43-6]* **M 159.6, m 234-238°(sublimes).** Recrystd from H_2O or EtOH.

Benzylideneacetophenone see **benzalacetophenone.**

***N*-Benzylideneaniline** *[538-51-2]* **M 181.2, m 48° (54°), b 300°/760mm.** Steam volatile and crystd from benzene or 85% EtOH.

Benzyl isocyanate *[3173-56-6]* **M 133.2, b 82-84°/10mm, 87°/14mm, 95°/17mm, 101-104°/33mm, d_4^{20} 1.08, n_D^{20} 1.524.** Purified by fractionation through a two-plate column. It is a viscous liquid and is **TOXIC**. [*JCS* 182 *1947*; *JACS* **81** 4838 *1959*; IR: *M* **88** 35 *1957*].

Benzyl isothiocyanate *[622-78-6]* **M 149.2, b 123-124°/1mm, 138-140°/20mm, 255-260°/atm, d_4^{20} 1.1234, n_D^{20} 1.6039.** Dissolve in Et_2O, filter, if there is any solid, and distil through an efficient column at 11mm with bath temperature at *ca* 150°. Characterise by reacting (0.5ml) in EtOH (1ml) with 50% $NH_2NH_2.H_2O$ (2 ml) to give *4-benzylthiosemicarbazide* as colourless needles which are recrystallised from EtOH, **m** 130°. [*JCS* 1582 *1950*; *A* **612** 11 *1958*; IR and UV: *Acta Chem Scand* **13** 442 *1959*].

***S*-Benzyl-isothiouronium chloride** *[538-28-3]* **M 202.7, two forms, m 150° and 175°.** Crystd from 0.2M HCl (2ml/g) or EtOH and dried in air.

Benzylmalonic acid *[616-75-1]* **M 194.2, m 121°.** Crystd from C_6H_6.

Benzylidene malononitrile *[2700-22-3]* **M 154.2, m 83-84°.** Recrystd from EtOH [Bernasconi et al. *JACS* **107** 3612 *1985*].

Benzyl mercaptan *[100-53-8]* **M 124.2, b 70.5-70.7°/9.5mm, d 1.058, n 1.5761.** Purified *via* the mercury salt [see Kern *JACS* **75** 1865 *1953*], which was crystd from benzene as needles (**m** 121°), and then dissolved in $CHCl_3$. Passage of H_2S gas regenerated the mercaptan. The HgS ppte was filtered off, and washed thoroughly with $CHCl_3$. The filtrate and washings were evaporated to remove $CHCl_3$, then residue was fractionally distd under reduced pressure [Mackle and McClean, *TFS* **58** 895 *1962*].

(-)-*N*-Benzyl-*N*-methylephedrinium bromide *[58648-09-2]* **M 350.3, m 209-211°, 212-214°,** $[\alpha]_D^{25}$ **-3.8° (c 1.45, MeOH),** $[\alpha]_D^{20}$ **-5.3° (c 1.45, MeOH).** Recrystd from MeOH/Et_2O. [*A* 710 *1978*]. The *chloride* is recrystd from EtOAc/*n*-hexane, **m** 198-199° $[\alpha]_D^{25}$ -8.67° (c 1.45, MeOH). [*JCS Perkin Trans I* 574 *1981*].

Benzyl methyl ketone see **phenylacetone.**

Benzyl Orange *[589-02-6]* **M 405.5.** Crystd from H_2O.

Benzyloxyacetyl chloride *[19810-31-2]* **M 184.6, b 81°/0.2mm, 84-87°/0.4mm, 105-107°/5mm,** d_4^{20} **1.19,** n_D^{20} **1.523.** Check IR to see if there are OH bands. If so then it may be contaminated with free acid formed by hydrolysis. Add oxalyl chloride (amount depends on contamination and needs to be judged, *ca* 3mols) heat at 50° in the absence of moisture for 1h and fractionate twice, **b** 81°/0.2mm (with bath temp at 81°). Excessive heating results in decomposition to give benzyl chloride. The *anilide* is formed by adding aniline in $CHCl_3$ soln, **m** 49°. [*HCA* **16** 1130 *1933*].

Benzyloxybutan-2-one *[6278-91-7]* **M 178.2, b 90-92°/0.1mm, 88-91°/0.5mm, 121-126°/5mm,** d_4^{20} **1.0275,** n_D^{20} **1.5040.** Dissolve in $CHCl_3$, wash with H_2O, aqueous saturated $NaHCO_3$, H_2O, dry ($MgSO_4$), evaporate the $CHCl_3$, and fractionate. [*JACS* **79** 2316 *1957*].

Benzyloxycarbonyl chloride *[501-53-1]* **M 170.6, b 103°/20mm, d 1.195, n 1.5190.** Commercial material is better than 95% pure and may contain some toluene, benzyl alcohol, benzyl chloride and HCl. After long storage (e.g. two years at 4°. Greenstein and Winitz [*The Chemistry of the Amino Acids* **Vol 2**, p 890, J Wiley and Sons NY, *1961*] recommended that the liquid should be flushed with a stream of dry air, filtered and stored over sodium sulphate to remove CO_2 and HCl which are formed by decomposition. It may further be distilled from an oil bath at a temperature below 85° because Thiel and Dent [*Annalen* **301** 257 *1898*] stated that benzyloxycarbonyl chloride decarboxylates to benzyl chloride slowly at 100° and vigorously at 155°. Redistillation at higher vac below 85° yields material which shows no other peaks than those of benzyloxycarbonyl chloride by NMR spectroscopy. **LACHRYMATORY**.

***N*-Benzyloxycarbonylglycyl-L-alaninamide** *[17331-79-2]* **M 279.3.** Recrystd from EtOH/ethyl ether.

***N*-Benzyloxycarbonyl-*N*'-methyl-L-alaninamide** *[33628-84-1]* **M 236.3.** Recrystd from ethyl acetate.

5-Benzyloxyindole *[1215-59-4]* **M 223.3, m 96-97°; 100-103°, 104-106° (dimorphic ?).** Recrystd from C_6H_6-pet ether or pet ether. The *picrate*, red crystals from C_6H_6, has **m** 142-143°. [*Chemistry & Industry (London)* 1035 *1953*; *JACS* **76** 5579 *1954*; fluorescence: *BJ* **107** 225 *1968*].

***p*-(Benzyloxy)phenol** *[103-16-2]* **M 200.2, m 122.5°.** Crystd from EtOH or water, and dried over P_2O_5 under vacuum. [Walter et al. *JACS* **108** 5210 *1986*].

***S*-(-)-3-Benzyloxypropan-1,2-diol** *[17325-85-8]* **M 182.2, m 24-26°, b 117-118°/10^{-4}mm, 115-116°/0.02mm, 121-123°/0.2mm,** d_4^{20} **1.1437,** n_D^{22} **1.5295,** $[\alpha]_D^{25}$ **-5.9° (neat).** Purified by repeated fractional distn. [*JBC* **193** 835 *1951*, **230** 447 *1958*].

***N*-Benzylpenicillin sodium salt** see entry in Chapter 5.

2-Benzylphenol *[28994-41-4]* **M 184.2, m 54.5°, b 312°/760mm, 175°/18mm.** Crystd from EtOH, stable form has **m** 52° and unstable form has **m** 21°.

4-Benzylphenol *[101-53-1]* **M 184.2, m 84°.** Crystd from water.

1-Benzyl-4-piperidone *[3612-20-2]* **M 189.3, b 107-108°/0.2mm, 114-116°/0.3mm, 143-146°/5mm, 157-158°/11mm, d_{24}^{24} 1.0523, n_D^{25} 1.5369.** If physical properties show contamination then dissolve in the minimum volume of H_2O, made strongly alkaline with aqueous KOH, extract with toluene several times, dry the extract with K_2CO_3, filter, evaporate and distil the residue at high vacuum using a bath temp of 160-190°, and redistil. [*JCS* 3173 *1957*, *JACS* **53** 1030 *1930*]. The *hydrochloride* has **m** 159-161° (from Me_2CO + Et_2O), and the *picrate* has **m** 174-182° (from Me_2CO + Et_2O). [*HCA* **41** 1184 *1958*].

2-Benzylpyridine *[101-82-6]* **M 169.2, b 98.5°/4mm, d 1.054, n^{26} 1.5771,**
4-Benzylpyridine *[2116-65-6]* **M 169.2, b 110.0°/6mm, d 1.065, n^{26} 1.5814.** Dried with NaOH for several days, then distd from CaO under reduced pressure, redistilling the middle fraction.

4-*N*-Benzylsulphanilamide *[1709-54-2]* **M 262.3, m 175°.** Crystd from dioxane/H_2O.

Benzyl sulphide *[538-74-9]* **M 214.3, m 50°.** Crystd from EtOH, then chromatographed on alumina using pentane as eluent, and finally recrystd from EtOH [Kice and Bowers *JACS* **84** 2390 *1962*].

Benzylthiocyanate *[3012-37-1]* **M 149.2, m 43°, b 256°(dec).** Crystd from EtOH or aqueous EtOH.

S-Benzylthiuronium chloride see **S-benzylisothiuronium chloride**.

Benzyl toluene-*p*-sulphonate *[1024-41-5]* **M 162.3, m 58°.** Crystd from pet ether (b 40-60°).

Benzyltributylammonium bromide *[25316-59-0]* **M 356.4, m 169-171°, 174-175°.** Recrystd from EtOAc/EtOH and EtOH/Et_2O. [*JACS* **73** 4122 *1951*, **81** 3264 *1959*].

Benzyltrimethylammonium chloride *[56-93-9]* **M 185.7, m 238-239°(dec).** A 60% aq soln was evapd to dryness under vac on a steam bath, and then left in a vac desiccator containing a suitable dehydrating agent. The solid residue was dissolved in a small amount of boiling absolute EtOH and pptd by adding an equal volume of ethyl ether and cooling. After washing, the ppte was dried under vac [Karusch *JACS* **73** 1246 *1951*].

Benzyltrimethylammonium hydroxide (Triton B) *[100-85-6]* **M 167.3, d 0.91.** A 38% soln (as supplied) was decolorized (charcoal), then evaporated under reduced pressure to a syrup, with final drying at 75° and 1mm pressure. Prepared anhydrous by prolonged drying over P_2O_5 in a vacuum desiccator.

Benzyltriphenylphosphonium chloride see Chapter 4.

Berbamine *[478-61-5]* **M 608.7, m 197-210°.** Crystd from pet ether.

Berberine *[2086-83-1]* **M 608.7, m 145°.** Crystd from pet ether.

Berberine hydrochloride ($2H_2O$) *[633-65-8]* **M 371.8, m 204-206°(dec).** Crystn from water gives the dihydrate. The anhydrous salt may be obtained by recrystn from EtOH/Et_2O, wash with Et_2O and dry in a vacuum. It has pKa 2.47. The *iodide* has **m** 250°(dec) (from EtOH). [IR: *JCS* **113** 503 *1918*; 2036 *1969*].

Betaine *[107-43-7]* **M 117.1, m 301-305°(dec) (anhydrous).** Crystd from aqueous EtOH.

Betamethasone (9α-fluoro-11β,17α,21-trihydroxy-16β-methylpregna-1,4-diene-3,20-dione) *[378-44-9]* **M 392.5, m 231-136°(dec), 235-237°(dec), $[\alpha]_D^{20}$ +108° (c 1, Me_2CO).** Crystd from ethyl acetate, and has λ_{max} 238nm (log ε 4.18) in MeOH.

Biacetyl (Butan-2,3-dione) *[431-03-8]* **M 86.1, b 88°, d 0.981, $n^{18.5}$ 1.3933.** Dried with anhydrous $CaSO_4$, $CaCl_2$ or $MgSO_4$, then vacuum distd under nitrogen, taking the middle fraction and storing it at Dry-ice temperature in the dark (to prevent polymerization).

Bibenzyl *[103-29-7]* **M 182.3, m 52.5-53.5°.** Crystd from hexane, MeOH, or 95% EtOH. It has also been sublimed under vacuum, and further purified by percolation through columns of silica gel and activated alumina.

Bicuculline *[485-49-4]* **M 367.4, m 215° (196°, 177°), $[\alpha]_{546}^{20}$ +159° (c 1, $CHCl_3$).** Crystd by dissolving in $CHCl_3$ and adding MeOH or EtOH.

Bicyclohexyl *[92-51-3]* **M 166.3, b 238° (*cis-cis*), 217-219° (*trans-trans*).** Shaken repeatedly with aqueous $KMnO_4$ and with conc H_2SO_4, washed with water, dried, first from $CaCl_2$ then from sodium, and distd. [Mackenzie *JACS* **77** 2214 *1955*].

Bicyclo[3.2.1]octane *[6221-55-2]* **M 110.2, m 141°.** Purified by zone melting.

Biguanide *[56-03-1]* **M 101.1, m 130°.** Crystd from EtOH.

Bilirubin *[635-65-4]* **M 584.7, ε_{450nm} 55,600 in $CHCl_3$.** Meso-type impurities eliminated by successive Soxhlet extraction with ethyl ether and MeOH. Then crystd from $CHCl_3$, and dried to constant weight at 80° under vacuum. [Gray et al. *JCS* 2264 *1961*].

Biliverdin *[114-25-0]* **M 582.6, m >300°.** Crystd from MeOH.

***R*-(+)-1,1'-Bi-2-naphthol** *[18531-94-7]* **M 286.3, m 207-208°, $[\alpha]_D^{20}$ + 43.0 (c 0.9, THF);**
***S*-(-)-1,1'-Bi-2-naphthol** *[18531-99-2]*. Dissolve in cold 2.5N NaOH, extract with CH_2Cl_2, and acidify with 5% HCl. Collect the white ppte and recryst from aq EtOH and dry in a vacuum [*TET* **27**, 5999, *1971*]. Optically stable in dioxane-water (100°/24h), slowly racemises in 1.2N HCl and in 0.68M KOH in BuOH [*JACS* **95** 2693 *1973*]. *Racemate* crysts from chlorobenzene, **m** 238°.

2,2'-Binaphthyl *[61-78-2]* **M 254.3, m 188°.** Crystd from benzene.

***R*-(-)-1,1'-Binaphthyl-2,2'-diylhydrogen phosphate** *[39648-67-4]* **M 348.3, m 217°, $[\alpha]_D^{20}$ -608° (c 1, MeOH),**
***S*-(+)-1,1'-Binaphthyl-2,2'-diylhydrogen phosphate** *[35193-64-7]*. They have been recrystallised from EtOH. Reflux for 3h in N NaOH is required to hydrolyse the cyclic phosphate. [*TET LETT* 4617 *1971* ; **24**, 343 *1983*].

Biopterin,
D-Biotin,
D-(+)-Biotin hydrazide,
D-(+)-Biotin *N*-hydroxysuccinimide ester,
D-(+)-Biotin 4-nitrophenyl ester,
***N*-(+)-Biotinyl-4-aminobenzoic acid,**
***N*-Biotinyl-6-aminocaproic *N*-succinimidyl ester,**
***N*-Biotinyl-6-aminocaproyl hydrazide,**
***N*-Biotinyl-L-lysine (Biocytin)** see entries in Chapter 5.

Biphenyl *[92-52-4]* **M 154.2, m 70-71°, b 255°, d 0.992.** Crystd from EtOH, MeOH, aq MeOH, pet ether (b 40-60°) or glacial acetic acid. Freed from polar impurities by passage of its soln in benzene through an alumina column, followed by evapn of the C_6H_6. Its soln in CCl_4 has been purified by distn under vacuum and by zone refining. Purified by treatment with maleic anhydride to remove anthracene-like impurities. Recrystd from EtOH followed by repeated vacuum sublimation and passage through a zone refiner. [Taliani and Bree *JPC* **88** 2351 *1984*].

***p*-Biphenylamine** *[CAS:92-67-1]* **M 169.2, m 53°, b 191°/15mm.** It has been recrystallised from H_2O. **CARCINOGEN.**

4-Biphenylcarbonyl chloride *[12920-38-9]* **M 216.7, m 114-115°.** Dissolve in a large volume of pet ether (10 x, b 50-70°), filter through a short column of neutral alumina, evaporate to dryness *in vacuo* and recryst from pet ether (b 60-80°). **LACHRYMATORY.**

Biphenyl-2-carboxylic acid *[947-84-2]* **M 198.2, m 114°, b 343-344°,**
Biphenyl-4-carboxylic acid *[92-92-2]* **M 198.2, m 228°.** Crystd from C_6H_6-pet ether or aq EtOH.

2,4'-Biphenyldiamine *[492-17-1]* **M 184.2, m 45°, b 363°/760mm.** Crystd from aqueous EtOH.

Biphenylene *[259-79-0]* **M 152.2, m 152°.** Recrystd from cyclohexane then sublimed in vacuum.

α-(4-Biphenylyl)butyric acid *[959-10-4]* **M 240.3, m 175-177°,**
γ-(4-Biphenylyl)butyric acid *[6057-60-9]* **M 240.3, m 118°.** Crystd from MeOH.

2-Biphenylyl diphenyl phosphate see entry in Chapter 4.

2,2'-Bipyridyl *[366-18-7]* **M 156.2, m 70.5°, b 273°.** Crystd from hexane, or EtOH, or (after charcoal treatment of a $CHCl_3$ soln) from pet ether. Also ppted from a conc soln in EtOH by addition of H_2O. Dried in a vacuum over P_2O_5. Further purification by chromatography on Al_2O_3 or by sublimation. [Airoldi et al. *JCSDT* 1913 *1986*].

4,4'-Bipyridyl *[553-26-4]* **M 156.2, m 73°(hydrate), 114° (171-171°)(anhydrous), b 305°/760mm, 293°/743mm.** Crystd from water, benzene/pet ether, ethyl acetate and sublimed *in vacuo* at 70°. Also purified by dissolving in 0.1M H_2SO_4 and twice ppted by addition of 1M NaOH to pH 8. Recrystd from EtOH. [Man et al. *JCSFT 1* **82** 869 *1986*; Collman et al. *JACS* **109** 4606 *1987*].

2,2'-Bipyridylamine *[1202-34-2]* **M 171.2, m 95.1°.** Crystd from Me_2CO.

2,2'-Biquinolin-4,4'-dicarboxylic acid (2,2'-bicinchoninic acid) *[1245-13-2]* **M 344.3, m 367°.** Dissolve in dilute NaOH and ppte with acetic acid, filter, wash well with H_2O and dry at 100° in a vacuum oven. Attempts to form a picrate failed. The *methyl ester* ($SOCl_2$-MeOH) has **m** 165.6-166°. [*JACS* **64** 1897 *1942*; **68** 2705 *1946*].

2,2'-Biquinolin-4,4'-dicarboxylic acid dipotassium salt *[63451-34-3]* **M 420.51.** Recryst from H_2O. The *Cu salt* has λ_{max} at 562nm. [*AB* **56** 4409 *1973*].

2,2'-Biquinolyl *[119-91-5]* **M 256.3, m 196°.** Decolorized in $CHCl_3$ soln (charcoal), then crystd to constant melting point from EtOH or pet ether [Cumper, Ginman and Vogel *JCS* 1188 *1962*].

Bis-acrylamide (*N,N'*-methylene bisacrylamide) *[110-26-9]* **M 154.2.** Recrystd from MeOH (100g dissolved in 500ml boiling MeOH and filtered without suction in a warmed funnel. Allowed to stand at room temperature and then at -15°C overnight. Crystals collected with suction in a cooled funnel and washed with cold MeOH). Crystals air-dried in a warm oven. The **TOXICITY** of bis-acrylamide is similar to acrylamide.

Bis-(4-aminophenylmethane *[101-77-9]* **M 198.3, m 92-93°, b 232°/9mm.** Crystd from 95% EtOH.

2,5-Bis-(4-aminophenyl)-1,3,4-oxadiazole see **BAO.**

2,5-Bis(2-benzothiazolyl)hydroquinone *[33450-09-8]* **M 440.3.** Purified by repeated crystn from dimethylformamide followed by sublimation in vacuum [Erusting et al. *JPC* **91** *1404 1987*].

Bis-(*p*-bromophenyl)ether *[53563-56-7]* **M 328.0, m 60.1-61.7°.** Crystd twice from EtOH, once from benzene and dried under vac [Purcell and Smith *JACS* **83** 1063 *1961*].

Bis-*N*-*tert*-butyloxycarbonyl-L-cystine, m 144.5-145°, $[\alpha]_D^{20}$ -133.2° (c 1.2, MeOH). Recrystd by dissolving in ethyl acetate and adding hexane [Ferraro *Biochemical Preparations* **13** 39 *1971*].

Bis-(*p*-*tert*-butylphenyl)phenyl phosphate see entry in Chapter 4.

2*R*,3*R*-(+)-1,4-Bis-(4-chlorobenzoyl)-2,3-butane diol *[85362-86-3]* **M 371.3, m 76-77°, $[\alpha]_D^{20}$ + 6.4° (c 3.11 $CHCl_3$),**
2*S*,3*S*-(-)-1,4-Bis-(4-chlorobenzoyl)-2,3-butane diol *[85362-85-2]* **M 371.3, m 75-77°, $[\alpha]_D^{20}$ - 6.4° (c 3.04 $CHCl_3$).** Recrystd from toluene-hexane. [*TET* **40** 4617 *1984*].

Bis-(β-chloroethyl)amine hydrochloride *[821-48-7]* **M 178.5, m 214-215°.** Crystd from Me_2CO.

Bis-(β-chloroethyl) ether *[111-44-4]* **M 143.0, b 178.8°, d 1.220, n 1.45750.** Washed with conc H_2SO_4, then Na_2CO_3 soln, drying with anhydrous Na_2CO_3, and finally passing through a 50cm column of activated alumina. Alternatively, washed with 10% ferrous sulphate soln, then water, and dried with $CaSO_4$. Distd at 94°/33mm. **TOXIC**.

***N*,*N*-Bis-(2-chloroethyl)2-naphthylamine** *[494-03-1]* **M 268.3, m 54-56°, b 210°/5mm.** Crystd from pet ether. **CARCINOGENIC.**

Bis-(chloromethyl)durene *[3022-16-0]* **M 231.2, m 197-198°.** Crystd three times from benzene, then dried under vacuum in an Abderhalden pistol.

3,3'-Bis-(chloromethyl)oxacyclobutane *[78-71-1]* **M 155.0, m 18.9°.** Shaken with aqueous $NaHCO_3$ or $FeSO_4$ to remove peroxides. Separated, dried with anhydrous Na_2SO_4, then distd under reduced pressure from a little CaH_2 [Dainton, Ivin and Walmsley *TFS* **65** 17884 *1960*].

2,2-Bis-(4-chlorophenyl)-1,1-dichloroethane (*p,p*-DDD) *[72-54-8]* **M 320.1, m 111-112°.** Crystd from EtOH, and the purity checked by TLC.

Bis-(2-chlorophenyl) phenyl phosphate see entry in Chapter 4.

2,2-Bis-(4-chlorophenyl)-1,1,1-trichloroethane (DDT) *[50-29-7]* **M 354.5, m 108°.** Crystd from *n*-propyl alcohol (5ml/g), then dried in air or in an air oven at 50-60°.

2,2'-Bis-[di-(carboxymethyl)-amino]diethyl ether, $(HOOCCH_2)_2NCH_2CH_2OCH_2CH_2N$-$(CH_2COOH)_2$ *[923-73-9]* **M 336.3,**
1,2-Bis-[2-di-(carboxymethyl)-aminoethoxy]ethane,
$(HOOCCH_2)_2NCH_2CH_2OCH_2CH_2OCH_2CH_2N$-$(CH_2COOH)_2$ *[67-42-5]* **M 380.4.** Crystd from EtOH.

4,4'-Bis-(dimethylamino)benzophenone *[90-93-7]* **M 268.4, m 175°.** Crystd from EtOH (25ml/g) and dried under vacuum.

4,4'-Bis-dimethylaminobenzophenone imine hydrochloride see **Auramine O.**

Bis-(4-dimethylaminobenzylidene)benzidine *[6001-51-0]* **M 454.5, m 318°.** Crystd from nitrobenzene.

1,8-Bis-(dimethylamino)naphthalene (Proton sponge) *[20734-58-1]* **M 214.3, m 47-48°.** Crystd from EtOH and dried in a vacuum oven. Stored in the dark.

Bis-(dimethylthiocarbamyl)disulphide (tetramethylthiuram disulphide) *[137-26-8]* **M 240.4, m 155-156°.** Crystd from $CHCl_3$, by addition of EtOH.

1,2-Bis-(diphenylphosphine)ethane see **ethylenebis-(diphenylphosphine).**

Bis-(2-ethoxyethyl) ether see **diethylene glycol diethyl ether.**

Bis-(2-ethylhexyl) 2-ethylhexyl phosphonate,
Bis-(2-ethylhexyl) phosphoric acid see entries in Chapter 4.

Bis-(4-fluoro-3-nitrophenyl) sulphone *[312-30-1]* **M 344.3, m 193-194°.** Recrystd from Me_2CO and H_2O (5:1). It should give a yellow colour in aqueous base. [*B* **86** 172 *1953*].

***N,N*-Bis-(2-hydroxyethyl)-2-aminoethanesulphonic acid (BES)** *[10191-18-1]* **M 213.3, m 150-155°.** Crystd from aqueous EtOH.

Bis-(2-hydroxyethyl)amino-tris-(hydroxymethyl)methane (Bis-Tris) *[6976-37-0]* **M 209.2, m 89°.** Crystd from hot 1-butanol. Dried in a vacuum at 25°.

***N,N*-Bis-(2-hydroxyethyl)glycine (Bicine)** *[150-25-4]* **M 163.2, m 191-194°(dec).** Crystd from 80% MeOH.

1,2-Bis(hydroxymethyl)benzene see **1,2-benzenedimethanol.**

3,4-Bis-(4-hydroxyphenyl)hexane *[5635-50-7]* **M 270.4, m 187°.** Freed from diethylstilboestrol by zone refining.

Bis-(2-methoxyethyl) ether see **diglyme.**

1,4-Bismethylaminoanthraquinone (Disperse Blue 14) *[2475-44-7]* **M 266.3, λmax 640 (594)nm.** Purified by thin-layer chromatography on silica gel plates, using toluene/acetone (3:1) as eluent. The main band was scraped off and extracted with MeOH. The solvent was evapd and the dye was dried in a drying pistol [Land, McAlpine, Sinclair and Truscott *JCSFT 1* **72** 2091 *1976*].

Bis-(1-naphthylmethyl)amine *[5798-49-2]* **M 329.4, m 62°.** Crystd from pet ether.

***N,N'*-Bis-(nicotinic acid) hydrazide** *[840-78-8]* **M 227-228°.** Crystd from water.

Bis-(4-nitrophenyl) carbonate *[5070-13-3]* **M 304.3, m 142-143°**. Dissolve in $CHCl_3$, wash with 2N NaOH (3 x) and once with conc HCl, dry (Na_2SO_4), evaporate and crystallise from toluene (authors say 15 vols of benzene, prisms). [*HCA* **46** 795 *1963*].

Bis-(4-nitrophenyl) ether *[101-63-3]* **M 260.2, m 142-143°,**
Bis-(4-nitrophenyl) methane *[1817-74-9]* **M 258.2, m 183°.** Crystd twice from C_6H_6, and dried under vacuum.

Bisnorcholanic acid *[57761-00-9]* **M 332.5, m 214° (α-form), 242° (β-form), 210-211° (γ-form), 184° (δ-form), 181° (ε-form).** Crystd from EtOH (α-form), or acetic acid (all forms).

3,3'-Bis-(phenoxymethyl)oxacyclobutane *[1224-69-7]* **M 270.3, m 67.5-68°.** Crystd from MeOH.

1,4-Bis-(2-pyridyl-2-vinyl)benzene *[20218-87-5]* **M 284.3.** Recrystd from xylene, then chromatogrphy (in the dark) on basic silica gel (60-80-mesh), using CH_2Cl_2 as eluent. Vacuum sublimed in the dark to a cold surface at 10^{-3} torr.

Bis-[4-(1,1,3,3-tetramethylbutyl)phenyl)phenyl]phosphate calcium salt (Selectophore] see entry in Chapter 4.

Bistrifluoroacetamide *[407-24-9]* **M 209.1, m 85°, b 135-136°/744mm, 141°/760mm.** Major impurity is trifluoroacetamide. Add trifluoroacetic anhydride, reflux for 2h and fractionate using a Vigreux column at atmospheric pressure. [*JC* **78** 273 *1973*].

Bis-(trifluoroacetoxy)iodobenzene *[2712-78-9]* **M 430.0, m 112-114° (dec), 120-121°, 124-126°.** Cryst from warm trifluoroacetic acid and dry over NaOH pellets. Recrystd from Me_2CO/pet ether. Melting point depends on heating rate. [*S* 445 *1975*].

Bis-(trimethylsilyl)acetylene see entry in Chapter 4.

Biuret *[108-19-0]* **M 103.1, sinters at 218° and chars at 270°.** Crystd from EtOH.

Bixin *[6983-79-5]* **M 394.5, m 198°.** Crystd from Me_2CO (violet prisms)

Blue Tetrazolium *[1871-22-3]* **M 727.7, m 254-255°(dec).** Crystd from 95% EtOH/anhydrous ethyl ether, to constant absorbance at 254nm.

Bombesin (2-L-glutamine-6-L-asparaginealytesin) see entry in Chapter 5.

Borane pyridine complex,
Borane triethylamine complex ,
Borane trimethylamine complex see entries in Chapter 4.

***R*-2-*endo*-Borneol** *[464-43-7]* **M 154.3, m 208° $[\alpha]_D^{20}$ +15.8° (in EtOH).** Crystd from boiling EtOH (charcoal).

(±)-Borneol *[6627-72-1]* **M 154.3, m 130°(dec).** Crystd to constant melting point from pet ether (b 60-80°).

Brazilin *[474-07-7]* **M 269.3, m 130°(dec).** Crystd from EtOH.

Brilliant Cresyl Blue *[4712-70-3]* **M 332.8.** Crystd from pet ether.

Brilliant Green *[633-03-4]* **M 482.7, m 209-211°(dec).** Purified by pptn as the perchlorate from aqueous soln (0.3%) after filtering, heating to 75° and adjustment to pH 1-2. Recrystd from EtOH/water (1:4) [Kerr and Gregory *Analyst* **94** 1036 *1969*].

***N*-Bromoacetamide** *[79-15-2]* **M 138.0, m 102-105°, 107-109°, 108° (anhyd).** Possible contaminant is CH_3CONBr_2. Recrystd from $CHCl_3$/hexane (1:1, seed if necessary) or water and dried over $CaCl_2$. [Oliveto and Gerold *Org Synth* Col Vol IV 104 *1963*).

4-Bromoacetanilide *[103-88-8]* **M 214.1, m 167°.** Crystd from aq MeOH or EtOH. Purified by zone refining.

Bromoacetic acid *[79-08-3]* **M 138.9, m 50°, b 118°/15mm, 208°/760mm.** Crystd from pet ether (b 40-60°). Ethyl ether soln passed through an alumina column, and the ether evaporated at room temperature under vacuum. **LACHRYMATORY.**

Bromoacetone *[598-31-2]* **M 137.0, b 31.5°/8mm.** Stood with anhydrous $CaCO_3$, distd under low vacuum, and stored with $CaCO_3$ in the dark at 0°. **LACHRYMATORY.**

4-Bromoacetophenone *[99-90-1]* **M 199.1, m 54°,**
ω–Bromoacetophenone *[70-11-1]* **M 199.1, m 57-58°.** Crystd from EtOH, MeOH or from pet ether (b 80-100°). [Tanner *JOC* **52** 2142 *1987*].

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1-Bromoadamantane see **1-adamantyl bromide.**

2-Bromoallyltrimethylsilane see entry in Chapter 4.

4-Bromoaniline *[106-40-7]* **M 172.0, m 66°.** Crystd (with appreciable loss) from aqueous EtOH.

2-Bromoanisole *[578-57-4]* **M 187.0, f.p. 2.5°, b 124°/40mm, d 1.513, n^{25} 1.5717,**
4-Bromoanisole *[104-92-7]* **M 187.0, f.p. 13.4°, b 124°/40mm, d 1.495, n^{25} 1.5617.** Crystd by partial freezing (repeatedly), then distd under reduced pressure.

9-Bromoanthracene *[1564-64-3]* **M 98-100°.** Crystd from MeOH or EtOH followed by sublimation *in vacuo*. [Masnori et al. *JACS* **108** 126 *1986*].

4-Bromobenzal diacetate *[55605-27-1]* **M 287.1, m 95°.** Crystd from hot EtOH (3ml/g).

Bromobenzene *[108-86-1]* **M 157.0, b 155.9°, d 1.495, n 1.5588, n^{15} 1.56252.** Washed vigorously with conc H_2SO_4, then 10% NaOH or $NaHCO_3$ solns, and H_2O. Dried with $CaCl_2$ or Na_2SO_4, or passed through activated alumina, before refluxing with, and distilling from, Ca turnings or sodium, using a glass helix-packed column.

4-Bromobenzene diazonium tetrafluoroborate *[673-40-5]* **M 270.8, m 133° (dec), 135-140° (dec), 135° (dec).** Wash with Et_2O until the wash is colourless and allow to dry by blowing N_2 over it. Store at 0-4° in the dark. [*B* **64** 1340 *1931*].

4-Bromobenzenesulphonyl chloride *[98-58-8]* **M 255.5, m 73-75°, 74.3-75.1, 75-76°, 77°, b 153°/15mm, 150.6°/13mm.** Wash with cold water, dry and recryst from pet ether, or from ethyl ether cooled in powdered Dry-ice after the ether soln had been washed with 10% NaOH until colourless, then dried with anhydrous Na_2SO_4. Alternatively dissolve in $CHCl_3$, wash with H_2O, dry (Na_2SO_4), evaporate and crystallise. [*JACS* **62** 511 *1940*]. Test for the SO_2Cl group by dissolving in EtOH and boiling with NH_4CNS whereby a yellow amorphous ppte forms on cooling [*JACS* **25** 198 *1901*].

2-Bromo-1,3,2-benzodioxaborole see entry in Chapter 4.

***o*-Bromobenzoic acid** *[88-65-3]* **M 201.0, m 148.9°.** Crystd from C_6H_6 or MeOH.

***m*-Bromobenzoic acid** *[585-76-2]* **M 201.0, m 155°.** Crystd from acetone/water, MeOH or acetic acid.

***p*-Bromobenzoic acid** *[586-76-5]* **M 201.0, m 251-252°, 254-256°, 257-258°.** Crystd from MeOH, or MeOH/water mixture, 90% EtOH and Et_2O. The *methyl ester* has **m** 81° from Et_2O or dilute MeOH. [Male and Thorp *JACS* **35** 269 *1913*; Lamneck *JACS* **76** 406 *1954*]. It has a pKa^{25} of 3.93 in H_2O. [Vandenbelt et al. *AC* **26** 926 *1954*].

***p*-Bromobenzophenone** *[90-90-4]* **M 261.1, m 81°.** Crystd from EtOH.

***p*-Bromobenzoyl chloride** *[586-75-4]* **M 219.5, m 36-39°, 39.8°, 41°, b 62°/0.1mm, 104.5°/6mm, 126.4-127.2°/14mm.** Check IR of a film to see if OH bands are present. If absent then recryst from pet ether and dry in a vacuum. If OH bands are weak then distil *in vacuo* and recryst if necessary. If OH bands are very strong then treat with an equal volume of redistilled $SOCl_2$ reflux for 2h then evaporate excess of $SOCl_2$ and distil residual oil or low melting solid. Store in the dark away from moisture. **LACHRYMATORY**. [Martin and Partington *JCS* 1175 *1936*].

***p*-Bromobenzyl bromide** *[589-15-1]* **M 249.9, m 60-61°,**
***p*-Bromobenzyl chloride** *[589-17-3]* **M 123.5, m 40-41°, b 105-115°/12mm.** Crystd from EtOH. **LACHRYMATORY.**

p-**Bromobiphenyl** *[92-66-0]* **M 233.1, m 88.8-89.2°.** Crystd from abs EtOH and dried under vacuum.

1-Bromobutane see ***n*-butyl bromide.**

2-Bromobutane *[78-76-2]* **M 137.0, b 91.2°, d 1.255, n 1.4367, n^{25} 1.4341.** Washed with conc HCl, water, 10% aqueous $NaHSO_3$, and then water. Dried with $CaCl_2$, Na_2SO_4 or anhydrous K_2CO_3, and fractionally distd through a 1m column packed with glass helices.

(+)-3-Bromocamphor-8-sulphonic acid *[+: 14671-04-6],[endo: 21633-53-4]* **M 311.2, m 195-196°(anhydrous), $[\alpha]_D^{20}$ +88.3° (in H_2O).** Crystd from water.

3-Bromocamphor-10-sulphonic acid *[24262-38-2]* **M 311.2, m 47.5°, $[\alpha]_D^{20}$ +98.3° (in H_2O), (+)-3-Bromocamphor-8-sulphonic acid ammonium salt** *[14575-84-9]* **M 328.2, m 270°(dec) $[\alpha]_D^{20}$ +84.8° (in H_2O).** Crystd from water.

4-Bromo-4'-chlorobenzophenone *[27428-57-5]* **M 295.6.** Purified by zone refining [Lin and Hanson *JPC* **91** 2279 *1987*].

Bromocresol Green *[76-60-8]* **M 698.0, m 218-219°(dec).** Crystd from glacial acetic acid or dissolved in aqueous 5% $NaHCO_3$ soln and ppted from hot soln by dropwise addition of aqueous HCl. Repeated until the extinction did not increase (λ_{max} 423nm).

Bromocresol Purple *[115-40-2]* **M 540.2, m 241-242°(dec).** Dissolved in aqueous 5% $NaHCO_3$ soln and ppted from hot soln by dropwise addition of aqueous HCl. Repeated until the extinction did not increase (λ_{max} 419nm). Can also be crystd from benzene.

5-Bromocytosine *[2240-25-7]* **M 190.0, m 245-255°(dec), 250°(dec).** Recryst from H_2O or 50% aq EtOH. Alternatively, dissolve *ca* 3g in conc HCl (10ml) and evaporate to dryness. Dissolve the residual hydrochloride in the minimum volume of warm H_2O and make faintly alkaline with aq NH_3. Collect the crystals and dry in a vacuum at 100°. [*JACS* **56** 134 *1934*].

1-Bromodecane see ***n*-decyl bromide.**

p-**Bromo-*N*,*N*-dimethylaniline** *[586-77-6]* **M 200.1, m 55°, b 264°.** Refluxed for 3h with two equivalents of acetic anhydride, then fractionally distd under reduced pressure

1-Bromo-2,4-dinitrobenzene *[584-48-5]* **M 247.0, m 75°.** Crystd from ethyl ether, isopropyl ether, 80% EtOH or absolute EtOH.

5-Bromo-2'-deoxyuridine *[59-14-3]* **M 307.1, m 193-197°(dec), 217-218°, $[\alpha]_D^{25}$ -41° (c 0.1, H_2O).** Recrystd from EtOH or 96% EtOH. It has λ_{max} 279 mn at pH 7.0, and 279 nm (log ε 3.95) at pH 1.9. Its R_F values are 0.49, 0.46 and 0.53 in *n*-BuOH-AcOH-H_2O (4:1:1), *n*-BuOH-EtOH-H_2O (40:11:19) and -PrOH-25% aq NH_3-H_2O (7:1:1) respectively. [*Nature* **209** 230 *1966*; *Coll Czech Chem Comm* **29** 2956 *1964*].

Bromoethane see **ethyl bromide.**

2-(2-Bromoethyl)-1,3-dioxane *[33884-43-4]* **M 195.1, b 67-70°/2.8mm, 71-72°/4mm, 95°/15mm, d_4^{20} 1.44, n_D^{20} 1.4219.** Purify by vacuum fractionation. Also dissolve in Et_2O, wash with aqueous $NaHCO_3$, dry extract with Na_2SO_4, filter and fractionate. NMR in CCl_4 has δ 1.3 (m, 1H), 2.1 (m, 3H), 3.36 (t, 2H), 3.90 (m, 4H) and 4.57 (t, H) ppm. [*JOC* **41** 560 *1976*; NMR, MS: *TET* **35** 1969 *1979*; *J Pharm Sci* **60** 1250 *1971*].

2-(2-Bromoethyl)-1,3-dioxolane *[18742-02-4]* **M 181.1, b 68-80°/8mm, 68-73°/10mm, 78-80°/20mm, d_4^{20} 1.510, n_D^{20} 1.479.** Dissolve in pentane, wash with 5% aqueous $NaHCO_3$, dry (Na_2SO_4), and evaporate. Distil the residue. [NMR: *JOC* **34** 1122 *1969*; *J Pharm Sci* **60** 1250 *1971*].

***N*-(2-Bromoethyl)phthalimide** *[574-98-1]* **M 254.1, m 81-83°, 82.5-83.5°.** The following is to be carried out in a good **FUME HOOD**. Dissolve the compound (180g) in CS_2 (500 ml) by refluxing for 15 min (to cause the separation of the most likely impurity, 1,2-diphthalimidoethane), filter and evaporate under reduced pressure. The product forms light tan crystals. (**m** 78-80°). Recryst from EtOH (charcoal) [the compound (50g) is dissolved in hot 75% EtOH (200ml), boiled for *ca* 10 min, carbon added (5g, Norite), filtered and cooled to 0°], as white crystals (40g) which can be recrystd (**m** 80-81°) and further recrystn gave **m** 82-83°. [*Org Synth* Coll Vol I 119 *1932*, *S* 389 *1976*; NMR: *Bull Soc Chim Fr* 165 *1979* -II].

Bromoform *[75-25-2]* **M 252.8, f.p. 8.1°, 55-56°/35mm, 149.6°/760mm, d^{15} 2.9038, d^{30} 2.86460, n^{15} 1.60053, n 1.5988.** Storage and stability of bromoform and chloroform are similar. Ethanol, added as a stabilizer, is removed by washing with H_2O or with saturated $CaCl_2$ soln, and the $CHBr_3$, after drying with $CaCl_2$ or K_2CO_3, is fractionally distd. Prior to distn, $CHBr_3$ has also been washed with conc H_2SO_4 until the acid layer no longer became coloured, then dilute NaOH or $NaHCO_3$, and H_2O. A further purification step is fractional crystn by partial freezing.

3-Bromofuran *[22037-28-1]* **M 147.0, b 38.5°/40mm, 50°/110mm, 102.5-103°/atm, d_4^{20} 1.661, n_D^{20} 1.4970.** Purified by two steam distillations and dried over fresh CaO. It can be dried over Na metal (NO REACTION) and fractionated. It is difficultly soluble in H_2O but soluble in organic solvents. Freshly distilled, it is a clear oil, but darkens on standing and eventually resinifies. It can be stored for long periods by covering the oil with an alkaline soln of hydroquinone and redistilled when required. It forms a characteristic *maleic anhydride adduct*, **m** 131.5-132°. [*JACS* **52** 2083 *1930*, **53** 737 *1931*, adduct: **55** 430 *1933*].

1-Bromoheptane see ***n*-heptyl bromide.**

(±)-2-Bromohexadecanoic acid (2-bromopalmitic acid) *[1826-25-7]* **M 335.3, m 51-53°, 52.3-52.5°, 53°.** Recrystd from pet ether (60-80°, charcoal) and finally from EtOH. The *ethyl ester* has **b** 177-178°/2mm, d_{28}^{28} 1.0484, n_D^{20} 1.4560. [IR: *JOC* **21** 1426 *1956*].

1-Bromohexane see ***n*-hexyl bromide.**

5-Bromoindole *[10075-50-0]* **M 196.1, m 90.5-91°, 90-92°.** Purified by steam distn from a faintly alkaline soln. Cool the aqueous distillate, collect the solid, dry in a vacuum desiccator over P_2O_5 and recryst from aqueous EtOH (35% EtOH) or pet ether-Et_2O. It has pKa 16.85 (16.30). λ_{max} in MeOH: 279, 287 and 296 (log ε 3.70, 3.69 and 3.53. The *picrate* has **m** 137-138°(dec) (from Et_2O-pet ether). [UV: *B* 95 2205 *1962*; UV and NMR: *Bull Soc Chim France* 4091 *1970*].

5-Bromoisatin *[87-48-9]* **M 226.0, m 245°(dec), 251-153°, 255-256°.** Forms red prisms or needles from EtOH. The *N-acetate* crystallises as yellow prisms from C_6H_6, **m** 170-172°, and the *N-methyl* derivative form orange-red needles from MeOH, **m** 172-173°. [*B* **47** 360 *1914*, **53** 1545 *1920*; *Rec Trav Chim Pays Bas* **73** 197 *1954*; *TET LETT* 215 *1978*].

4-Bromo-1-isopropylaminopentane hydrobromide M 208.1, m 167-167.5°. Crystd from Me_2CO/Et_2O.

Bromomethane see **methyl bromide.**

2-Bromomethylanthraquinone *[7598-10-9]* **M 301.1, m 200-202°.** Recrystd from AcOH, the crystals are washed with a little Et_2O, dried in air and then in vac at 100°. It is prepared by bromination of 2-methylanthraquinone with $Br_2/PhNO_2$ at 145-150°, or *N*-bromosuccinimide in CCl_4 containing a trace of $(PhCOO)_2$.

2-(Bromomethyl)benzonitrile *[22115-41-9]* **M 195.1, m 72-73°, 79°, b 152-155°/15mm.** Purified by steam distn. Extract the distillate with Et_2O, dry extract (Na_2SO_4), evap and distil residue. The solidified distillate can be recrystd from pet ether or cyclohexane. NMR ($CDCl_3$) δ: 7.8-7.2 (m 4H), 4.62 (s, 2H) ppm; IR ν: 2238 cm^{-1}. **LACHRYMATORY** [*B* **24** 2570 *1891*, **74** 675 *1934*; *Australian J Chem* **22** 577 *1969*].

***S*-(+)-1-Bromo-2-methylbutane** *[534-00-9]* **M 151.1, b 38.2°/39mm, 49°/62mm, 60.8°(57-58°)/100mm, 65-65.6°/140mm, 116-122°/atm, d_4^{20} 1.2232, n_D^{20} 1.4453, $[\alpha]_D^{20}$ +5.1° (neat, +5.8° (c 5, $CHCl_3$).** Wash with ice-cold H_2O, dried by freezing, shake twice with an equal vol of H_2SO_4 at 0°, and twice with an equal volume of H_2O at 0°. Freeze dried and kept over freshly heated (and then cooled) K_2CO_3, and distd through a vacuum jacketed column of broken glass. Alternatively, dissolve in pet ether (b 40-60°), wash with 5% NaOH, conc H_2SO_4 (at 0°), then H_2O, dry ($CaCl_2$), evaporate and distil. [*JACS* **74** 4858 *1952*, **81** 2779 *1959*; *JCS* 1413 *1959*, 2685 *1950*].

2-Bromo-3-methylindole (2-bromoskatole) *[1484-28-2]* **M 210.1, m 102-104°.** Purified by chromatography on silica gel in $CHCl_3$/pet ether (1:2) followed by crystn from aqueous EtOH. [Phillips and Cohen *JACS* **108** 2023 *1986*].

4-(Bromomethyl)-7-methoxycoumarin *[35231-44-8]* **M 269.1, m 208-209°, 213-215°, 216-218°.** Cryst from boiling AcOH, crystals are washed with AcOH, EtOH and dried in a vacuum, NMR (TFA) δ 3.97s, 4.57s, 6.62s, 6.92-7.19m and 7.80d. [*BBRC* **45** 1262 *1971*].

2-(Bromomethyl)-naphthalene *[939-26-4]* **M 221.1, m 52-54°, 56°, 56-57°, b 133-136°/0.8mm, 214°/100mm.** Dissolve in toluene, wash with saturated aqueous $NaHCO_3$, dry ($Mg SO_4$), evaporate and fractionally distil the residue and recrystallise the distillate from EtOH. [*JCS* 5044, *1952*; *Bull Soc Chim France* 566 *1953*].

1-Bromo-2-methylpropane see **isobutyl bromide.**

2-Bromo-2-methylpropane *[507-19-7]* **M 137.0, b 71-73°, d 1.218, n 1.429.** Neutralised with K_2CO_3, distd, and dehydrated using molecular sieves (5A), then vacuum distd and degassed by freeze-pump-thaw technique. Sealed under vacuum.

1-Bromonaphthalene *[90-11-9]* **M 207.1, b 118°/6mm, d 1.489.** Purified by passage through activated alumina, and three vacuum distns.

2-Bromonaphthalene *[580-13-2]* **M 207.1, m 59°.** Purified by fractional elution from a chromatographic column. Crystd from EtOH.

1-Bromo-2-naphthol *[573-97-7]* **M 223.1, m 76-78°,**
6-Bromo-2-naphthol *[15231-91-1]* **M 223.1, m 122-126°.** Crystd from EtOH.

5-Bromonicotinic acid *[20826-04-4]* **M 202.0, m 178-182°, 189-190°.** Recryst from H_2O and then from EtOH using charcoal. It has a pKa^{25} in 50% aq EtOH of 4.02. The *amide* has **m** 219-219.5° (from aq EtOH) and the *methyl ester* prepared by addition of ethereal diazomethane can be purified by sublimation in a vacuum and has **m** 98-99°, the *acid chloride* also can be sublimed in *vacuo* and has **m** 74-75° and gives the methyl ester in MeOH. [*J Prakt Chem* **138** 244 *1933*; *JACS* **70** 2381 *1948*; **82** 4430 *1960*; *JCS* 35 *1978*].

ω-Bromo-4-nitroacetophenone *[99-81-0]* **M 244.1, m 98°.** Crystd from C_6H_6-pet ether.

***o*-Bromonitrobenzene** *[577-19-5]* **M 202.1, m 43°,**
***m*-Bromonitrobenzene** *[585-79-5]* **M 202.1, m 55-56°,**

p-**Bromonitrobenzene** *[586-78-7]* **M 202.1, m 127°.** Crystd twice from pet ether, using charcoal before the first crystn.

α-**Bromo-***p*-**nitrotoluene** see *p*-**nitrobenzyl bromide.**

1-Bromooctadecane *[112-89-0]* **M 333.4, m 26°, 27.3°, 28-30°, b 178-179°/2mm, 214-218°/15mm, d^{20} 0.976, n_D^{20} 1.46145.** Twice recrystd from the melt then distilled under vacuum three times and using the middle cut. Alternatively, wash the oil with aqueous Na_2SO_4, then conc H_2SO_4 (cool) and again with aqueous Na_2SO_4 and then fractionate. [*JACS* **55** 1574 *1933*, **72** 171 *1950*; IR: *Australian J Chem* **12** 743 *1959*; IR: *Bull Soc Chim France* 516 *1957*].

1-Bromooctane see ***n*-octyl bromide.**

1-Bromopentane see ***n*-amyl bromide.**

(±)-2-Bromopentane *[107-81-3]* **M 151.1, b 117.2°/753mm, 116-117°/atm, 117.5°/740mm, d_4^{20} 1.2190, n_D^{20} 1.4401.** Dry over K_2CO_3 and distil through a short Vigreux column. [IR: *JACS* **74** 4063 *1952*, **78** 2199 *1956*].

p-**Bromophenacyl bromide** *[99-73-0]* **M 277.9, m 110-111°.** Crystd from EtOH (*ca* 8ml/g).

o-**Bromophenol** *[95-56-7]* **M 173.0, b 194°, d 1.490.** Purified by at least two passes through a chromatographic column.

p-**Bromophenol** *[106-41-2]* **M 173.0, m 64°.** Crystd from $CHCl_3$, CCl_4, pet ether (b 40-60°), or water. and dried at 70° under vacuum for 2h.

Bromophenol Blue *[115-39-9]* **M 670.0, m 270-271°(dec).** Crystd from benzene or acetone/glacial acetic acid, and air dried.

(4-Bromophenoxy)acetic acid *[1878-91-7]* **M 231.1, m 158°,**
ß-(4-Bromophenoxy)propionic acid *[93670-18-9]* **M 247.1, m 146°.** Crystd from EtOH.

4-Bromophenylacetic acid *[1878-68-8]* **M 215.1, m 112-113°, 113-115°, 114°** Recrystd from H_2O as needles. pKa 4.19. The *acid chloride* has **b** 238°/atm, **m** 50°, and the *anilide* has **m** 174-175°. [*JCS* 161 *1934*, *1251* 1948; *JOC* **11** 798 *1946*].

2-Bromo-4'-phenylacetophenone see *p*-**phenylphenacyl bromide.**

4-Bromophenylhydrazine *[589-21-9]* **M 187.1, m 108-109°.** Crystd from H_2O.

4-Bromophenyl isocyanate *[2492-02-9]* **M 189.0, m 41-42°.** Crystd from pet ether (b 30-40°).

4-Bromophenyl isothiocyanate *[1985-12-2]* **M 214.1, m 56-58°.** Recryst from boiling *n*-hexane. Any insoluble material is most probably the corresponding urea. It can be purified by steam distn, cool the receiver, add NaCl and extract in Et_2O, wash extract with N H_2SO_4; dry ($MgSO_4$), evaporate and recrystallise the residual solid. [*Org Synth* Coll Vol IV 700 *1963*; Coll Vol I 447 *1941*].

Bromopicrin *[464-10-8]* **M 297.8, m 10.2-10.3°, b 85-87°/16mm, d 2.7880, n 1.5790.** Steam distd, dried with anhydrous Na_2SO_4 and vacuum distd. **TOXIC.**

1-Bromopropane see ***n*-propyl bromide.**

2-Bromopropane see **isopropyl bromide.**

3-Bromopropene see **allyl bromide.**

***R*-(+)-2-Bromopropionic acid** *[10009-70-8]* **M 153.0, b 78°/4mm, $[\alpha]_D^{25}$ +27.2° (neat).** Dissolve in Et_2O, dry ($CaCl_2$), evap and distil through a short column. Distillation through a Podbielniak column led to decomposition. Store in the dark under N_2, preferably in sealed ampoules. Even at -10° it slowly decomposes. [*JACS* **76** 6054 *1954*].

3-Bromopropionic acid *[590-92-1]* **M 153.0, m 62.5°, 62.5-63.5°, 63-64°.** Crystallises as plates from CCl_4. It is soluble in organic solvents and H_2O. It has a pKa^{25} in H_2O of 4.01, and its *methyl ester* has **b** 65°/18mm and 80°/27mm. The *S-benzylisothiouronium salt* has **m** 136°. [*Org Synth* Coll Vol I 134 *1948*; *A* **599** 140 *1956*].

(3-Bromopropyl)benzene see **3-phenylpropyl bromide.**

***N*-(3-Bromopropyl)phthalimide** *[5460-29-7]* **M 268.1, m 72-74°, 74°.** Place in a Soxhlet and extract with Et_2O, whereby the bis-phthalimido impurity is not extracted. Evaporate the Et_2O and recryst from EtOH or aqueous EtOH or pet ether. [*B* **21** 2669 1888; *A* **614** 83 *1958*; *Canad J Chem* **31** 1060 *1953*].

2-Bromopyridine *[109-04-6]* **M 158.0, b 49.0°/2.7mm, d 1.660, n 1.5713.** Dried over KOH for several days, then distd from CaO under reduced pressure, taking the middle fraction.

Bromopyrogallol Red *[16574-43-9]* **M 576.2, m 300°.** Crystd from 50% EtOH.

Bromopyruvic acid *[1113-59-3]* **M 167.0, m 79-82°.** Dried by azeotropic distn (toluene), and then recrystd from dry $CHCl_3$. Dried for 48h at 20° (0.5 Torr) over P_2O_5. Stored at 0°. [Labandiniere et al. *JOC* **52** 157 *1987*].

5-Bromosalicyl hydroxamic acid *[5798-94-7]* **M 210.1, m 232°(dec).** Crystd from EtOH.

4-Bromostyrene *[2039-82-9]* **M 183.1, b 49.5-50°/2.5mm, 87-88°/12mm, 102-104°/20mm, d $_4^{20}$ 1.3984, n_D^{20} 1.5925.** It polymerises above 75° in the presence of benzoyl peroxide. To purify, if it has not gone to a solid resin, dissolve in Et_2O, dry ($MgSO_4$), add *ca* 0.1g of 4-*tert*butylcatechol (polymerisation inhibitor) per 100g of bromostyrene. Filter, evap under reduced press (use as high a vac as possible) and distil. Store in dark bottles in the presence of the inhibitor (concn as above). [*Org Synth* Coll Vol III 204 *1955*].

***N*-Bromosuccinimide** *[128-08-5]* **M 178.0, m 183-184°(dec).** *N*-Bromosuccinimide (30g) was dissolved rapidly in 300ml of boiling water and filtered through a fluted filter paper into a flask immersed in an ice bath, and left for 2h. The crystals were filtered, washed thoroughly with *ca* 100ml of ice-cold water and drained on a Büchner funnel before drying under vac over P_2O_5 or $CaCl_2$ [Dauben and McCoy *JACS* **81** 4863 *1959*]. Has also been crystd from acetic acid or water (10 parts, washed in water and dried *in vacuo*, [Wilcox et al. *JACS* **108** 7693 *1986;* Shell et al. *JACS* **108** 121 *1986*; Phillips and Cohen *JACS* **108** 2013 *1986*].

Bromosulfalein (phenoltetrabromophthalein 3',3'-disulphonic acid disodium salt) *[71-67-0]* **M 838.0.** Purified by TLC on silica Gel G (Merck 250μ) in two solvent systems (BuOH-AcOH-H_2O 30:7.5:12.5 v/v; and BuOH-propionic acid-H_2O 30:20:7.5 v/v). When the solvent reached a height of 10cm the plate was removed, dried in air and developed with NH_3 vapour giving blue coloured spots. Also the dye was chromatographed on MN Silica Gel with *t*-BuOH-H_2O-*n*-BuOH (32:10:5 v/v and visualised with a dilute KOH (or NaOH if the Na salt is required) spray. The product corresponding to bromosulfalein was scraped off and eluted with H_2O, filtered and evap to dryness in a vacuum. It was dissolved in H_2O and filtered through Sephadex G-25 and evaporated to dryness. [UV and IR identification: *J Pharm Sci* **57** 819 *1968*; NMR: *Chem Pharm Bull Japan* **20** 581 *1972*; *AB* **83** 75 *1977*].

Bromotetronic acid *[21151-51-9]* **M 179.0, m 183°(dec).** Decolorized, and free bromine was removed by charcoal treatment of an ethyl acetate soln, then recrystd from ethyl acetate [Schuler, Bhatia and Schuler *JPC* **78** 1063 *1974*].

Bromotheophylline *[10381-75-6]* **M 259.1, m 309°, 315-320° (with browning and dec).** It is purified by dissolving in the minimum volume of dilute NaOH (charcoal), filter and acidify to pH *ca* 3.5-4 and the solid that separates is collected, dried *in vacuo* at 100° and stored in a dark container. [*J prakt Chem* [2] **118** 158 *1928*; *B* **28** 3142 *1895*].

Bromothymol Blue *[76-59-5]* **M 624.4, m 201-203°.** Dissolved in aq 5% $NaHCO_3$ soln and ppted from the hot soln by dropwise addn of aq HCl. Repeated until the extinction did not increase (λ_{max} 420nm).

α-Bromotoluene see **benzyl bromide.**

***p*-Bromotoluene** *[106-38-7]* **M 171.0, m 28°, b 184°, d 1.390.** Crystd from EtOH [Taylor and Stewart *JACS* **108** 6977 *1986*].

α-Bromo-4-toluic acid *[6232-88-8]* **M 215.1, m 229-230°.** Crystd from Me_2CO.

Bromotrichloromethane *[75-62-7]* **M 198.3, f.p. -5.6°, b 104.1°, d 2.01, n 1.5061.** Washed with aq NaOH soln or dilute Na_2CO_3, then with H_2O, and dried with $CaCl_2$, BaO or $MgSO_4$ before distilling in diffuse light and storing in the dark. Has also been purified by treatment with charcoal and by fractional crystn by partial freezing. Purified by vigorous stirring with portions of conc H_2SO_4 until the acid did not discolour during several hours stirring. Washed with Na_2CO_3 and water, dried with $CaCl_2$ and then P_2O_5. Illuminated with a 1000W projection lamp at 6-in for 10h, after making 0.01M in bromine. Passed through a 30 x 1.5cm column of activated alumina before fractionally distilling through a 12-in Vigreux column. The middle fraction was passed through a fresh activated alumina column [Firestone and Willard *JACS* **83** 3511 *1961*].

Bromotrifluoromethane (Freon) *[75-63-8]* **M 148.9, b -59°, d 1.590.** Passed through a tube containing P_2O_5 on glass wool into a vac system where it was frozen out in a quartz sample tube and degassed by a series of cycles of freezing, evacuating and thawing.

Bromo trimethyl silane see entry in Chapter 4.

5-Bromouracil *[51-20-7]* **M 191.0, m 293°, 303-305°, 312°(dec).** Purified by dissolving in 2N NaOH (charcoal), filter and acidify with HCl. The ppte is dried *in vacuo* at 100° and recryst (prisms) twice from H_2O. [*JACS* **56** 134 *1934*, UV: *JACS* **81** 3786 *1959*; *JOC* **23** 1377 *1958*].

5-Bromovaleric acid *[2067-33-6]* **M 181.0, m 40°.** Crystd from pet ether.

α-Bromo-*p*-xylene *[104-81-4]* **M 185.1, m 35°, b 218-220°/740mm.** Crystd from EtOH.

Bromural *[496-67-3]* **M 223.1, m 154-155°.** Crystd from toluene, and air dried.

Brucine,
α-Brucine sulphate (hydrate) see entries in Chapter 5.

Bufotenine hydrogen oxalate *[2963-79-3]* **M 294.3, m 96.5°.** Crystd from Et_2O.

1,3-Butadiene *[106-99-0]* **M 54.1, b -2.6°.** Dried by condensing with a soln of aluminium triethyl in decahydronaphthalene; then flash distd. Also dried by passage over anhydrous $CaCl_2$ or distd from $NaBH_4$. Also purified by passage through a column packed with molecular sieves (4A), followed by cooling in Dry-ice/MeOH bath overnight, filtering off the ice and drying over CaH_2 at -78° and distd in a vacuum line.

***n*-Butane** *[106-97-8]* **M 58.1, m -135°, b -0.5°.** Dried by passage over anhydrous $Mg(ClO_4)_2$ and molecular sieves type 4A. Air was removed by prolonged and frequent degassing at -107°.

1,4-Butanediol *[110-63-4]* **M 90.1, f.p. 20.4°, b 107-108°/4mm, 127°/20mm, d 1.02, n 1.4467.** Distd and stored over Linde type 4A molecular sieves, or crystd twice from anhydrous ethyl

ether/acetone, and redistd. Also purified by recrystn from the melt and doubly distd *in vacuo* in the presence of Na_2SO_4.

***meso*-2,3-Butanediol** *[513-85-9]* **M 90.1, m 25°.** Crystd from isopropyl ether.

***threo*-2,3-butanediol** *[*D (-): *24347-58-8] [*L (+):*19132-06-0]* **M 90.1, m 16-19°, 19.7°, b 77,5-78°/10mm, 179-180°/atm, $[\alpha]_D^{20}$ (-) or (+) 13.1° (neat).** Purified by fractional distn. The *bis-(4-nitrobenzoate)* has **m** 141-142° and $[\alpha]_D^{25} \pm 52°$ (c 4 $CHCl_3$). [*JACS* **79** 734 *1957*, **74** 425 *1952*, *Canad J Res* **27** 457 *1949*].

2,3-Butanedione see **biacetyl.**

1-Butanesulphonyl chloride *[2386-60-9]* **M 156.6, b 75-76°/7mm, 98°/13mm, d_4^{20}1.2078, n_D^{20} 1.4559.** It has a pungent odour and is **LACHRYMATORY.** If IR shows OH bands then dissolve in Et_2O, wash with cold saturated aq $NaHCO_3$ (care since CO_2 will be generated) then H_2O, dry over solid Na_2SO_4, filter evaporate and distil the residue twice. Characterised by shaking a soln in Et_2O or C_6H_6 with aq NH_3, collect the solid and recryst from $CHCl_3$, CCl_4 or Et_2O-pet ether, **m** 48°. [*JACS* **60** 1488 *1938*; *JOC* **5** 83 *1940*].

1-Butanethiol *[109-79-5]* **M 90.2, b 98.4°, d^{25} 0.837, n 1.44298, n^{25} 1.44034.** Dried with $CaSO_4$ or Na_2SO_4, then refluxed from magnesium; or dried with, and distd from CaO, under nitrogen [Roberts and Friend *JACS* **108** 7204 *1986].* Has been separated from hydrocarbons by extractive distn with aniline. Dissolved in 20% NaOH, extracted with a small amount of C_6H_6, then steam distd, until clear. The soln was then cooled and acidified slightly with 15% H_2SO_4. The thiol was distd out, dried with $CaSO_4$ or $CaCl_2$, and fractionally distd under N_2 [Mathias and Filho *JPC* **62** 1427 *1958*]. Also purified by pptn as lead mercaptide from alcoholic soln, with regeneration by adding dilute HCl to the residue after steam distn. *All operations should be carried out in a fume cupboard due to the* **TOXICITY** *and obnoxious odour of the thiol.*

2-Butanethiol *[513-53-1]* **M 90.2, b 37.4°/134mm, d^{25} 0.8456, n^{25} 1.43385.** Purified as for 1-butanethiol.

***n*-Butanol** *[71-36-3]* **M 74.1, b 117.7°, d^{25} 0.80572, n 1.39922, n^{15} 1.40118.** Dried with $MgSO_4$, CaO, K_2CO_3, Ca or solid NaOH, followed by refluxing with, and distn from, calcium, magnesium activated with iodine, aluminium amalgam or sodium. Can also dry with molecular sieves, or by refluxing with *n*-butyl phthalate or succinate. (For method, see *Ethanol.*) *n*-Butanol can also be dried by efficient fractional distn, water passing over in the first fractn as a binary azeotrope (contains about 37% water). An ultraviolet-transparent distillate has been obtained by drying with magnesium amd distilling from sulphanilic acid. To remove bases, aldehydes and ketones, the alcohol has been washed with dil H_2SO_4, then $NaHSO_4$ soln; esters were removed by boiling for 1.5h with 10% NaOH.
Also purified by adding 2g $NaBH_4$ to 1.5L butanol, gently bubbling with argon and refluxing for 1 day at 50°. Then added 2g of freshly cut sodium (washed with butanol) and refluxed for 1 day. Distd and the middle fraction collected [Jou and Freeman *JPC* **81** 909 *1977*].

2-Butanol see ***sec*-butyl alcohol.**

***tert*-Butanol** see ***tert*-butyl alcohol .**

2-Butanone *[78-93-0]* **M 72.1, b 79.6°, d 0.853, n 1.37850, n^{25} 1.37612.** In general, purification methods are the same as for acetone. Aldehydes can be removed by refluxing with $KMnO_4$ + CaO, until the Schiff aldehyde test is negative, prior to distn. Shaking with satd K_2CO_3, or passage through a small column of activated alumina, removes cyclic impurities. The ketone can be dried by careful distn (an azeotrope containing 11% water boils at 73.4°), or by $CaSO_4$, P_2O_5, Na_2SO_4, or K_2CO_3, followed by fractional distn. Purification as the bisulphite addition compound is achieved by shaking with excess satd Na_2SO_3, cooled to 0°, filtering off the ppte, washing with a little ethyl ether and drying in air; this is followed by decomposition with a slight excess of Na_2CO_3 soln and steam distn, the distillate being satd with K_2CO_3 so that the ketone can be separated, dried with K_2CO_3, filtered, and distd. Purification as the *NaI addition compound* (**m** 73-74°) is more

convenient. (For details, see *Acetone*.) Small quantities of 2-butanone can be purified by conversion to the semicarbazone, recrystn to constant melting point, drying under vac over $CaCl_2$ and paraffin wax, refluxing for 30min with excess oxalic acid, followed by steam distn, salting out, drying and distilling [Cowan, Jeffery and Vogel *JCS* 171 *1940*].

***cis*-2-Butene** *[590-18-1]* **M 56.1, b 2.95-3.05°/746mm,**
***trans*-2-Butene** *[624-64-9]* **M 56.1, b 0.3-0.4°/744mm.** Dried with CaH_2. Purified by gas chromatography.

2-Butene-1,4-dicarboxylic acid (*trans*-ß-hydromuconic acid) *[4436-74-2]* **M 144.1, m 194-197°.** Crystd from boiling water, then dried at 50-60° in a vacuum oven.

But-3-en-2-one (methyl vinyl ketone) *[78-94-4]* **M 70.1, b 79-80°/760mm, d 0.842.** Dried with K_2CO_3, then Na_2SO_4, and fractionally distd.

2-Butoxyethanol (butyl cellosolve) *[111-76-2]* **M 118.2, b 171°/745mm, d 0.903, n 1.4191.** Peroxides can be removed by refluxing with anhydrous $SnCl_2$ or by passage under slight pressure through a column of activated alumina. Dried with anhydrous K_2CO_3 and $CaSO_4$, filtered and distd, or refluxed with, and distd from NaOH.

2-(2-Butoxyethoxy)ethanol see **diethylene glycol mono-*n*-butyl ether.**

4-Butoxyphenylacetic acid *[4547-57-3]* **M 208.3, m 80-85°, 86-87°, 88.5°**. Purified by recrystn from pet ether (b 40-60°). [*JACS* **68** 2592 *1946*].

***n*-Butyl acetate** *[123-86-4]* **M 116.2, b 126.1°, d 0.882, n 1.39406.** Distd, refluxed with successive small portions of $KMnO_4$ until the colour persisted, dried with anhydrous $CaSO_4$, filtered and redistd.

***tert*-Butyl acetate** [540-88-5 *[540-88-5]* **M 116.2, b 97-98°, d 0.72.** Washed with 5% Na_2CO_3 soln, then saturated aqueous $CaCl_2$, dried with $CaSO_4$ and distd.

tert*-Butyl acetoacetate** *[1694-31-1]* **M 158.2, b 71°/10mm, 85°/20mm, d_4^{20} 0.954, n_4^{20} 1.42.** Dist under reduced press through a short column. [*Org Synth* **42** 28 *1962*]. *Vapour is* ***harmful.

***tert*-Butylacetylchloride** *[7065-46-5]* **M 134.6, b 68-71°/100mm, 81°/180mm, 128-132°/atm, d_4^{20} 0.964, n_D^{20} 1.4229.** Distil under vacuum. If IR shows OH group then treat with thionyl chloride or oxalyl chloride at *ca* 50° for 30min, evap and fractionate using a short column. Strongly **LACHRYMATORY**, use a good fume hood. [*JACS* **72** 222 *1950*; *JOC* **22** 1551 *1957*].

Butyl acrylate *[141-32-2]* **M 128.2, b 59°/25mm, d 0.894, n^{12} 1.4254.** Washed repeatedly with aqueous NaOH to remove inhibitors such as hydroquinone, then with distilled water. Dried with $CaCl_2$. Fractionally distd under reduced pressure in an all-glass apparatus. The middle fraction was sealed under nitrogen and stored at 0° in the dark until used [Mallik and Das *JACS* **82** 4269 *1960*].

***n*-Butyl alcohol** see ***n*-butanol.**

(±)-*sec*-Butyl alcohol *[15892-23-6]* **M 74.1, b 99.4°, d 0.808.** Purification methods are the same as for *n*-Butanol. These include drying with K_2CO_3 or $CaSO_4$, followed by filtration and fractional distn, refluxing with CaO, distn, then refluxing with magnesium and redistn; and refluxing with, then distn from CaH_2. Calcium carbide has also been used as a drying agent. Anhydrous alcohol is obtained by refluxing with *sec*-butyl phthalate or succinate. (For method see *Ethanol*.) Small amounts of alcohol can be purified by conversion to the alkyl hydrogen phthalate and recrystn [Hargreaves, *JCS* 3679 *1956*]. For purification of optical isomers, see Timmermans and Martin [*JCP* **25** 411 *1928*].

***tert*-Butyl alcohol** *[75-65-0]* **M 74.1, m 23-25°, 25.7°, b 28.3°/60mm, 43.3°/123.8mm, 61.8°/315mm, 72.5°/507mm, 82.45°/760mm, d_4^{20} 0.7858, n_D^{20} 1.3878.** Synthesised commercially by the hydration of 2-methylpropene in dilute H_2SO_4. Dried with CaO, K_2CO_3, $CaSO_4$ or $MgSO_4$, filtered and fractionally distd. Dried further by refluxing with, and distilling from, either magnesium activated with iodine, or small amounts of calcium, sodium or potassium, under nitrogen. Passage through a column of type 4A molecular sieve is another effective method of drying. So, also, refluxing with *tert*-butyl phthalate or succinate. (For method see *Ethanol.*) Other methods include refluxing with excess aluminium *tert*-butylate, or standing with CaH_2, and distilling as needed. Further purification is achieved by fractional crystn by partial freezing, taking care to exclude moisture. *tert*-Butyl alcohol samples containing much water can be dried by adding benzene, so that the water distils off as a tertiary azeotrope, b 67.3°. Traces of isobutylene have been removed from dry *tert*-butyl alcohol by bubbling dry pre-purified nitrogen through for several hours at 40-50° before using. It form azeotropic mixtures with a large number of compounds. It has also been purified by distn from CaH_2 into Linde 4A molecular sieves which had been activated at 350° for 24h [Jaeger et al. *JACS* **101** 717 *1979*].

***n*-Butylamine** *[109-73-9]* **M 73.1, b 77.8°, d 0.740, n 1.4009, n^{25} 1.3992.** Dried with solid KOH, K_2CO_3, $LiAlH_4$, CaH_2 or $MgSO_4$, then refluxed with, and fractionally distd from P_2O_5, CaH_2, CaO or BaO. Further purified by pptn as the *hydrochloride*, **m** 213-213.5°, from ether soln by bubbling HCl gas into it. Re-ppted three times from EtOH by adding ether, followed by liberation of the free amine using excess strong base. The amine was extracted into ether, which was separated, dried with solid KOH, the ether removed by evapn and then the amine was distd. It was stored in a desiccator over solid NaOH [Bunnett and Davis *JACS* **82** 665 *1960*].

***R*-(-)-*sec*-Butylamine** *[13250-12-9]* **M 73.1, b 61-63°/atm, 62.5°/atm, d_4^{20} 0.731, n_D^{20} 1.393, $[\alpha]_D^{20}$ +7.5° (neat).** Dry over solid NaOH overnight and fractionate through a short helices packed column. The L-*hydrogen tartrate salt* has **m** 139-140° (from H_2O), the *1H_2O* has **m** 96° $[\alpha]_D^{21}$ +18.1° (c 11, H_2O); the *hydrochloride* has **m** 152° $[\alpha]_D^{21}$ -1.1° (c 13, H_2O) and the *benzoyl derivative* crystallises from EtOH as needles **m** 97°, $[\alpha]_D^{21}$ -34.9° (c 11, H_2O). [*JCS* 921 *1956*; *Acta Chem Scand* **11** 898 *1957*].

***tert*-Butylamine** *[75-64-9]* **M 73.1, b 42°, d 0.696.** Dried with KOH or $LiAlH_4$. Distd from CaH_2 or BaO.

***n*-Butyl *p*-aminobenzoate** *[94-25-7]* **M 193.2, m 57-59°.** Crystd from EtOH.

***tert*-Butylammonium bromide** *[60469-70-7]* **M 154.1.** Recrystd several times from absolute EtOH and thoroughly dried at 105°.

4-*tert*-Butylaniline *[769-92-6]* **M 149.2, m 14.5-15°, 15-16°, b 98.5-99°/3mm, 122°/20mm, d_4^{20} 0.945, n_D^{20} 1.5385.** Isolate as sulphate salt then liberate the free base with 10% aqueous NaOH, separate layers, dry over solid KOH and dist twice from Zn dust in a vacuum and store in brown containers. It has pKa^{25} (H_2O) 4.95 and (50% aq EtOH) 4.62. [*JACS* **76** 2349 *1954*]. The *anilide* has **m** 171.5-172.3°, and the *hydrochloride* has **m** 270-274°. [*JCS* 680 *1952*; *JACS* **76** 6179 *1954*].

2-*tert*-Butylanthracene *[13719-97-6]* **M 234.3, m 148-149°.** Recrystd from EtOH and finally purified by TLC.

***n*-Butylbenzene** *[104-51-8]* **M 134.2, b 183.3°, d 0.860, n 1.48979, n^{25} 1.48742.** Distd from sodium. Washed with small portions of conc H_2SO_4 until the acid was no longer coloured, then with water and aqueous Na_2CO_3. Dried with anhydrous $MgSO_4$, and distd twice from Na, collecting the middle fraction [Vogel *JCS* 607 *1948*].

***tert*-Butylbenzene** *[98-06-6]* **M 134.2, b 169.1°, d 0.867, n 1.49266, n^{25} 1.49024.** Washed with cold conc H_2SO_4 until a fresh portion of acid was no longer coloured, then with 10% aqueous NaOH, followed by distd water until neutral. Dried with $CaSO_4$ and distd in a glass helices-packed column, taking the middle fraction.

4-*tert*-Butyl benzoyl chloride *[1710-98-1]* **M 196.7, b 135°/10mm, 149.9-150.5°/14mm, 266-268°(dec), d_4^{20} 1.082, n_D^{20} 1.536.** Distil under vac. If IR shows OH group then treat with thionyl chloride or oxalyl chloride at *ca* 50° for 30min, evap and fractionate in a vac using a short column. Strongly **LACHRYMATORY**, use a good fume hood. [*Bull Chem Soc Japan* **32** 960 *1959*; *JACS* **72** 5433 *1950*].

***n*-Butyl bromide** *[109-65-9]* **M 137.0, b 101-102°, d^{25} 1.2678, n 1.4399, n^{25} 1.4374.** Washed with conc H_2SO_4, water, 10% Na_2CO_3 and again with H_2O. Dried with $CaCl_2$, $CaSO_4$ or K_2CO_3, and distd. Redistd after drying with P_2O_5, or passed through two columns containing 5:1 silica gel/Celite mixture and stored with freshly activated alumina.

***sec*-Butyl bromide** see **2-bromobutane.**

***tert*-Butyl bromoacetate** *[5292-43-3]* **M 195.1, b 52°/10mm, 74-76°/25mm, d_4^{20} 1.324, n_D^{25} 1.4162.** Dissolve in Et_2O, wash well with ice cold 10% aqueous K_2CO_3, dry over $CaCl_2$, filter and evaporate the Et_2O then fractionate through a Vigreux column in a vacuum. **LACHRYMATORY** [*Org Synth* **34** 28 *1954*, Coll Vol III 144 *1955*; *JACS* **64** 2274 *1942*, **65** 986 *1943*].

4-*tert*-Butylcalix[4]arene *[60705-62-6]* **M 648.9, m >300° (dec), 380° (dec), 344-346°.** Recrystd from $CHCl_3$ in large solvated prisms (**m** 380° dec) effloresces on drying in air; *tetra-acetate* crysts from Ac_2O in colourless prisms **m** 332-333° dec. Crysts from CCl_4 or chlorobenzene + EtOH (**m** >300°) and *tetra-acetate* cryst from $CHCl_3$ + EtOH **m** >290° dec. Crysts from toluene in white plates with toluene of crystallisation **m** 344-346° (330-332°); the *tetra-acetate* crystallises with 1AcOH of crystallisation **m** 383-386° (softening at 330-340°, also **m** 283-286°), but acetylation with Ac_2O-NaOAc gives *triacetate* which recrysts from AcOH with 1AcOH of crystn **m** 278-281°. 4-*tert*-Butylcalix[4]arene (100mg) is unchanged after boiling for 4h with 10N KOH (0.04ml) in xylene (4ml). [*BJP* **10** 73 *1955*; *M* **109** 767 *1978*; *JACS* **103** 3782 *1981*; see also J.Vicens and V.Böhner eds,*Calixarenes*, Kluawer Academic Publ., Boston, 1991].

4-*tert*-Butylcalix[6]arene *[78092-53-2]* **M 972.3, m >300°, 380-381°.** Recryst from $CHCl_3$ or $CHCl_3$ - MeOH as a white solid from the mother liquors of the calix[8]arene preparation. The *hexa-acetate* (Ac_2O-H_2SO_4) crystallises from $CHCl_3$-MeOH **m** 360-362° dec, and the $(SiMe_3)_6$ derivative crystallises from $CHCl_3$-MeOH **m** 410-412°. Stability in KOH-xylene is same as for the 4-*tert*-butylcalix[4]arene. [*JACS* **103** 3782 *1981*; see also J.Vicens and V.Böhner eds,*Calixarenes*, Kluawer Academic Publ., Boston, 1991].

4-*tert*-Butylcalix[8]arene *[68971-82-42]* **M 1297.8, m 411-412°.** Recryst from $CHCl_3$ in fine colourless glistening needles. It melts sharply between 400-401° and 411-412° depending on the sample and is sensitive to traces of metal ions. TLC on silica gel (250µm thick) and elution with $CHCl_3$-hexane (3:4); it has R_F 0.75. The *octa-acetate* is prepared from 8g in Ac_2O (50ml) and 2 drops of conc H_2SO_4 refluxed for 2h. On cooling a colourless ppte separates and is recrystd from Ac_2O (1.2g 48%) **m** 353-354°. The $(SiMe_3)_8$ is prepared from 4-*tert*-butylcalix[8]arene (0.65g) in pyridine (4ml) with excess of hexamethyldisilazane (1ml) and trimethylchlorosilane (0.5ml) and refluxed under N_2 for 2h. Cool, evaporate the pyridine, triturate gummy residue with MeOH. Chromatography on silica gel using hexane-CH_2Cl_2 gave 0.5g (61%) with one spot on TLC. Crystallises from hexane-Me_2CO as colourless needles **m** 358-360°. [*JACS* **103** 3782 *1981*; *JOC* **43** 4905 1978; **44** 3962 *1979*; *JCSCC* 533 *1981*; see also J.Vicens and V.Böhner eds,*Calixarenes*, Kluawer Academic Publ., Boston, 1991].

***tert*-Butyl carbazate** *[870-46-2]* **M 132.2, m 41-42°, b 64°/0.01mm, 55-57°/0.4mm.** Dist in a Claisen flask with a water or oil bath at *ca* 80°. After a couple of drops have distd the carbazate is collected as an oil which solidifies to a snow white solid. It can be crystd with 90% recovery from a 1:1 mixt of pet ether (b 30-60°) and pet ether (b 60-70°). [*Org Synth* **44** 20 *1964*].

Butyl carbitol see **diethylene glycol mono-*n*-butyl ether.**

4-*tert*-Butylcatchol *[98-29-3]* **M 166.22, m 47-48°, 52-55°, 55-56°, 75°, b 265°/atm.** Vacuum distd and recrystd from pentane or pet ether (or C_6H_6).

Butyl cellosolve see **2-butoxyethanol.**

***n*-Butyl chloride** *[109-69-3]* **M 92.6, b 78°, d 0.886, n 1.4021.** Shaken repeatedly with conc H_2SO_4 (until no further colour developed in the acid), then washed with water, aq $NaHCO_3$ or Na_2CO_3, and more water. Dried with $CaCl_2$, or $MgSO_4$ (then with P_2O_5 if desired), decanted and fractionally distd. Alternatively, a stream of oxygen continuing *ca* three times as long as was necessary to obtain the first coloration of starch iodide paper by the exit gas. After washing with $NaHCO_3$ soln to hydrolyze ozonides and to remove the resulting organic acid, the liquid was dried and distd [Chien and Willard *JACS* **75** 6160 *1953*].

***sec*-Butyl chloride** see **2-chlorobutane.**

***tert*-Butyl chloride** *[507-20-0]* **M 92.6, f.p. -24.6°, b 50.4°, d 0.851, n 1.38564.** Purification methods commonly used for other alkyl halides lead to decomposition. Some impurities can be removed by photochlorination with a small amount of chlorine prior to use. The liquid can be washed with ice water, dried with $CaCl_2$ or $CaCl_2$ + CaO and fractionally distd. It has been further purified by repeated fractional crystn by partial freezing.

***tert*-Butyl chloroacetate** *[107-59-5]* **M 150.6, b 48-49°/11mm, 60.2°/15mm, 155°/atn (dec), d_4^{25} 1.4204, n_D^{20} 1.4259.** Check the NMR spectrum, if satisfactory then dist in a vac, if not then dissolve in Et_2O, wash with H_2O, 10% H_2SO_4 until the acid extract does not become cloudy when made alkaline with NaOH. Wash the organic layer again with H_2O, then satd aq $NaHCO_3$, dry over Na_2SO_4, evap and fractionate through a carborundum-packed column or a 6-inch Widmer column (*see tert-butyl ethyl malonate for precautions to avoid decomposition during distn*). [*JCS* 940 *1940*; *JACS* **75** 4995 *1953*; *Org Synth* Coll Vol 144 *1944*].

6-*tert*-Butyl-1-chloro-2-naphthol *[525-27-9]* **M 232.7, m 76°, b 185°/15mm.** Crystd from pet ether.

***tert*-Butyl cyanide** *[630-18-2]* **M 83.1, m 16-18°, d 0.765, b 104-106°.** Purified by a two stage vac distn and degassed by freeze-pump-thaw technique. Stored under vac at 0°.

***tert*-Butyl cyanoacetate** *[1116-98-9]* **M 141.2, b 40-42°/0.1mm, 54-56°/0.3mm, 90°/10mm, 107-108°/23mm, d_4^{20} 0.989, n_D^{20} 1.4198.** The IR spectrum of a film should have bands at 1742 (ester CO) and 2273 (C≡N) but not OH band (*ca* 3500 broad) cm^{-1}. If it does not have the last named band then fractionally dist, otherwise dissolve in Et_2O, wash with satd aq $NaHCO_3$, dry over K_2CO_3, evap Et_2O, and dist residue under a vacuum (*see tert-butyl ethyl malonate for precautions to avoid decomposition during distn*). [*JCS* 423 *1955*; *HCA* **42** 1214 *1959*].

4-*tert*-Butyl-1-cyclohexanone *[98-53-3]* **M 154.3, m 49-50°.** Crystd from pentane.

***tert*-Butyldimethylsilyl chloride** see entry in Chapter 4.

***n*-Butyl disulphide** *[629-45-8]* **M 178.4, b 110-113°/15mm, d 0.938, n^{22} 1.494.** Shaken with lead peroxide, filtered and distd in vacuum under N_2.

***n*-Butyl ether** *[142-96-1]* **M 130.2, b 52-53°/26mm, 142.0°/760mm, d 0.764, n 1.39925, n^{25} 1.39685.** Peroxides (detected by the liberation of iodine from weakly acid (HCl) solns of 2% KI) can be removed by shaking 1L of ether with 5-10ml of a soln comprising 6.0g of ferrous sulphate and 6ml conc H_2SO_4 and 110ml of water, with aq Na_2SO_3, or with acidified NaI, water, then $Na_2S_2O_3$. After washing with dil NaOH, KOH, or Na_2CO_3, then water, the ether is dried with $CaCl_2$ and distd. It can be further dried by distn from CaH_2 or Na (after drying with P_2O_5), and stored in the dark with Na or NaH. The ether can also be purified by treating with CS_2 and NaOH, expelling the excess sulphide by heating. The ether is then washed with water, dried with NaOH and distd [Kusama and Koike *J Chem Soc Japan, Pure Chem Sect* **72** 229 *1951*]. Other purification procedures include passage through an activated alumina column to remove peroxides, or through a column of silica gel, and distn after adding about 3% (v/v) of a 1M soln of MeMgI in *n*-butyl ether.

***n*-Butyl ethyl ether** *[628-81-9]* **M 102.2, b 92.7°, d 0.751, n 1.38175, n^{25} 1.3800.** Purified by drying with $CaSO_4$, by passage through a column of activated alumina (to remove peroxides), followed by prolonged refluxing with Na and then fractional distn.

***tert*-Butyl ethyl ether** *[637-92-3]* **M 102.2, b 71-72°, d 0.741.** Dried with $CaSO_4$, passed through an alumina column, and fractionally distd.

***tert*-Butyl ethyl malonate** *[32864-38-3]* **M 188.2, b 83-85°/8mm, 93-95°/17mm, 107-109°/24mm, d_4^{25} 0.994, n_D^{24} 1.4150.** Likely impurity is monoethyl malonate, check IR for OH bands at 3330 br. To *ca* 50g of ester add ice cold NaOH (50g in 200ml of H_2O and 200g of ice). Swirl a few times (filter off ice if necessary), place in a separating funnel and extract with 2 x 75ml of Et_2O. Dry extract ($MgSO_4$) (since traces of acid decompose the *t*-Bu group of the ester, the distillation flask has to be washed with aq NaOH, rinsed with H_2O and allowed to dry). Addition of some K_2CO_3 or MgO before distilling is recommended to inhibit decomposition. Distil under reduced press through a 10 cm Vigreux column. *Decomposition is evidenced by severe foaming due to autocatalytic decomposition and cannot be prevented from accelerating except by stopping the distillation and rewashing the distillation flask with alkali again.* [*JACS* **66** 1287 *1944*, **64** 2714 *1942*; *Ogr Synth* Coll Vol IV 417 *1963*; *Org Synth* **37** 35 *1957*].

***n*-Butyl formate** *[592-84-7]* **M 102.1, b 106.6°, d 0.891, n 1.3890.** Washed with satd $NaHCO_3$ soln in the presence of satd NaCl, until no further reaction occurred, then with saturated NaCl soln, dried ($MgSO_4$) and fractionally distd.

Butyl glycolate *[7397-62-8]* **M 132.2, b 191-192°/755mm, 187-190°/atm, d_4^{20} 1.019, n_D^{20} 1.4263.** Dissolve in $CHCl_3$ (EtOH-free), wash with 5% $KHCO_3$ until effervescence ceases (if free acid is present), dry over $CaCl_2$, filter, evaporate and distil through a short column. [Bøhme and Opfer *Z anal Chem* **139** 255 *1953*; *cf JACS* **73** 5265 *1951*].

***tert*-Butyl hydroperoxide (TBHP)** *[75-91-2]* **M 90.1, f.p. 5.4°, m 0.5-2.0°, b 38°/18mm, d 0.900, n 1.4013.** *Care should be taken when handling this peroxide because of the possiblility of* **EXPLOSION. It explodes when heating over an open flame.** Alcoholic and volatile impurities can be removed by prolonged refluxing at 40° under reduced pressure, or by steam distn. For example, Bartlett, Benzing and Pincock [*JACS* **82** 1762 *1960*] refluxed at 30mm pressure in an azeotropic separation apparatus until two phases no longer separated, and then distilled at 41°/23mm. Pure material is stored under N_2, in the dark at 0°. Crude commercial material has been added to 25% NaOH below 30°, and the crystals of the sodium salt have been collected, washed twice with benzene and dissolved in distd water. After adjusting the pH of the soln to 7.5 by adding solid CO_2, the peroxide was extracted into pet ether, from which, after drying with K_2CO_3, it was recovered by distilling off the solvent under reduced pressure at room temperature [O'Brien, Beringer and Mesrobian *JACS* **79** 6238 *1957*]. **The temperatures should be kept below 75°.** It has also been distilled through a helices packed column (*ca* 15 plates) and material collected had **b** 34-35°/20 mm. Similarly, a soln in pet ether has been extracted with cold aq NaOH, and the hydroperoxide has been regenerated by adding at 0°, $KHSO_4$ at a pH not higher than 4.5, then extracted into ethyl ether, dried with $MgSO_4$, filtered and the ether evapd in a rotary evaporator under reduced pressure [Milac and Djokic *JACS* **84** 3098 *1962*].
A 3M soln of TBHP in CH_2Cl_2 is prepared by swirling 85ml (0.61mol) of commercial TBHP (70% TBHP-30% H_2O, d 0.935 *ca* 7.2mmol/ml) with 140ml of CH_2Cl_2 in a separating funnel. The milky mixture is allowed to stand until the phases separate (*ca* 30min). The organic (lower) layer (*ca* 200ml) containing 0.60mole of TBHP was separated from the aqueous layer (*ca* 21ml) and used without further drying. TBHP is assayed by iodometric titration. With 90% grade TBHP (w/w, d 0.90, *ca* 9.0mmole/ml) no separation of layers occurs; i.e. when TBHP (66.67ml, 0.60mole) is added to CH_2Cl_2 (140ml) the resulting soln (*ca* 200ml) is clear. [*JACS* **77** 60032 *1955*, **74** 4742 *1952*; Akashi, Palermo and Sharpless *JOC* **43** 2063 *1978* states quality of available grades, handling and compatibility for reactions].

2-*tert*-Butyl hydroquinone *[1948-33-0]* **M 166.2, m 125-127°, 127-128°, 129°.** Recrysts from H_2O or MeOH and dried in a vacuum at 70°. Store in a dark container. [*Angew Chemie* **69** 699 *1957*].

***n*-Butyl iodide** *[542-69-8]* **M 184.0, b 130.4°, d 1.616, n^{25} 1.44967.** Dried with $MgSO_4$ or P_2O_5, fractionally distd through a column packed with glass helices, taking the middle fraction and storing with calcium or mercury in the dark. Also purified by prior passage through activated alumina or by shaking with conc H_2SO_4 then washing with Na_2SO_3 soln. It has also been treated carefully with sodium to remove free HI and H_2O, before distilling in a column containing copper turnings at the top. Another purification consisted of treatment with bromine, followed by extraction of free halogen with $Na_2S_2O_3$, washing with H_2O, drying and fractional distn.

***sec*-Butyl iodide** see **2-iodobutane.**

***tert*-Butyl iodide** *[558-17-8]* **M 184.0, b 100°(dec), d 1.544.** Vacuum distn has been used to obtain a distillate which remained colourless for several weeks at -5°. More extensive treatment has been used by Boggs, Thompson and Crain [*JPC* **61** 625 *1957*] who washed with aq $NaHSO_3$ soln to remove free iodine, dried for 1h with Na_2SO_3 at 0°, and purified by four or five successive partial freezings of the liquid to obtain colourless material which was stored at -78°.

***tert*-Butyl isocyanide** *[7188-38-7]* **M 83.1, b 91-92°/730mm, 90°/758mm, d^{20} 0.735.** Dissolve in pet ether (b 40-60°) wash with H_2O, dry (Na_2SO_4), remove pet ether under slight vacuum, dist using a vacuum-jacketed Vigreux column at atmospheric pressure, IR: ν 2134 cm^{-1}. [*B* **93** 239 *1960*].

***tert*-Butyl isocyanate** *[1609-86-5]* **M 99.1, m 10.5-11.5°, b 30.5-32°/10mm, 64°/52mm, d_{25}^{25} 0.9079, n_D^{25} 1.470.** It is **LACHRYMATORY** and **TOXIC**, and should have IR with 2251 (C≡N) cm^{-1} and no OH bands. The NMR should have one band at 1.37 ppm from TMS. Purified by fractional distn under reduced pressure. [*JOC* **36** 3056 *1971*; *J prackt Chem.* **125** 152 *1930*].

***tert*-butyl isocyanoacetate** *[2769-72-4]* **M 141.2, b 50°/0.1mm, 49-50°/10mm, 63-65°/15mm, d_4^{20} 0.970, n_D^{20} 1.420.** If it contains some free acid (OH bands in IR) then dissolve in Et_2O, shake with 20% Na_2CO_3, dry over anhydrous K_2CO_3, evaporate and distil. [*B* **94** 2814 *1961*].

***n*-Butyl mercaptan** see **1-butanethiol.**

***sec*-Butyl mercaptan** see **2-butanethiol.**

***tert*-Butyl mercaptan** see **2-methylpropane-2-thiol.**

***n*-Butyl methacrylate** *[97-88-1]* **M 142.2, b 49-52°/0.1mm,**
***tert*-Butyl methacrylate** *[585-07-9]* **M 142.2.** Purified as for butyl acrylate.

2-*tert*-Butyl-4-methoxyphenol (2-*tert*-butyl-4-hydroxyanisole) *[121-00-6]* **M 180.3, m 64.1°.** Fractionally distd *in vacuo*, then passed as a soln in $CHCl_3$ through alumina, and the solvent evaporated from the eluate. Recrystd from pet ether.

***n*-Butyl methyl ether** *[628-28-4]* **M 88.2, b 70°, d 0.744.** Dried with $CaSO_4$, passed through an alumina column to remove peroxides, and fractionally distd.

***dl-sec*-Butyl methyl ether** *[1634-04-4]* **M 88.2, b 54°, n 1.369.** Same as for *n*-butyl methyl ether.

***tert*-Butyl methyl ketone** *[75-97-8]* **M 100.2, b 105°/746mm, 106°/760mm, d 0.814, n 1.401.** Refluxed with a little $KMnO_4$. Dried with $CaSO_4$ and distd.

***sec*-Butylmetrazole** *[25717-83-3]* **M 194.3, m 70°.** Crystd from pet ether, and dried for 2 days under vacuum over P_2O_5.

***tert*-Butyl nitrite** *[540-80-7]* **M 103.1, b 34°/250mm, 61-63°/atm, d_4^{20} 0.8671, n_D^{25} 1.3660.** If it is free from OH bands (IR) then distil through a 12inch helices packed column under reduced pressure,

otherwise wash with aq 5% $NaHCO_3$ (**effervescence**), then H_2O, dry (Na_2SO_4) and fractionate through a 10 theoretical plates column at *ca* 10mm pressure. [*JCS* 1968 *1954*, *JACS* **70** 1516 *1948*; UV: *JOC* **21** 993 *1956*; IR: *Bull Soc Chim Belges* **60** 240 *1951*].

***p-tert*-Butylnitrobenzene** *[3282-56-2]* **M 179.2, m 28.4°.** Fractionally crystd three times by partially freezing a mixture of the mono-nitro isomers, then recryst from MeOH twice and dried under vacuum [Brown *JACS* **81** 3232 *1959*].

***N*-(*n*-Butyl)-5-nitro-2-furamide** *[14121-89-2]* **M 212.2, m 89-90°.** Recrystd twice from EtOH/water mixture.

Butyloxirane (1-hexene oxide) *[1436-34-6]* **M 100.2, b 116-117°/atm, 116-119°/atm, d_4^{20} 0.833, n_D^{20} 1.44051.** Purified by fractional distn through a 2ft helices packed column at atmospheric pressure in a N_2 atm. [*JOC* ***30*** 1271 *1965*; *JCS* 2433 *1927* ; ^{13}C NMR *JCS Perk Tran II* 861 *1975*].

***tert*-Butyl peracetate** *[107-71-1]* **M 132.2, b 23-24°/0.5mm, n^{25} 1.4030.** Washed with $NaHCO_3$ from a benzene soln, then redistd to remove benzene [Kochi *JACS* **84** 774 *1962*]. *Handle with adequate protection due to possible* **EXPLOSIVE** *nature.*

***tert*-Butylperoxy isobutyrate** *[109-13-7]* **M 160.2, f.p. -45.6°.** After diluting 90ml of the material with 120ml of pet ether, the mixture was cooled to 5° and shaken twice with 90ml portions of 5% NaOH soln (also at 5°). The non-aqueous layer, after washing once with cold water, was dried at 0° with a mixture of anhydrous $MgSO_4$ and $MgCO_3$ containing *ca* 40% MgO. After filtering, this material was passed, twice, through a column of silica gel at 0° (to remove *tert*-butyl hydroperoxide). The soln was evapd at 0°/0.5-1mm to remove the solvent, and the residue was recrystd several times from pet ether at -60°, then subjected to high vac to remove traces of solvent [Milos and Golubovic *JACS* **80** 5994 *1958*]. *Handle with adequate protection due to possible* **EXPLOSIVE** *nature.*

***tert*-Butylperphthalic acid** *[15042-77-0]* **M 238.2.** Crystd from Et_2O and dried over H_2SO_4. *Possibly* **EXPLOSIVE**.

***p-tert*-Butylphenol** *[98-54-4]* **M 150.2, m 99°.** Crystd to constant melting point from pet ether (b 60-80°). Also purified *via* its benzoate, as for phenol.

***p-tert*-Butylphenoxyacetic acid** *[1798-04-5]* **M 208.3, m 88-89°.** Crystd from pet ether/C_6H_6 mixture.

***n*-Butylphenyl *n*-butylphosphonate** see entry in Chapter 4, also see **tributyl phosphate** in Chapter 4.

***tert*-Butyl phenyl carbonate** *[6627-89-0]* **M 194.2, b 74-78°/0.5mm, 83°/0.6mm, d_4^{20} 1.05, n_D^{20} 1.480.** If IR is free from OH then purify by redistillation, otherwise, dissolve in Et_2O, wash with 5% HCl, then H_2O, dry over $MgSO_4$, evap and distil through a Claisen head under vacuum. Care should be taken in the distillation as distn of large quantities can lead to decomposition with liberation of CO_2 and isobutylene, **use the necessary precautions.** [*JACS* **79** 98 *1957*].

***p-tert*-Butylphenyl diphenylphosphate** see entry in Chapter 4.

***n*-Butyl phenyl ether** *[1126-79-0]* **M 150.2, b 210.5°, d 0.935.** Dissolved in ethyl ether, washed first with 10% aq NaOH to remove traces of phenol, then repeatedly with distilled water, followed by evaporation of the solvent and distn under reduced pressure [Arnett and Wu *JACS* **82** 5660 *1960*].

***N-tert*-Butyl α-phenyl nitrone** *[3376-24-7]* **M 177.2, m 73-74°.** Crystd from hexane.

Butyl phosphate see **tri-*n*-butyl phosphate** entry in Chapter 4.

Butyl phthalate *[84-74-2]* **M 278.4, f.p. -35°, b 340°/760mm, d 1.043.** Freed from alcohol by washing with H_2O, or from acids and butyl hydrogen phthalate by washing with dilute NaOH. Distd at 10torr or less.

4-*tert*-Butyl pyridine *[3978-81-2]* **M 135.2, f.p. -44.4°, b 194-197°atm, 197°/765mm, d_4^{20} 0.923, n_D^{20} 1.495.** It is dried over solid KOH and is purified by fractional distn through an efficient column under dry N_2. It has a pKa^{25} (H_2O) 5.82. Its *picrate* has **m** 153.9-154°, and the *hydrochloride* has **m** 151.7-154.8° (from Me_2CO). [*JACS* **73** 3308, 3310 *1951*, IR: *JACS* **100** 214 *1978*; *JCS* 4454 *1960*].

Butyl stearate *[123-95-5]* **M 340.6, m 26.3°, d 0.861.** Acidic impurities removed by shaking with 0.05M NaOH or a 2% $NaHCO_3$ soln, followed by several water washes, then purified by fractional freezing of the melt and fractional crystn from solvents with boiling points below 100°.

S-*tert*-Butyl thioacetate *[999-90-6]* **M 132.2, b 31-32°/11mm, 38°/14mm, 44-45°/28mm, 67°/54mm, 135.6-135.9°/773mm, d_4^{25} 0.9207, n_D^{20} 1.4532.** Dissolve in $CHCl_3$ (EtOH-free), wash with H_2O, 10% H_2SO_4, saturated aqueous $NaHCO_3$ (care CO_2 liberated), H_2O again, dried over Drierite and anhydrous K_2CO_3, and fractionate under reduced pressure. [*JACS* **72** 3021 *1950*].

***p*-*tert*-Butyltoluene [98-51-1] M 148.3, f.p. -53.2°, b 91°/28mm, d 0.854, n 1.4920.** A sample containing 5% of the *meta*-isomer was purified by selective mercuration. Fractional distn of the solid arylmercuric acetate, after removal from the residual hydrocarbon, gave pure *p*-*tert*-butyltoluene [Stock and Brown *JACS* **81** 5615 *1959*].

***tert*-Butyl 2,4,6-trichlorophenyl carbonate** *[19065-08-5]* **M 297.6, m 64-66°.** Crystd from a mixture of MeOH (90ml) and water (6ml) using charcoal [Broadbent et al. *JCS(C)* 2632 *1967*].

***N*-*tert*-Butyl urea** *[1118-12-3]* **M 116.2, m 182°, 185°(dec).** Possible impurity is *N,N'*-di-*tert*-butyl urea which is quite insol in H_2O. Recrystd from hot H_2O, filter off insol material, and cool to 0° to -5° with stirring. Dry in vac at room temp over KOH or H_2SO_4. If dried at higher temperatures it sublimes slowly. It can be recrystd from EtOH as long white needles or from 95% aq EtOH as plates. During melting point determination the bath temp has to be raised rapidly as the urea sublimes slowly above 100° at 760mm. [*Org Synth* Coll Vol III 151 *1955*].

Butyryl chloride (butanoyl chloride) *[141-75-3]* **M 106.6, m -89°, b 101-102°/atm, d_4^{20} 1.026, n_D^{20} 1.412.** Check IR to see if there is a significant peak at 3000-3500 cm^{-1} (br) for OH. If OH is present then reflux with less than one mol equiv of $SOCl_2$ for 1h and distil directly. The fraction boiling between 85-100° is then refractionated at atm pressure. Keep all apparatus free from moisture and store the product in sealed glass ampoules under N_2. **LACHRYMATORY** - *handle in a good fume hood.* [*Org Synth* Coll Vol I 147 *1941*].

***n*-Butyl vinyl ether** *[111-34-2]* **M 100.2, b 93.3°, d 0.775.** After five washings with equal volumes of water to remove alcohols (made slightly alkaline with KOH), the ether was dried with sodium and distd under vacuum, taking the middle fraction [Coombes and Eley *JCS* 3700 *1957*]. Stored over KOH.

2-Butyne *[503-17-3]* **M 54.1, b 0°/253mm, d 0.693.** Stood with sodium for 24h, then fractionally distd under reduced pressure.

2-Butyne-1,4-diol *[110-65-6]* **M 86.1, m 54-57°.** Crystd from EtOAc.

***n*-Butyraldehyde** *[123-72-8]* **M 72.1, b 74.8°, d 0.810, n 1.37911, n^{15} 1.38164.** Dried with $CaCl_2$ or $CaSO_4$, then fractionally distd under N_2. Lin and Day [*JACS* **74** 5133 *1952*] shook with batches of $CaSO_4$ for 10min intervals until a 5ml sample, on mixing with 2.5ml of CCl_4 containing 0.5g of aluminium isopropoxide, gave no ppte and caused the soln to boil within 2min. Water can be removed from *n*-butyraldehyde by careful distn as an azeotrope distilling at 68°. The aldehyde has also been purified through its

bisulphite compound which, after decomposing with excess $NaHCO_3$ soln, was steam distd, extracted under N_2 into ether and, after drying, the extract was fractionally distd [Kyte, Jeffery and Vogel *JCS* 4454 *1960*].

Butyramide *[514-35-5]* **M 87.1, m 115°, b 230°.** Crystd from acetone, benzene, CCl_4-pet ether, 20% EtOH or water. Dried under vacuum over P_2O_5, $CaCl_2$ or 99% H_2SO_4.

***n*-Butyric acid** *[107-92-6]* **M 88.1, f.p. -5.3°, b 163.3°, d 0.961, n 1.39796, n^{25} 1.39581.** Distd, mixed with $KMnO_4$ (20g/L), and fractionally redistd, discarding the first third [Vogel *JCS* 1814 *1948*].

***n*-Butyric anhydride** *[106-31-0]* **M 158.2, b 198°, d 0.968.** Dried by shaking with P_2O_5, then distd.

γ-Butyrolactone *[96-48-0]* **M 86.1, b 83.8°/12mm, d 1.124.** Dried with anhydrous $CaSO_4$, then fractionally distd. *Handle in a fume cupboard due to* **TOXICITY.**

Butyronitrile *[109-74-0]* **M 69.1, b 117.9°, d 0.793, n 1.3846, n^{30} 1.37954.** Treated with conc HCl until the smell of the isonitrile had gone, then dried with K_2CO_3 and fractionally distd [Turner *JCS* 1681 *1956*]. Alternatively it was twice heated at 75° and stirred for several hours with a mixture of 7.7g Na_2CO_3 and 11.5g $KMnO_4$ per L of butyronitrile. The mixture was cooled, then distd. The middle fraction was dried over activated alumina. [Schoeller and Wiemann *JACS* **108** 22 *1986*].

Cactheline

(2,3-dihydro-4-nitro-2,3-dioxo-9,10-*seco*strychnidin-10-oic acid) *[561-20-6]* **M 508.4.** Yellow crystals from H_2O. It is then dried over H_2SO_4 which gives the *dihydrate*, and in a vacuum over H_2SO_4 at 105° to give the anhydrous compound. The *hydrochloride* separates as the hydrate (on heating in vacuum at 80°) in orange-yellow prisms or plates, **m** 250°(dec), and forms a *resorcinol complex* which gives brown crystals from EtOH, **m** 325°, and a *hydroquinone complex* as dark red crystals from EtOH, **m** 319°. [*B* **43** 1042 *1910*, **86** 232, UV: 242 *1953*; complexes: Gatto *Gazetta Chim Ital* **85** 1441 *1955*].

Caffeic acid *[331-39-5]* **M 180.2, m 195°.** Crystd from water.

Caffeine *[58-08-2]* **M 194.2, m 237°.** Crystd from water or absolute EtOH.

(+)-Calarene (+ β-gurjunen, 1,3,3,11-tetramethyltricyclo[5.4.0.$0^{2,4}$]undecan-7-ane, (1a*R*)-1,1,7c,7ac-tetramethyl-1a,2,3,5,6,7,7a,7b-octahydro-1*H*-cyclopropa[α]naphthalene, new name 1(10)aristolene) *[17334-55-3]* **M 204.35, b 45-47°/0.008-0.01mm, 255-258°/atm, d_4^{20} 0.9340, n_D^{20} 1.55051, $[\alpha]_D^{20}$ +58° (EtOH), +81.8° (neat).** Purified by gas chromatography (7% propylene glycol adipate on unglazed tile particles of size 0.2-0.3mm, 400 cm column length and 0.6 cm diameter, at 184°, with N_2 carrier gas at a flow rate of 0.54 ml/sec using a Griffith and George Type IIA thermal detector). Also purified by chromatography on alumina (200 times the weight of calarene) and eluted with pet ether. UV: λ_{max} 200 and 210 nm (ε 9560, 5480) in EtOH. [IR: Sorm *Coll Czech Chem Comm* **18** 512 *1953*, **29** 795 *1964*; *TET LETT* 827 *1962*, 225 *1963*].

Calcein *[1461-15-0]* **M 622.5.** Free acid crystd from 50% aq MeOH, or 300mg sample in minimum amount of 0.1M NaOH, add 50ml 10-20% aqueous MeOH and filter. To the filtrate add 1M HCl to adjust to pH 2.5. Refrigerate overnight and filter on a No 4 glass filter. Wash well with MeOH and dry *in vacuo*. [Wallach et al. *AC* **31** 456 *1959*].

Calcon carboxylic acid *[3737-95-9]* **M 428.4, m 300°.** Purified through its *p*-toluidinium salt. The dye was dissolved in warm 20% aq MeOH and treated with *p*-toluidine to ppte the salt after cooling. Finally recrystd from hot water. [Itoh and Ueno *Analyst* **95** 583 **1970**].

Calmagite *[3147-14-6]* **M 358.4, m 300°.** Crude sample was extracted with anhydrous ethyl ether [Lindstrom and Diehl *AC* **32** 1123 *1960*].

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bisulphite compound which, after decomposing with excess $NaHCO_3$ soln, was steam distd, extracted under N_2 into ether and, after drying, the extract was fractionally distd [Kyte, Jeffery and Vogel *JCS* 4454 *1960*].

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γ-Butyrolactone *[96-48-0]* **M 86.1, b 83.8°/12mm, d 1.124.** Dried with anhydrous $CaSO_4$, then fractionally distd. *Handle in a fume cupboard due to* **TOXICITY.**

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Cactheline (2,3-dihydro-4-nitro-2,3-dioxo-9,10-*seco*strychnidin-10-oic acid) *[561-20-6]* M 508.4.

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Calmagite *[3147-14-6]* **M 358.4, m 300°.** Crude sample was extracted with anhydrous ethyl ether [Lindstrom and Diehl *AC* **32** 1123 *1960*].

Campesterol (24*R*-24-methylcholest-5-en-3β-ol) *[474-62-4]* **M 400.7, m 156-159°, 157-158°, $[\alpha]_D^{24}$ -35.1° (c 1.2, $CHCl_3$).** Recryst twice from hexane and once from Me_2CO. The *benzoyl derivative* has **m** 158-160° $[\alpha]_D^{23}$ -8.6° ($CHCl_3$), the *acetyl derivative* has ***m*** *137-138°* (from EtOH) and $[\alpha]_D^{23}$ -35.1° (c 2.9, $CHCl_3$) [*JACS* **63** 1155 *1941*].

1*R*,4*S*-(-)-Camphanic acid *[13429-83-9]* **M 198.2, m 190-192°, 198-200°, $[\alpha]_{548}^{20}$ -22.5° (c 1, dioxane), -4.4° (c 8, EtOH).** Dissolve in CH_2Cl_2, dry ($MgSO_4$), filter, evaporate and residue is sublimed at 120°/0.5mm or 140°/1mm. [*HCA* **61** 2773 *1978*].

1*R*,4*S*-(-)-Camphanic acid chloride *[39637-74-6]* **M 216.7, m 65-66.5°, 70.5-71°, $[\alpha]_{548}$ -23° (c 2, CCl_4), -7.5° (c 0.67, benzene).** Soluble in toluene (50g/100ml at 0°) and crysts from pet ether (b 40-60°). It sublimes at 70°/5mm, Store dry at 0°, ν (CCl_4) 1805s and 1780m cm^{-1}. [*JCSDT* 2229 *1976*].

***RS*-Camphene** *[565-00-4]* **M 136.2, m 51-52°, b 40-70°/10mm.** Crystd twice from EtOH, then repeatedly melted and frozen at 30mm pressure. [Williams and Smyth *JACS* **84** 1808 *1962*]. Alternatively it is dissolved in Et_2O, dried over $CaCl_2$ and Na, evaporated and the residue sublimed in a vacuum [NMR: *B* **111** 2527 *1978*].

(-)-Camphene (1*S* -2,2-dimethyl-3-methylene norbornane) *[5794-04-7]* **M 136.2, m 49.2-49.6°, 49-50°, b 79-80°/58mm, 91.5°/100mm, d_4^{54} 0.8412, n_D^{54} 1.4564, $[\alpha]_D^{25}$ -106.2° (c 40, C_6H_6), -117.5° (c 19, toluene), -113.5° (c 9.7, Et_2O).** Purified by fractionation through a Stedman column at 100mm in a N_2 atmosphere, crystallised from EtOH and sublimed in a vacuum below its melting point. It is characterised by its *camphenilone semicarbazone*, **m** 217-218.5°, or *camphor semicarbazone*, **m** 236-238°. [NMR: *B* **111** 2527 *1978*; *A* **623** 217 *1959*; Bain et al. *JACS* **72** 3124 *1950*]

***R*-(+)-** *[464-49-3]* **and *S*-(-)-** *[464-48-2]* **Camphor (1*R*-bornan-2-one) M 136.2, m 178.8°, 179.97°(open capillary), b 204°/atm, $[\alpha]_{546}^{35}$ ±59.6° (in EtOH), $[\alpha]_D^{20}$ ±44.3° (c 10, EtOH), $[\alpha]_{579}^{179}$ ±70.85° (melt).** Crystd from EtOH, 50% EtOH/water, MeOH, or pet ether or from glacial acetic acid by addition of water. It can be sublimed (50°/14mm) and also fractionally crystd from its own melt. It is steam volatile. It should be stored in tight containers as it is appreciably volatile at room temperature. The solubility is 0.1% (H_2O), 100% (EtOH), 173% (Et_2O) and 300% ($CHCl_3$). The *R-oxime* (from Et_2O, $CHCl_3$, or dil EtOH) **m** 119° $[\alpha]_D^{20}$ -42.4° (c 3, EtOH); the ± *oxime* has **m** 118-119°. [*B* **67** 1432 *1934*; Allan and Rodgers *JCS (B)* 632 *1971*; UV, NMR: Fairley et al. *JCS Perkin Trans I* 2109 *1973*; *JACS* **62** 8 *1940*].

***(1R,2S)*-(+)-** *[124-83-4]* **and *(1S,2R)*-(-)-** *[560-09-9]* **Camphoric acid (1,2,2-trimethylcyclopentan-1*r*,3*c*-dicarboxylic acid) M 200.2, m 186-188°, 187°, 186.5-189°, $[\alpha]_{546}^{20}$ ±57° (c 1, EtOH), $[\alpha]_D^{20}$ ±47.7° (c 4, EtOH).** Purified by repptn from an alkaline soln by HCl, filtered, and rerystd from water several times, rejecting the first crop. It forms leaflets from EtOH and Me_2CO and H_2O and is insol in $CHCl_3$. Sol in H_2O is 0.8% at 25° and 10% at 100°; 50% (EtOH) and 5% in ethylene glycol. The *(±)-acid* has **m** 202-203°. The *(+)-1-methyl ester* had **m** 86° (from pet ether) $[\alpha]_D^{20}$ +45° (c 4, EtOH), and the *(+)-3-methyl ester* has **m** 77° (from pet ether) $[\alpha]_D^{17.5}$ +53.9° (c 3, EtOH). [*JACS* **53** 1661 *1931*; *HCA* **30** 933 *1947*; *Acta Chem Scand* **2** 597 *1948*]. The acid has pKa values of 4.71 and 5.83 in H_2O [*JACS* **80** 6316 *1958*].

(±)-Camphoric anhydride *[595-30-2]* **M 182.2, transition temp 135°, m 223.5°.** Crystd from EtOH.

(1R)*-(-)-** *[10334-26-6]* ***(1S)*-(+)-** *[2767-84-2]* **Camphorquinone (borna-2,3-dione) M 166.2, m 198.7°, 198-199°, 197-201°, $[\alpha]_D^{25}$ ±101.1° (c 2, EtOH).** It can be purified by steam distillation, recrystn (yellow prisms) from EtOH, C_6H_6 or Et_2O-pet ether and can be sublimed in a vacuum. The *(±)-quinone* forms needles from EtOH, **m** 197-198°, 203°. [*HCA* **13** 1026; ***B **67** 1432 *1934*].

***(1R)*-(-)Camphor-10-sulphonic acid** *[35963-20-3]* **M 232.3, m 197.4-198°(dec), 197-198°, $[\alpha]_D^{20}$ -20.7° (c 5.4, H_2O).** Forms prisms from AcOH or EtOAc, and is deliquescent in moist air. Store

in tightly stoppered bottles. The *NH_4 salt* forms needles from H_2O $[\alpha]_D^{16}$ ±20.5° (c 5, H_2O). [*JCS* **127** 279 *1925* ; *JACS* **78** 3063 *1956*].

(*1S*)-(+)Camphor-10-sulphonic acid *[3144-16-9]* **M 232.3, m 193°(dec), 197-198°, $[\alpha]_{546}^{20}$ +27.5° (c 10, H_2O), $[\alpha]_D^{20}$ +43.5° (c 4.3, EtOH).** Crystd from ethyl acetate and dried under vacuum.

(*1S*)-(+)- *[21286-54-4]* **and (*1R*)-(-)-** *[39262-22-1]* **Camphor-10-sulphonyl chloride M 250.7, m 67-68°, 70°, $[\alpha]_D^{20}$ ±32.2° (c 3, $CHCl_3$).** If free from OH bands in the IR then recryst from Et_2O or pet ether, otherwise treat with $SOCl_2$ at 50° for 30min, evaporate, dry residue over KOH in a vacuum and recrystallise. The *(±)-acid chloride* has **m** 85°. Characterised as the *amide* (prisms from EtOH) **m** 132°, $[\alpha]_D^{17}$ ±1.5° (EtOH). [Read and Storey *JCS* 2761 *1930*; *JACS* **58** 62 *1936*].

***S*-Canavanine** *[543-38-4]* **M 176.2, m 184°, $[\alpha]_D^{17}$ +19.4° (c 2, H_2O),**
***S*-Canavanine sulphate** *[2219-31-0]* **M 274.3, m 172°(dec), $[\alpha]_D^{20}$ +17.3° (c 3.2, H_2O).** Crystd from aqueous EtOH.

Cannabinol *[521-35-7]* **M 310.4, m 76-77°, b 185°/0.05mm.** Crystd from pet ether. Sublimed.

Canthaxanthin (*trans*) *[514-78-3]* **M 564.9, m 211-212°, $\varepsilon_{1cm}^{1\%}$ 2200 (470nm) in cyclohexane.** Purified by chromatography on a column of deactivated alumina or magnesia, or on a thin layer of silica gel G (Merck), using dichloromethane/ethyl ether (9:1) to develop the chromatogram. Stored in the dark and in an inert atmosphere at -20°.

Capric acid (decanoic acid) *[334-48-5]* **M 172.3, m 31.5°, b 148°/11mm, d 0.8858, n^{25} 1.4239.** Purified by conversion to its *methyl ester*, **b** 114.0°/15mm (using excess MeOH, in the presence of H_2SO_4). After removal of the H_2SO_4 and excess MeOH, the ester was distd under vacuum through a 3ft column packed with glass helices. The acid was then obtained from the ester by saponification. [Trachtman and Miller *JACS* **84** 4828 *1962*].

***n*-Caproamide** *[628-02-4]* **M 115.2, m 100°.** Crystd from hot water.

Caproic acid *[142-62-1]* **M 116.2, b 205.4°, d 0.925, n 1.4168.** Dried with $MgSO_4$ and fractionally distilled from $CaSO_4$.

ε-Caprolactam (azepan-2-one, aza-2-cycloheptanone) *[105-60-2]* **M 113.2, m 70°, 70.5-71.5°, 70-71°, 262.5°/760mm.** Distd at reduced pressure, crystd from acetone or pet ether and redistd. Purified by zone melting. Very *hygroscopic*. Discolours in contact with air unless small amounts (0.2g/L) of NaOH, Na_2CO_3 or $NaBO_2$ are present. Crystd from a mixture of pet ether (185ml of b 70°) and 2-methyl-2-propanol (30ml), from acetone, or pet ether. Distd under reduced pressure and stored under nitrogen. [*S* 614 *1978*].

Capronitrile *[124-12-9]* **M 125.2, b 163.7°, n 1.4069, n^{25} 1.4048.** Washed twice with half-volumes of conc HCl, then with saturated aqueous $NaHCO_3$, dried with $MgSO_4$, and distilled.

Caprylic acid see ***n*-octanoic acid.**

Caprylolactam (azanon-2-one, azacyclononan-2-one, 8-aminooctanoic acid lactam) *[935-30-8]* **M 141.2, m 72°, 73°, 74-76°, 75°, 76-77°, b 119-122°/0.7mm, 150-151°/7-8mm, 164°/14mm, d_4^{73} 1.0087, n_D^{73} 1.4889.** Dissolve in $CHCl_3$, decolorise with charcoal, evaporate to dryness and recrystallise from $CHCl_3$-hexane. Sublime at high vacuum. pKa^{25} 0.55 in AcOH. The *oxime* has **m** 117° (from C_6H_6 or pet ether). [*J Med Chem* **14** 501 *1971*; *A* **607** 67 *1957*].

Capsaicin (*E*-*N*-[(4-hydroxy-3-methoxyphenyl)-methyl]-8-methyl-6-nonenamide) *[404-86-4]* **M 305.4, m 64-66°, 65°, 66.1°, b 210-220°/0.01mm.** Recrystd from pet ether (b 40-60°), or pet ether-Et_2O (9:1). Also purified by chromatography on neutral Al_2O_3 (grade V) and eluted successively with

C_6H_6, C_6H_6-EtOAc (17:3) and C_6H_6-EtOAc (7:3), and distilled at 120°/10^{-5}mm, and repeatedly recrystd from isopropanol (charcoal), needles. [*JCS* 11025 *1955*, *JCS(C)* 442 *1968*].

Capsorubin *[470-38-2]* **M 604.9, m 218°, λ_{max} 443, 468, 503 nm, in hexane.** Possible impurities: zeaxanthin and capsanthin. Purified by chromatography on a column of $CaCO_3$ or MgO. Crystd from benzene/pet ether or CS_2.

Captan *[133-06-2]* **M 300.5, m 172-173°.** Crystd from CCl_4.

Captopril (*S*-1-[3-mercapto-2-methyl-1-oxopropyl]-L-proline) *[62571-86-2]* **M 217.3, m 103-104°(polymorphic unstable form m 86°, melts at 87-88° solidifies and then melts again at 104-105°), $[\alpha]_D^{22}$ -131° (c 1.7, EtOH).** Purified by recrystn from EtOAc-hexane. Also purified by dissolving in EtOAc and chromatographed on a column of Wakogel C200 using a linear gradient of MeOH in EtOAc (0-100°) and fractions which give a positive nitroprusside test (for SH) are combined, evap and recrystd from EtOAc-hexane (1:1), white crystals $[\alpha]_D^{20}$ -128.2° (c 2.0, EtOH). It has pKa values of 3.7 and 9.8 in H_2O. [Nam *J Pharm Sci* **73** 1843 *1984*]. Alternatively, dissolve in H_2O, apply to a column of AG-50Wx2 (BioRad) and eluted with H_2O. The free acid is converted to the dicyclohexylamine salt in MeCN by addition until the pH is 8-9 (moist filter paper). The salt is converted to the free acid by shaking with EtOAc and 10% aq $KHSO_4$ or passage through an AG50Wx2 column. The EtOAc soln is dried ($MgSO_4$) and recrystd as above from EtOAc-hexane [*BJ* **16** 5484 *1977*; NMR and IR: Horii and Watanabe *J Pharm Soc Japan* **81** 1786 *1961*].

4-(Carbamoylmethoxy)acetanilide *[14260-41-4]* **M 208.2, m 208°.** Crystd from water.

3-Carbamoyl-1-methylpyridinium chloride *[1005-24-9]* **M 172.6.** Crystd from MeOH.

Carbanilide *[102-07-8]* **M 212.3, m 242°.** Crystd from EtOH or a large volume (40ml/g) of hot water.

9-Carbazolacetic acid *[524-80-1]* **M 225.2, m 215°.** Crystd from ethyl acetate.

Carbazole *[86-74-8]* **M 167.2, m 240-243°.** Dissolved (60g) in conc H_2SO_4 (300ml), extracted with three 200ml portions of benzene, then stirred into 1600ml of an ice-water mixture. The ppte was filtered off, washed with a little water, dried, crystd from benzene and then from pyridine/benzene. [Feldman, Pantages and Orchin *JACS* **73** 4341 *1951*]. Has also been crystd from EtOH or toluene, sublimed in vacuum, zone-refined, and purified by TLC.

Carbazole-9-carbonyl chloride *[73500-82-0]* **M 300.0, m 100-103°, 103.5-104.5°**. Recrystd from C_6H_6. If it is not very pure (presence of OH or NH bands in the IR) dissolve in pyridine, shake with phosgene in toluene, evaporate and recrystallise the residue. Carry out this experiment in a good fume cupboard as $COCl_2$ is very **TOXIC**, and store the product in the dark. It is moisture sensitive. The *amide* has **m** 246.5-247°, and the *dimethylaminoethylamide hydrochloride* has **m** 197-198°. {Weston et al. *JACS* **75** 4006 *1953*].

4-Carboethoxy-3-methyl-2-cyclohexen-1-one *[487-51-4]* **M 182 , b 79-80°/0.2mm, 121-123°/4mm, 142-144°/15mm, d_4^{20} 1.038.** Dissolve in ether, shake with solid K_2CO_3, aqueous saturated $NaHCO_3$, dry ($MgSO_4$) and distil. *Semicarbazone* has **m** 165-167° (169°). [*JACS* **65**, 631, *1943*].

1-Carbethoxy-4-methylpiperazine hydrochloride *[532-78-5]* **M 204.7, m 168.5-169°.** Crystd from absolute EtOH.

***N*-Carboethoxyphthalimide** *[22509-74-6]* **M 219.2, m 87-89°, 90-92°.** Crystd from toluene-pet ether (or benzene-pet ether). Partly soluble in Et_2O, benzene and $CHCl_3$. [*B* **54** 1112 *1921*].

Carbitol see **diethylene glycol monoethyl ether.**

Carbobenzoxy chloride see **benzyloxycarbonyl chloride.**

γ–Carboline *[244-63-3]* **M 168.2, m 225°.** Crystd from water.

Carbon Black Leached for 24h with 1:1 HCl to remove oil contamination, then washed repeatedly with distd water. Dried in air, and eluted for one day each with benzene and acetone. Again dried in air at room temp, then heated in a vacuum for 24h at 600° to remove adsorbed gases. [Tamamushi and Tamaki *TFS* **55** 1007 *1959*].

Carbon disulphide *[75-15-0]* **M 76.1, b 46.3°, d 1.264, n 1.627.** Shaken for 3h with three portions of $KMnO_4$ soln (5g/L), twice for 6h with mercury (to remove sulphide impurities) until no further darkening of the interface occurred, and finally with a soln of $HgSO_4$ (2.5g/L) or cold, satd $HgCl_2$. Dried with $CaCl_2$, $MgSO_4$, or CaH_2 (with further drying by refluxing with P_2O_5), followed by fractional distn in diffuse light. **Alkali metals cannot be used as drying agents**. Has also been purified by standing with bromine (0.5ml/L) for 3-4h, shaking with KOH soln, then copper turnings (to remove unreacted bromine), and drying with $CaCl_2$. CS_2 is highly **TOXIC** and highly **FLAMMABLE**. *Work in a good fumehood.*
Small quantities of CS_2 have been purified (including removal of hydrocarbons) by mechanical agitation of a 45-50g sample with a soln of 130g of sodium sulphide in 150ml of H_2O for 24h at 35-40°. The aqueous sodium thiocarbonate soln was separated from unreacted CS_2, then ppted with 140g of copper sulphate in 350g of water, with cooling. After filtering off the copper thiocarbonate, it was decomposed by passing steam into it. The distillate was separated from H_2O and distd from P_2O_5. [Ruff and Golla *Z anorg Chem* **138** 17 *1924*].

Carbon tetrabromide *[558-13-4]* **M 331.7, m 92.5°.** Reactive bromide was removed by refluxing with dilute aqueous Na_2CO_3, then steam distd, crystd from EtOH, and dried in the dark under vacuum. [Sharpe and Walker *JCS* 157 *1962*]. Can be sublimed at 70° at low pressure.

Carbon tetrachloride *[56-23-5]* **M 153.8, b 76.8°, d^{25} 1.5842.** For many purposes, careful fractional distn gives adequate purification. Carbon disulphide can be removed by shaking vigorously for several hours with saturated KOH, separating, and washing with water: this treatment is repeated. The CCl_4 is shaken with conc H_2SO_4 until there is no further coloration, then washed with water, dried with $CaCl_2$ or $MgSO_4$ and distd (from P_2O_5 if desired). **It must not be dried with sodium.** An initial refluxing with mercury for 2h removes sulphides. Other purification steps include passage of dry CCl_4 through activated alumina, and distn from $KMnO_4$. Carbonyl containing impurities can be removed by percolation through a Celite column impregnated with 2,4-dinitrophenylhydrazine (DNPH), H_3PO_4 and water. (Prepared by dissolving 0.5g DNPH in 6ml of 85% H_3PO_4 by grinding together, then mixing with 4ml of distd water and 10g Celite.) [Schwartz and Parks *AC* **33** 1396 *1961*]. Photochlorination of CCl_4 has also been used: CCl_4 to which a small amount of chlorine has been added is illuminated in a glass bottle (e.g. for 24h with a 200W tungsten lamp near it), and, after washing out the excess chlorine with 0.02M Na_2SO_3, the CCl_4 is washed with distd water and distd from P_2O_5. It can be dried by passing through 4A molecular sieves and distd. Another purification procedure is to wash CCl_4 with aq NaOH, then repeatedly with water and N_2 gas bubbled through the liquid for several hours. After drying over $CaCl_2$ it is percolated through silica gel and distd under dry N_2 before use [Klassen and Ross *JPC* **91** 3664 *1987*].

Carbon tetrafluoride *[75-73-0]* **M 88.0, b -15°.** Purified by repeated passage over activated charcoal at solid-CO_2 temperatures. Traces of air were removed by evacuating while alternately freezing and melting. Alternatively, liquefied by cooling in liquid air and then fractionally distilled under vacuum. (The chief impurity originally present was probably CF_3Cl).

Carbon tetraiodide *[507-25-5]* **M 519.6, m 168°(dec).** Sublimed *in vacuo*.

***N,N'*-Carbonyldiimidazole** *[530-62-1]* **M 162.2, m 115.5-116°.** Crystd from benzene or tetrahydrofuran, in a dry-box.

1,1'-Carbonyldi(1,2,4-triazole) *[41864-22-6]* **M 164.1, m 134-136°, 145-150°.** Dissolve in tetrahydrofuran and evaporate at 10mm until it crystallises. Wash crystals with cold tetrahydrofuran and dry in a vacuum desiccator over P_2O_5 in which it can be stored for months. [*Rec Trav Chim Pays Bas* **80** 1372 *1961*; Potts *JOC* **27** 2631 *1962*; Staab *A* **106** 75 *1957*].

Carbonyl sulphide *[463-58-1]* **M 60.1, b -47.5°.** Passed through traps containing saturated aqueous lead acetate and then through a column of anhydrous $CaSO_4$. **TOXIC.**

Carbostyril see **2-hydroxyquinoline.**

(Carboxymethyl)trimethylammonium chloride hydrazide see **Girard reagent T.**

o-**Carboxyphenylacetonitrile** *[6627-91-4]* **M 161.2, m 114-115°.** Crystd (with considerable loss) from benzene or glacial acetic acid.

***S*-Carnosine,**
α-, β-, γ-, and ξ-Carotenes,
λ–Carrageenan see entries in Chapter 5.

(-)-Caryophyllene oxide (1-*S*-5*c*-6*t*-epoxy-6*c*,10,10-trimethyl-2-methylene-1*r*,9*t*-bicyclo[7.2.0]undecane) *[1139-30-6]* **M 220.4, m 62-63°, 63.5-64°, 64°, b 114-117°/1.8mm, 141-142°/11mm, d_4^{20} 0.9666, n_D^{20} 1.49564, $[\alpha]_D^{20}$ −79° (c 2,$CHCl_3$), $[\alpha]_D^{20}$ −68° (supercooled melt).** Purified by TLC on silica gel with EtOAc-pet ether (b 60-80°) (15:85), and recrystallised from MeOH or C_6H_6. [NMR: Warnhoff *Canad J Chem* **42** 1664 *1964*, Ramage and Whitehead *JCS* 4336 *1954*].

Catechin *[7295-85-4]* **M 272.3, m 177° (anhyd).** Crystd from hot water. Dried at 100°.

Catechol *[120-80-9]* **M 110.1, m 105°.** Crystd from benzene or toluene. Sublimed under vacuum. [Rozo et al. *AC* **58** 2988 *1986*].

Cation exchange resin. Conditioned before use by successive washing with water, EtOH and water, and taken through two H^+-Na^+-H^+ cycles by successive treatment with M NaOH, water and M HCl then washed with water until neutral. [Ion exchange resins, BDH Handbook, 5th edn 1971].

(+)-Cedrol (octahydro-3,6,8,8-tetramethyl-1-3a,7-methanoazulen-6-ol, 8a*S*-6*c*-hydroxy-3*c*,6*t*,8,8-tetramethyl[8a*r*-*H*)-octahydro-3*H*,3a*t*,7*t*-methanoazulene), m 82-86°, 86-87°, $[\alpha]_D^{28}$ +10.5° (c 5,$CHCl_3$), $[\alpha]_D^{18}$ +13.1° (c 5.5, EtOH), $[\alpha]_D^{18}$ +14.3° (c 10, dioxane). Purified by recrystn from aqueous MeOH. It is estimated colorimetrically with H_3PO_4 in EtOH followed by vanillin and HCl [Hayward and Seymour *AC* **20** 572 *1948*]. The *3,5-dinitrobenzoyl derivative* has **m** 92-93°. [*JACS* **83** 3114 *1961*].

β-Cellobiose *[528-50-7]* **M 342.3, m 228-229°(dec), $[\alpha]_D^{25}$ +33.3° (c 2, water).** Crystd from 75% aqueous EtOH.

Cellosolve see **2-ethoxyethanol.**

Cellulose triacetate *[9012-09-3]* **M 72,000-74,000.** Extracted with cold EtOH, dried in air, washed with hot distd water, again dried in air, then dried at 50° for 30min. [Madorsky, Hart and Straus *J Res Nat Bur Stand* **60** 343 *1958*].

Cerulenin (helicocerin, 2*R*,3*S*-2,3-epoxy-4-oxo-7*E*,10*E*-dodecadienamide) *[17397-89-6]* **M 223.3, m 93-94°, 93-95°, b 120°/10^{-8}mm, $[\alpha]_D^{16}$ +63° (c 2, MeOH).** White needles from C_6H_6. Also purified by repeated chromatography from Fuoresil and silica gel. It is soluble in EtOH, MeOH, C_6H_6, slightly soluble in H_2O and pet ether. The dl-form has **m** 40-42° (from C_6H_6-hexane), and the 2*R*,3*S*-tetrahydrocerulenin has **m** 86-87°, $[\alpha]_D^{20}$ +44.4 (c 0.25, MeOH after 24h). [*TET LETT* 2095 *1978*, 2039 *1979*; *JACS* **99** 2805 *1977*; *JOC* **47** 1221 *1982*].

Cetane see ***n*-hexadecane.**

Cetyl acetate *[629-70-9]* **M 284.5, m 18.3°.** Vacuum distd twice, then crystd several times from ethyl ether/MeOH.

Cetyl alcohol (1-hexadecanol) *[36653-82-4]* **M 242.5, m 49.3°.** Crystd from aqueous EtOH or from cyclohexane. Purified by zone refining. Purity checked by gas chromatography.

Cetylamide *[629-54-9]* **M 255.4,**
Cetylamine (1-hexadecylamine) *[143-27-1]* **M 241.5, m 78°.** Crystd from thiophene-free benzene and dried under vacuum over P_2O_5.

Cetylammonium chloride *[1602-97-7]* **M 278.0.** Crystd from MeOH.

Cetyl bromide (1-bromohexadecane) *[112-82-3]* **M 305.4, m 15°, b 193-196°/14mm.** Shaken with H_2SO_4, washed with water, dried with K_2CO_3 and fractionally distd.

Cetyl ether *[4113-12-6]* **M 466.9, m 54°.** Vacuum distd then crystd several times from MeOH/benzene.

Cetylpyridinium chloride (H_2O) *[6004-24-6]* **M 358.0, m 80-83°.** Crystd from MeOH or EtOH/ethyl ether and dried *in vacuo*. [Moss et al. *JACS* **108** 788 *1986*; Lennox and McClelland *JACS* **108** 3771 *1986*].

Cetyltrimethylammonium bromide (cetrimonium bromide) *[124-03-8]* **M 364.5, m 227-235°(dec).** Crystd from EtOH, EtOH/benzene or from wet acetone after extracting twice with pet ether. Shaken with anhydrous ethyl ether, filtered and dissolved in a little hot MeOH. After cooling in the refrigerator, the ppte was filtered at room temperature and redissolved in MeOH. Anhydrous ether was added and, after warming to obtain a clear soln, it was cooled and crystalline material was filtered. [Duynstee and Grunwald *JACS* **81** 4540 *1959*; Hakemi et al. *JACS* **91** 120 *1987*].

Cetyltrimethylammonium chloride *[112-02-7]* **M 320.0.** Crystd from acetone/ether mixture, EtOH/ether, or from MeOH. [Moss et al. *JACS* **109** 4363 *1987*].

Chalcone see **benzalacetophenone.**

Charcoal. Charcoal (50g) was added to 1L of 6M HCl and boiled for 45min. The supernatant was discarded, and the charcoal was boiled with two more lots of HCl, then with distilled water until the supernatant no longer gave a test for chloride ion. The charcoal (which was now phosphate-free) was filtered on a sintered-glass funnel and air dried at 120° for 24h. [Lippin, Talbert and Cohn *JACS* **76** 2871 *1954*]. The purification can be carried out using a Soxhlet extractor (without cartridge), allowing longer extraction times. Treatment with conc H_2SO_4 instead of HCl has been used to remove reducing substances.

Chaulmoogric acid *[502-30-7]* **M 280.4, m 68.5°, b 247-248°/20mm.** Crystd from pet ether or EtOH.

Chelerythrine *[2870-15-7]* **M 389.4, m 207°.** Crystd from $CHCl_3$ by addition of MeOH.

Chelex 100 *[11139-85-8]*. Washed successively with 2M ammonia, water, 2M nitric acid and water. Chelex 100 may develop an odour on long standing. This can be removed by heating to 80° for 2h in 3M ammonia, then washing with water. [Ashbrook *JC* **105** 151 *1975*].

Chelidamic acid see **4-hydroxypyridine-2,6-dicarboxylic acid.**

Chelidonic acid *[6003-94-7]* **M 184.1, m 262°.** Crystd from aqueous EtOH.

Chenodesoxycholic acid *[474-25-9]* **M 392.6, m 143°, $[\alpha]_{546}^{20}$ +14° (c 2, EtOH).** Crystd from ethyl acetate.

Chimyl alcohol (1-*O*-*n*-hexadecylglycerol) *[6145-69-3]* **M 316.5, m 64°.** Crystd from hexane.

Chloral *[75-87-6]* **M 147.4, b 98°.** Distd, then dried by distilling through a heated column of $CaSO_4$.

Chloralacetone chloroform *[512-47-0]* **M 324.9, m 65°.** Crystd from benzene.

α-Chloralose (*R*-1,2-*O*-[2,2,2-trichloroethylidene]-α-D-glucofuranose) *[15879-93]* **M 309.5, m 180-182°, 187°, 186-188°, $[\alpha]_D^{26}$ +19.5° (c 11, pyridine).** Recrystd from EtOH, 38% aqueous EtOH, Et_2O, H_2O or $CHCl_3$ The solubility is 0.44% in H_2O at 15°, 0.83% in H_2O at 37°, 6.7% in EtOH at 25°. [Whiton and Hixon *JACS* **55** 2438 *1933*; *HCA* **6** 621 *1923*]. The β-*isomer* is less soluble in H_2O, EtOH or Et_2O and has **m** 237.5-238° [*JACS* **59** 1955 *1937*; *Acta Chem Scand* **19** 359 *1965*].

2-Chloroacetophenone *[532-27-4]* **M 154.6, m 54-56°.** Crystd from MeOH [Tanner *JOC* **52** 2142 *1987*].

Chlorambucil *[305-03-3]* **M 304.2, m 64-66°.** Crystd from pet ether.

Chloramphenicol *[56-75-7]* **M 323.1, m 150.5-151.5°, $[\alpha]_{546}^{20}$ +25° (c 5, EtOH).** Crystd from water (sol 2.5mg/ml at 25°) or ethylene dichloride. Sublimed under high vacuum.

Chloramphenicol palmitate *[530-43-8]* **M 561.5, m 90°, $[\alpha]_D^{26}$ +24.6° (c 5, EtOH).** Crystd from benzene.

***p*-Chloranil (2,3,5,6-tetrachloro-1,4-benzoquinone)** *[118-75-2]* **M 245.9, m 290°, 294.2-294.6° (sealed tube).** Crystd from acetic acid, acetone, benzene, EtOH or toluene, drying under vac over P_2O_5, or from acetic acid, drying over NaOH in a vacuum desiccator. It can be sublimed under vacuum at 290°. Sample may contain significant amounts of the *o*-chloranil isomer as impurity. Purified by triple sublimation under vacuum. Recrystd before use. **It is a skin and mucous membrane irritant**. [UV: *Rec Trav Chim Pays Bas* **276** 684 *1924*; Brook *JCS* 5040 *1952*].

Chloranilic acid (2,5-dichloro-3,6-dihydroxy-1,4-benzoquinone) *[87-88-7]* **M 209.0, m 283-284°.** A soln of 8g in 1L of boiling water was filtered while hot, then extracted twice at about 50° with 200ml portions of benzene. The aq phase was cooled in ice-water. The crystals were filtered off, washed with three 10ml portions of water, and dried at 115°. It can be sublimed in vacuum. pKa^{25} 1.22 and 3.01 in H_2O [*JPC* **61** 765 *1957*]. The *diacetate* has **m** 182-185° [*JACS* **46** 1866 *1924*; Thamer and Voight *JPC* **56** 225 *1952*].

Chlorazol Sky Blue FF *[2610-05-1]* **M 996.9.** Freed from other electrolytes by adding aqueous sodium acetate to a boiling soln of the dye in distd water. After standing, the salted-out dye was filtered on a Büchner funnel, the process being repeated several times. Finally, the ppted dye was boiled several times with absolute EtOH to wash out any sodium acetate, then dried (as the sodium salt) at 105°. [McGregor, Peters and Petropolous *TFS* **58** 1045 *1962*].

Chlorendic anhydride (1,4,5,6,7,7,-hexachloro-5-norbornene-2,3-dicarboxylic anhydride) *[115-27-5]* **M 370.9, m 234-236°. 235-237°, 238°.** Steam distn or recrystn from H_2O yields the diacid. The purified diacid yields the anhydride with Ac_2O. [Prill *JACS* **69** 62 *1947*].

Chloroacetaldehyde dimethyl acetal *[97-97-2]* **M 124.6, m -34.4°, b 64°/23mm, 71-72°/35mm, d_4^{20} 1.0172, n_D^{20} 1.4175.** Purified by fractional distillation. [Melhotra *JICS* **36** 4405 *1959*; *Bull Soc Chim Belges* **61** 393 *1952*].

α-Chloroacetamide *[79-07-2]* **M 93.5, m 121°, b 224-225°/743mm.** Crystd from acetone and dried under vacuum over P_2O_5.

***p*-Chloroacetanilide** *[539-03-7]* **M 169.6, m 179°.** Crystd from EtOH or aqueous EtOH.

Chloroacetic acid *[79-11-8]* **M 94.5, m 62.8°, b 189°.** Crystd from $CHCl_3$, CCl_4, benzene or water. Dried over P_2O_5 or conc H_2SO_4 in a vacuum desiccator. Further purification by distn from $MgSO_4$, and by fractional crystn from the melt. Stored under vac or under dry N_2. [Bernasconi et al. *JACS* **107** 3621 *1985*].

Chloroacetic anhydride *[541-88-8]* **M 171.0, m 46°, d 1.5494.** Crystd from benzene.

Chloroacetone *[78-95-5]* **M 92.5, b 119°/763mm, d 1.15.** Dissolved in water and shaken repeatedly with small amounts of ethyl ether which extracts, preferentially, 1,1-dichloroacetone present as an impurity. The chloroacetone was then extracted from the aqueous phase using a large amount of ethyl ether, and distd at slightly reduced pressure. It was dried with $CaCl_2$ and stored at Dry-ice temperature. Alternatively, it was stood with $CaSO_4$, distd and stored over $CaSO_4$. **LACHRYMATORY.**

Chloroacetonitrile *[107-14-2]* **M 75.5, b 125°.** Refluxed with P_2O_5 for one day, then distd through a helices-packed column. Also purified by gas chromatography.

1-Chloroadamantane see **1-adamantyl chloride.**

o-**Chloroaniline** *[95-51-2]* **M 127.6, m -1.9°, b 208.8°, d 1.213, n 1.58807.** Freed from small amounts of the *p*-isomer by dissolving in one equivalent of H_2SO_4 and steam distilling. The *p*-isomer remains behind as the sulphate. [Sidgwick and Rubie *JCS* 1013 *1921*]. An alternative method is to dissolve in warm 10% HCl (11ml/g of amine) and on cooling, the hydrochloride of *o*-chloroaniline separates out. The latter can be recrystd until the acetyl derivative has a constant melting point. (In this way, yields are better than for the recrystn of the picrate from EtOH or of the acetyl derivative from pet ether.) [King and Orton *JCS* 1377 *1911*].

p-**Chloroaniline** *[106-47-8]* **M 127.6, m 70-71°.** Crystd from MeOH, pet ether (b 30-60°), or 50% aq EtOH, then benzene/pet ether (b 60-70°), then dried in a vacuum desiccator. Can be distd under vacuum (**b** 75-77°/33mm).

p-**Chloroanisole** *[623-12-1]* **M 142.6, b 79°/11.5mm, 196.6°/760mm, d 1.164, $n^{25.5}$ 1.5326.** Washed with 10% (vol) aqueous H_2SO_4 (three times), 10% aqueous KOH (three times), and then with water until neutral. Dried with $MgSO_4$ and fractionally distd from CaH_2 through a glass helices-packed column under reduced pressure.

9-Chloroanthracene *[716-53-0]* **M 212.9, m 105-107°.** Crystd from EtOH. [Masnori *JACS* **108** 1126 *1986*].

10-Chloro-9-anthraldehyde *[10527-16-9]* **M 240.7, m 217-219°.** Crystd from EtOH.

o-**Chlorobenzaldehyde** *[89-98-5]* **M 140.6. m 11°, b 213-214°, d 1.248, n 1.566.** Washed with 10% Na_2CO_3 soln, then fractionally distd in the presence of a small amount of catechol.

3-Chlorobenzaldehyde *[587-04-2]* **M 140.6, m 18°, b 213-214°, d 1.241, n 1.564.** Purified by low temperature crystn from pet ether (b 40-60°).

4-Chlorobenzaldehyde *[104-88-1]* **M 140.6, m 47°.** Crystd from EtOH/water (3:1), then sublimed twice at 2mm pressure at a temperature slightly above the melting point.

Chlorobenzene *[108-90-7]* **M 112.6, b 131.7°, d 1.107, n 1.52480.** The main impurities are likely to be chlorinated impurities originally present in the benzene used in the synthesis of chlorobenzene, and also unchlorinated hydrocarbons. A common purification procedure is to wash several times with conc H_2SO_4 then with aq $NaHCO_3$ or Na_2CO_3, and water, followed by drying with $CaCl_2$, K_2CO_3 or $CaSO_4$, then with P_2O_5, and distn. It can also be dried with Linde 4A molecular sieve. Passage through, and storage over, activated alumina has been used to obtain low conductance material. [Flaherty and Stern *JACS* **80** 1034 *1958*].

4-Chlorobenzenesulphonyl chloride *[98-60-2]* **M 211.1, m 53°, b 141°/15mm.** Crystd from ether in powdered Dry-ice, after soln had been washed with 10% NaOH until colourless and dried with Na_2SO_4.

4-Chlorobenzhydrazide *[536-40-3]* **M 170.6, m 164°.** Crystd from water.

2-Chlorobenzoic acid *[118-91-2]* **M 156.6, m 139-140°.** Crystd successively from glacial acetic acid, aq EtOH, and pet ether (b 60-80°). Other solvents include hot water or toluene (*ca* 4ml/g). Crude material can be given an initial purification by dissolving 30g in 100ml of hot water containing 10g of Na_2CO_3, boiling with 5g of charcoal for 15min, then filtering and adding 31ml of 1:1 aq HCl: the ppte is washed with a little water and dried at 100°.

3-Chlorobenzoic acid *[535-80-8]* **M 156.6, m 154-156°, 158°, d_4^{25} 1.496.** Crystd successively from glacial acetic acid, aqueous EtOH and pet ether (b 60-80°). It also recrysts from C_6H_6 or Et_2O-hexane, and sublimes at 55° in a vacuum. The pKa^{25} is 3.70 (H_2O) [*AC* **26** 726 *1954*], and 5.25 (in 50% dimethylacetamide). The *methyl ester* has **m** 21°, **b** 231°/atm. The *S-benzyl thiouronium salt* has **m** 164-165° (from EtOH) [*Acta Chem Scand* **9** 1425 *1955*; *JCS* 1318 *1960*].

4-Chlorobenzoic acid *[74-11-3]* **M 156.6, m 238-239°.** Same as for *m*-chlorobenzoic acid. Has also been crystd from hot water, and from EtOH.

2-Chlorobenzonitrile *[873-32-5]* **M 137.6, m 45-46°.** Crystd to constant melting point from benzene/pet ether (b 40-60°).

4-Chlorobenzophenone *[134-85-0]* **M 216.7, m 75-76°.** Recrystd for EtOH. [Wagner et al. *JACS* **108** 7727 *1986*].

2-Chlorobenzothiazole *[615-20-3]* **M 169.6, m 21°, 90-91.4°/4mm, 135-136°/28mm, d_4^{20} 1.303, n_D^{20} 1.6398.** It is purified by fractional distn *in vacuo*. The *2-chloro-3-methylbenzothiazolinium 2,4-dinitrobenzenesulphonate* crystallises from Ac_2O, **m** 162-163° (dec). [*JACS* **73** 4773 *1951*; *JOC* **19** 1830 *1954*; *JCS* 2190 *1930*].

o-**Chlorobenzotrifluoride** *[88-16-4]* **M 180.6, b 152.3°,**
m-**Chlorobenzotrifluoride** *[98-15-7]* **M 180.6, b 137.6°,**
p-**Chlorobenzotrifluoride** *[98-56-6]* **M 180.6, b 138.6°.** Dried with $CaSO_4$, and distd at high reflux ratio through a silvered vacuum-jacketed glass column packed with one-eight inch glass helices [Potter and Saylor *JACS* **73** 90 *1951*].

2-Chlorobenzoxazole *[615-18-9]* **M 153.6, b 95-96°/20mm, 198-202°/atm, d_4^{20} 1.331, n_D^{20} 1.570.** Purified by fractional distn, preferably in a vacuum. [Siedel *J Prakt Chem* (2) **42** 456 *1890*; *JACS* **75** 712 *1953*].

p-**Chlorobenzyl chloride** *[104-83-6]* **M 161.0, m 28-29°, b 96°/15mm.** Dried with $CaSO_4$, then fractionally distd under reduced pressure. Crystd from heptane or dry ethyl ether. **LACHRYMATORY.**

p-**Chlorobenzylisothiuronium chloride** *[544-47-8]* **M 237.1, m 197°.** Crystd from conc HCl by addition of water.

1-Chlorobutane see ***n*-butyl chloride.**

2-Chlorobutane *[78-86-4]* **M 92.6, b 68.5°, d 0.873, n^{25} 1.3945.** Purified in the same way as *n*-butyl chloride.

2-(4-Chlorobutyl)-1,3-dioxolane *[118336-86-0]* **M 164.6, b 56-58°/0.1mm, d_4^{20} 1.106, n_D^{20} 1.457.** If the IR has a CHO band then just distil in vacuum. If it is present then dissolve in Et_2O, wash with H_2O, then saturated $NaHCO_3$, dry over $MgSO_4$, evaporate and distil. [*JACS* **73** 1365 *1951*].

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***N*-Chlorocarbonyl isocyanate** *[27738-96-1]* **M 105.5, m -68°, b 63.6°/atm, d_4^{20} 1.310.** Fractionally distd at atmospheric pressure using a 40cm column. **TOXIC** *vapour use a good fume hood.* Store dry, ν 2260 (NCO), 1818 (CO) and 1420 (NCO sym) cm^{-1}. [*B* **106** 1752 *1975*].

4-Chlorocinnamic acid *[1615-02-7]* **M 182.6, m 243°, 248-250°, 249-251°.** Recrystd from EtOH or aq EtOH (charcoal). [*Org Synth* Coll Vol IV 731 *1963*, Walling and Wolfstin *JACS* **69** 852 *1947*].

Chlorocresol see **chloromethylphenol.**

Chlorocyclohexane *[542-18-7]* **M 118.6, b 142.5°, d 1.00, n^{25} 1.46265.** Washed several times with dilute $NaHCO_3$, then repeatedly with distilled water. Dried with $CaCl_2$ and fractionally distd.

4-Chloro-2,6-diaminopyrimidine (2,4-diamino-6-chloropyrimidine) *[156-83-2]* **M 144.6, m 198°, 199-202°.** Purified by recrystn from boiling H_2O (charcoal) as needles; also crystallises from Me_2CO. Its pKa^{25} in H_2O is 3.57. [Büttner *B* **36** 2232 *1903*; Roth *JACS* **72** 1914 *1950*; UV: *JCS* 3172 *1962*].

2-Chloro-1,4-dihydroxybenzene see **chloroquinol.**

4-Chloro-3,5-dimethylphenol *[88-04-0]* **M 156.6, m 115.5°.** Crystd from benzene or toluene.

1-Chloro-2,4-dinitrobenzene *[97-00-7]* **M 202.6, m 48-50°, 51°, 52-54°, 54°, b 315°/atm, d_4^{22} 1.697.** Usually crystd from EtOH or MeOH. Has also been crystd from Et_2O, C_6H_6, C_6H_6-pet ether or isopropyl alcohol. A preliminary purification step has been to pass its soln in benzene through an alumina column. Also purified by zone refining. It exists in three forms: one stable and two unstable. The stable form crysts as yellow needles from Et_2O, **m** 51°, **b** 315°/atm with some dec, and is sol in EtOH. The labile forms also crystallises from Et_2O, **m** 43°, and is more soluble in organic solvents. The second labile form has **m** 27°. [Hoffman and Dame, *JACS* **41** 1015 *1919*, Welsh *JACS* **63** 3276 *1941*; *JCS* 2476 *1957*].

4-Chloro-3,5-dinitrobenzoic acid *[118-97-8]* **M 246.6, m 159-161°.** Crystd from EtOH/water, EtOH or benzene.

2-Chloro-3,5-dinitropyridine *[2578-45-2]* **M 203.5, m 62-65°, 63-65°, 64°.** Dissolve in $CHCl_3$, shake with saturated $NaHCO_3$, dry ($MgSO_4$), evaporate and apply to an Al_2O_3 column, elute with pet ether (b 60-80°), evaporate and recryst from C_6H_6 or pet ether. [*Chem Pharm Bull Japan* **8** 28 *1960*; *Rec Trav Chim Pays Bas* **72** 573 *1953*].

Chloroethane see **ethyl chloride.**

2-Chloroethanol *[107-07-3]* **M 80.5, b 51.0°/31mm, 128.6°/760mm, d 1.201, n^{15} 1.44380.** Dried with, then distd from, $CaSO_4$ in the presence of a little Na_2CO_3 to remove traces of acid.

2-Chloroethyl bromide *[107-04-0]* **M 143.4, b 106-108°.** Washed with conc H_2SO_4, water, 10% Na_2CO_3 soln, and again with water, then dried with $CaCl_2$ and fractionally distd before use.

2-Chlorethyl chloroformate *[627-11-2]* **M 143.0, b 52-54°/12mm, 50°/15mm, 153°/760mm, d_4^{18} 1.3760, n_D^{20} 1.4460.** Purified by fractional distn, preferably in a vacuum and stored in dry atmosphere. [*JCS* 2735 *1957*].

1-(2-Chloroethyl)pyrrolidine hydrochloride *[7250-67-1]* **M 170.1, m 167-170°, 173.5-174°.** Purified by recrystn from isopropanol-di-idopropyl ether (charcoal) and recrystallised twice more. The *free base*, **b** 55-56°/11mm, 60-63°/23mm and 90°/56mm, is relatively unstable and should be converted to the hydrochloride immediately, by dissolving in iso-propanol and bubbling dry HCl through the soln at 0°, and filtering off the hydrochloride and recrystallising it. The *picrate* has **m** 107.3-107.8° (from EtOH), [Cason *JOC* **24** 247 *1959*; *JACS* **70** 3098 *1948*].

2-Chloroethyl vinyl ether *[110-75-8]* **M 106.6, b 109°/760mm, d 1.048, n 1.437.** Washed repeatedly with equal volumes of water made slightly alkaline with KOH, dried with sodium, and distd under vacuum. **TOXIC.**

Chloroform *[67-66-3]* **M 119.4, b 61.2°, d^{15} 1.49845, d^{10} 1.47060, n^{15} 1.44858.** Reacts slowly with oxygen or oxidising agents, when exposed to air and light, giving, mainly, phosgene, Cl_2 and HCl. Commercial $CHCl_3$ is usually stabilized by addn of up to 1% EtOH or of dimethylaminoazobenzene. Simplest purifications involve washing with water to remove the EtOH, drying with K_2CO_3 or $CaCl_2$, refluxing with P_2O_5, $CaCl_2$, $CaSO_4$ or Na_2SO_4, and distilling. **It must not be dried with sodium.** The distd $CHCl_3$ should be stored in the dark to avoid photochemical formation of phosgene. As an alternative purification, $CHCl_3$ can be shaken with several small portions of conc H_2SO_4, washed thoroughly with water, and dried with $CaCl_2$ or K_2CO_3 before filtering and distilling. EtOH can be removed from $CHCl_3$ by passage through a column of activated alumina, or through a column of silica gel 4-ft long by 1.75-in diameter at a flow rate of 3ml/min. (The column, which can hold about 8% of its weight of EtOH, is regenerated by air drying and then heating at 600° for 6h. It is pre-purified by washing with $CHCl_3$, then EtOH, leaving in conc H_2SO_4 for about 8hr, washing with water until the washings are neutral, then air drying, followed by activation at 600° for 6h. Just before use it is reheated for 2h to 154°.) [McLaughlin, Kaniecki and Gray *AC* **30** 1517 *1958*].
Carbonyl-containing impurities can be removed from $CHCl_3$ by percolation through a Celite column impregnated with 2,4-dinitrophenylhydrazine, phosphoric acid and water. (Prepared by dissolving 0.5g DNPH in 6ml of 85% H_3PO_4 by grinding together, then mixing with 4ml of distilled water and 10g of Celite.) [Schwartz and Parks *AC* **33** 1396 *1961*]. Chloroform can be dried by distn from powdered type 4A Linde molecular sieves. For use as a solvent in IR spectroscopy, chloroform is washed with water (to remove EtOH), then dried for several hours over anhydrous $CaCl_2$ and fractionally distd. This treatment removes material absorbing near 1600 cm^{-1}. (Percolation through activated alumina increases this absorbing impurity). [Goodspeed and Millson *Chemistry & Industry (London)* 1594 *1967*].

Chlorogenic acid *[327-97-9]* **M 354.3, m 208°, $[\alpha]_D^{25}$ -36° (c 1, H_2O).** Crystd from water. Dried at 110°.

5-Chloro-8-hydroxy-7-iodoquinoline *[130-26-7]* **M 305.5, m 178-179°.** Crystd from abs EtOH.

5-Chloroindole *[17422-32-1]* **M 151.6, m 67-68°, 69-71°, 71.5-72.5°, 72-73°, b 120-130°/0.4mm.** It is distd at high vacuum and recrystallises from pet ether (b 40-60°) or (b 80-100°) as glistening plates. The *picrate* has **m** 147° (146.5-147.5°)(from C_6H_6). [*JCS* 3493 *1955*; *JOC* **44** 578 *1979*].

4-Chloroiodobenzene *[637-87-6]* **M 238.5, m 53-54°.** Crystd from EtOH.

2,3-Chloromaleic anhydride *[1122-17-4]* **M 166.9, m 112-115°.** Purified by sublimation in vacuum [Katakis et al. *JCSDT 1491 1986*].

4-(Chloromercuri)benzenesulphonic acid monosodium salt *[14110-97-5]* **M 415.2.** The free acid is obtained by acidifying an aq soln, filtering off the acid, washing it with H_2O and recrystallising from hot H_2O to give a colourless solid which is dried in a vacuum over P_2O_5 and should give negative Cl^- ions. The Na salt is made by dissolving in one equivalent of aqueous NaOH and evaporate to dryness. [*B* **67** 130 *1934*; *JACS* **76** 4331 *1954*].

5-Chloro-2-methoxyaniline (2-amino-4-chloroanisole) *[95-03-4]* **M 157.6, m 81-83°, 82-84°, 84°.** Purified by steam distn and recrystn from H_2O or 40% aqueous EtOH. The *N-acetate* forms needles from hot H_2O **m** 104°; the *N-benzoyl* derivative forms needles from aq EtOH **m** 77-78°; the *picrate* has **m** 194° dec. [*JACS* **48** 2657 *1926*].

9-Chloromethyl anthracene *[24463-19-2]* **M 226.7, m 141-142° dec, 141-142.5°.** If it is free from OH in the IR then recryst from hexane-C_6H_6 or C_6H_6 as needles. If OH is present then some solvolysis has occurred. In this case treat 8.5g with $SOCl_2$ (4.8g) in dioxane (60ml) and reflux for 5h, then evaporate to

dryness and wash the residue with cold C_6H_6 and recrystallise. With KI/Me_2CO it forms the *iodomethyl* derivative. [Martin et al. *HCA* **38** 2009 *1955*; *JOC* **21** 1512 *1956*].

2-Chloro-3-methylindole (2-chloroskatole) *[51206-73-6]* **M 165.6, m 114.5-115.5°.** Purified by chromatography on silica gel in CH_2Cl_2/pet ether (1:2), followed by recrystn from aqueous EtOH or aqueous acetic acid. [Phillips and Cohen *JACS* **108** 2023 *1986*].

4-Chloro-2-methylphenol *[1570-64-5]* **M 142.6, m 49°.** Purified by zone melting.

4-Chloro-3-methylphenol *[59-50-76]* **M 142.6, m 66°.** Crystd from pet ether.

4-Chloro-2-methylphenoxyaceytic acid MCPA *[94-74-6]* **M 200.6, m 113-117°, 120°, 122-123°.** It is insoluble in H_2O (sol 0.55g/L at 20°), and recrystallises from C_6H_6 or chlorobenzene as plates. The pKa^{20} in H_2O is 3.62 (3.05) [*Acta Chem Scand* **6** 993 *1952*]. The *S-benzylthiouronium salt* has **m** 164-165°, and the Cu^{2+} salt has **m** 247-249°dec [Armarego et al. *Nature* **183** 1176 *1959*; UV: Duvaux and Grabe *Acta Chem Scand* **4** 806 *1950*; IR: Jöberg *Acta Chem Scand* **4** 798 *1950*].

Chloromethyl phenyl sulphide *[7205-91-6]* **M 158.7, b 63°/0.1mm, 98°/12mm, 113-115°/20mm.** Dissolve in CH_2Cl_2 or CCl_4 and dry over $CaCl_2$, or pass through a tube of $CaCl_2$ and fractionally distil using a fractionating column. ***Harmful*** *vapours.* It gives the *sulphone* (**b** 130°/1mm and **m** 53° from EtOH) on oxidation with permonophthalic acid. [*A* **563** 54 64 *1949*].

***N*-(Chloromethyl)phthalimide** *[17564-64-6]* **M 195.6, m 131-135°, 134-135°, 136.5°.** Purified by recrystn from EtOAc or CCl_4 [*JACS* **70** 2822 *1948*; Böhme et al. *B* **92** 1258 *1959*].

1-Chloro-2-methylpropane see **isobutyl chloride.**

2-Chloro-2-methylpropane see ***tert*-butyl chloride.**

4-(Chloromethyl)pyridine hydrochloride *[1822-51-1]* **M 164.0, m 160-163°, 170-175°, 172-173°.** Purified by recrystn from EtOH or EtOH-dry Et_2O. It melts between 171° and 175° and the clear melt resolidifies on further heating at 190° and turns red to black at 280° but does not melt again. The *picrate-hydrochloride* (prepared in EtOH) has **m** 146-147°. The free base is an oil, [Mosher and Tessieri *JACS* **73** 4925 *1951*].

2-Chloro-1-methylpyridinium iodide *[14338-32-0]* **M 255.5, m 203-205°, 205-206°(dec), 207°.** Purified by dissolving in EtOH and adding dry Et_2O. The solid is washed with Me_2CO and dried at 20°/0.35mm. Store in the dark. Attempted recrystn from Me_2CO-EtOH-pet ether (b 40-60°) caused some exchange of the Cl substituent by I. The *picrate* has **m** 106-107°, and the *perchlorate* has **m** 212-213°. [UV and solvolysis: Barlin and Benbow *JCS Perk Trans 2* 790 *1974*].

Chloromycetin see **chloramphenicol.**

Chloromycetin palmitate see **chloramphenicol palmitate.**

1-Chloronaphthalene *[90-13-1]* **M 162.6, f.p. -2.3°, b 136-136.5°/20mm, 259.3°/760mm, d 1.194, n 1.6326.** Washed with dilute $NaHCO_3$, then dried with Na_2SO_4 and fractionally distd under reduced pressure. Alternatively, before distn, it was passed through a column of activated alumina, or dried with $CaCl_2$, then distd from sodium. It can be further purified by fractional crystn by partial freezing or by crystn of its picrate to constant melting point (132-133°) from EtOH, and recovering from the picrate.

2-Chloronaphthalene *[91-58-7]* **M 162.6, m 61°, b 264-266°.** Crystd from 25% EtOH/water and dried under vacuum.

1-Chloro-2 naphthol *[633-99-8]* **M 178.6, m 70°.** Cryst from pet ether. Acetate has **m** 42-43°.

2-Chloro-1-naphthol *[606-40-6]* **M 178.6, m 64-65°**. Crystd from pet ether.

4-Chloro-1-naphthol *[604-44-4]* **M 178.6, m 116-117°, 120-121°.** Crystd from EtOH or chloroform.

6-Chloronicotinic acid *[5326-23-8]* **M 157.6, m 190-193°, 198-199°(dec).** Purified by recrystn from hot H_2O and is sublimed in a vacuum. [Pechmann and Welsch *B* **17** 2384 *1884*; Herz and Murty *JOC* **26** 122 *1961*].

4-Chloro-2-nitroaniline *[89-63-4]* **M 172.6, m 116-116.5°.** Crystd from hot water or EtOH/water and dried for 10h at 60° under vacuum.

2-Chloro-4-nitrobenzamide *[3011-89-0]* **M 200.6, m 172°.** Crystd from EtOH.

2-Chloro-1-nitrobenzene *[88-73-3]* **M 157.6, m 32.8-33.2°.** Crystd from EtOH, MeOH or pentane (charcoal).

3-Chloro-1-nitrobenzene *[121-73-3]* **M 157.6, m 45.3-45.8°.** Crystd from MeOH or 95% EtOH (charcoal), then pentane.

4-Chloro-1-nitrobenzene *[100-00-5]* **M 157.6, m 80-83°, 83.5-84°, b 113°/8mm, 242°/atm, $d_4^{100.5}$ 1.2914.** Crystd from 95% EtOH (charcoal) and sublimes in a vacuum. [Emmons *JACS* **76** 3470 *1954*; Newman and Forres *JACS* **69** 1221 *1947*].

4-Chloro-7-nitrobenzofurazane (7-chloro-4-nitrobenzoxadiazole) *[10199-89-0]* **M 199.6, m 96.5-97°, 97°, 99-100°.** Wash the solid with H_2O and recrystallise from aqueous EtOH (1:1) as pale yellow needles. It sublimes in a vacuum [UV, NMR: Bolton, Gosh and Katritzky *JCS* 1004 *1966*].

1-Chloronitroethane *[625-47-8]* **M 109.5, b 37-38°/20mm, n 1.4224, n^{25} 1.4235.** Dissolved in alkali, extracted with ether (discarded), then the aqueous phase was acidified with hydroxylamine hydrochloride, and the nitro compound fractionally distd under reduced pressure. [Pearson and Dillon *JACS* **75** 2439 *1953*].

2-Chloro-3-nitropyridine *[5470-18-8]* **M 158.5, m 100-103°, 101-102°, 103-104° (sublimes).** Forms needles from H_2O. Purified by continuous sublimation over a period of 2 weeks at 50-60°/0.1mm. It has a pKa^{20} in H_2O of -2.6 [Barlin *JCS* 2150 *1964*]. The *N-oxide* has **m** 99-100°(from CH_2Cl_2-Et_2O). [Taylor and Driscoll *JOC* **25** 1716 *1960*; Ochiai and Kaneko *Chem Pharm Bull Japan* **8** 28 *1960*].

2-Chloro-5-nitropyridine *[4548-45-2]* **M 158.5, m 108°.** Crystd from benzene or benzene/pet ether.

α-Chloro-3-nitrotoluene see **3-nitrobenzyl chloride.**

1-Chloropentane see ***n*-amyl chloride.**

3-Chloroperbenzoic acid *[937-14-4]* **M 172.6, m 92-94°(dec).** Recrystd from CH_2Cl_2 [Traylor and Mikztal *JACS* **109** 2770 *1987*]. Peracid of 99+% purity can be obtained by washing commercial 85% material with phosphate buffer pH 7.5 and drying the residue under reduced pressure. Alternatively the peracid can be freed from *m*-chlorobenzoic acid by dissolving 50g/L of benzene and washing with an aq soln buffered at pH 7.4 (NaH_2PO_4/NaOH) (5 x 100ml). The organic layer was dried over $MgSO_4$ and carefully evaporated under vacuum. *Necessary care should be taken in case of* **EXPLOSION**. The solid was recrystd twice from CH_2Cl_2/Et_2O and stored at 0° in a plastic container as glass catalyses the decomposition of the peracid. The acid is assayed iodometrically. [*JOC* **29** 1976 *1964*; Bortolini et al. *JOC* **52** 5093 *1987*].

2-Chlorophenol *[95-57-8]* **M 128.6, m 8.8°, b 61-62°/10mm, 176°/atm.** Passed at least twice through a gas chromatograph column. Also purified by fractional distn. It has pKa 8.34 at 25° in water.

3-Chlorophenol *[108-43-0]* **M 128.6, m 33°, b 44.2°/1mm, 214°/atm.** Could not be obtained solid by crystn from pet ether. Purified by distn under reduced pressure. It has pKa 9.06 at 15° in water.

4-Chlorophenol *[106-48-9]* **M 128.6, m 43°, 100-101°/10mm.** Distd, then crystd from pet ether (b 40-60°) or hexane, and dried under vacuum over P_2O_5 at room temp. It has pKa 9.38 at 20° in water. [Bernasconi and Paschalis *JACS* **108** 2969 *1986*].

Chlorophenol Red *[4430-20-0]* **M 423.3, λ_{max}573nm.** Crystd from glacial acetic acid.

4-Chlorophenoxyacetic acid *[122-88-3]* **M 186.6, m 157°,**
α-4-Chlorophenoxypropionic acid *[3307-39-9]* **M 200.6, m 116°,**
ß-4-Chlorophenoxypropionic acid *[3284-79-5]* **M 200.6, m 138°.** Crystd from EtOH.

3-Chlorophenylacetic acid *[1878-65-5]* **M 170.6, m 74°,**
4-Chlorophenylacetic acid *[1878-66-6]* **M 170.6, m 102-105°, 105°, 106°.** Crystd from EtOH/water, or as needles from C_6H_6 or H_2O (charcoal). The pKa is 4.12. The *acid chloride* (prepared by boiling with $SOCl_2$) has **b** 127-129°/15mm. [Dippy and Williams *JCS* 161 *1934*; Misra and Shukla *JICS* **28** 480 *1951*].

4-Chloro-1-phenylbutan-1-one *[939-52-6]* **M 182.7, m 19-20°, b 134-137°/5mm, d_4^{20} 1.149, n_D^{20} 1.55413.** Fractionate several times using a short column. It can be recrystd from anhydrous pet ether at -20° as glistening white rosettes and filtered at 0° and dried in a vacuum desiccator over H_2SO_4. The *semicarbazone* has **m** 136-137°. [*JACS* **46** 1882 *1924*, **51** 1174 *1929*, Hart and Curtis *JACS* **79** 931 *1957*].

1-(2-Chlorophenyl)-1-(4-chlorophenyl)-2,2-dichloroethane (Mitotane, op'-DDD) *[53-19-0]* **M 320.1, m 75.8-76.8°, 76-78°.** Purified by recrystallisation from pentane and from MeOH or EtOH. It is sol in isooctane and CCl_4. [Haller et al. *JACS* **67** 1600 *1945*].

3-(4-Chlorophenyl)-1,1-dimethylurea *[150-68-5]* **M 198.7, m 171°.** Crystd from MeOH.

2-Chlorophenyl diphenyl phosphate see Chapter 4.

4-Chloro-1,2-phenylenediamine *[95-83-0]* **M 142.6, m 69-70°.** Recrystd from pet. ether.

4-Chlorophenyl isocyanate *[104-12-1]* **M 153.6, m 28-31°, 31-32°, 32°, 32.5°, b 80.6-80.9°/9.5mm, 115-117°/45mm.** Purified by recrystn from pet ether (b 30-40°) or better by fractional distn. **TOXIC irritant.**

4-Chlorophenyl isothiocyanate *[2131-55-7]* **M 169.6, m 44°, 43-45°, 45°, 46°, 47°, b 110-115°/4mm, 135-136°/24mm.** Check the IR first. Slur with pet ether (b 30-60°) and decant the solvent. Repeat 5 times. The combined extracts are evap under reduced press to give almost pure compound as a readily crystallisable oil with a pleasant anise odour. It can be recrystd from the minimum vol of EtOH at 50° (do not boil too long in case it reacts). It can be purified by vac distn. **Irritant** [*Org Synth* Coll Vol V 223 *1973*].

4-Chlorophenyl 2-nitrobenzyl ether, M 263.7, m 69°,
4-Chlorophenyl 4-nitrobenzyl ether *[5442-44-4]* **M 263.7, m 102°.** Crystd from EtOH.

9-Chloro-9-phenylxanthene *[42506-03-6]* **M 292.8, m 105-106°.** Possible impurity is 9-hydroxy-9-phenylxanthene. If material contains a lot of the hydroxy product then boil 10g in $CHCl_3$ (50ml) with redistd acetyl chloride (1ml) until liberation of HCl is complete. Evapn leaves the chlorophenylxanthene as the hydrochloride which on heating with benzene loses HCl; and on adding pet ether prisms of chlorophenylxanthene separate and contain 0.5mol of benzene. The benzene-free compound is obtained on drying and melts to a colourless liquid. [*A* **370** 142 *1909*]. The 9-phenylxanthyl group is called pixyl. [*JCSCC* 639 *1978*].

Chlorophyll *a* *[479-61-8]* **M 983.5, m 117-120°, 150-153°, 178-180° (sinters at ~150°), $[\alpha]_D^{20}$ -262° (Me_2CO).** Forms green crystals from Me_2CO, Et_2O + H_2O, Et_2O + hexane + H_2O or Et_2O + pentane + H_2O. It is sparingly soluble in MeOH and insol in pet ether. In alkaline soln it gives a blue-green colour with deep red fluorescence. A very crude chlorophyll mixture has been purified by chromatography on low melting polyethylene (MI 0.044; 'Dow' melting index MI <2) and developed with 70% aq Me_2CO. The order of effluent from the bottom of the column is: xanthophylls, chlorophyll *b*, chlorophyll *a*, phaeophytins and carotenes. A mixture of chlorophylls a and b is best separated by chromatography on sugar and the order is cholorophyll b elutes first followed by chlorophyll *a*. To an Me_2CO-H_2O soln of chlorophylls 200ml of iso-octane is added and the mixt shaken in a separating funnel and the H_2O is carefully removed. The iso-octane layer is dried (Na_2SO_4) and applied to a glass column (5cm diameter) dry packed with 1000ml of powdered sucrose which has been washed with 250ml of iso-octane. Elution with 0.5% of isopropanol in iso-octane gives chlorophyll *a*. Keeping the eluate overnight at 0° yields micro crystals which are collected by filtration or centrifugation (Yield 40mg). UV_{EtOH} has λ_{max} **660**, 613, 577, 531, 498, **429** and 409 nm. [Anderson and Calvin *Nature* **194** 285 *1962*; Stoll and Weidemann *HCA* **16** 739 757 *1933*; NMR: Katz et al. *JACS* **90** 6841 *1968*, **85** 3809 *1963* for a and b; ORD: Inhoffen et al. *A* **704** 208 *1967*; Willstätter and Isler *A* **390** 269, 233 *1912*].

Chlorophyll *b* *[519-62-0]* **M 907.52, sinters at 86-92°, sinters at 170°, dec at 160-170°, m 183-185°, 190-195°, $[\alpha]_D^{20}$ -267° (Me_2CO + MeOH), $[\alpha]_{720}^{25}$ -133° (MeOH + Pyridine 95:5).** See purification of chlorophyll a, and is separated from "a" by chromatography on sucrose [UV, IR: Stoll and Weidemann *HCA* **42** 679, 681 *1959*]. It forms red-black hexagonal bipyramids or four sided plates from dilute EtOH and has been recrystd from $CHCl_3$-MeOH. It is soluble in MeOH, EtOH, EtOAc and insoluble in pet ether. [*JACS* **88** 5037 *1966*].

Chloropicrin *[76-06-2]* **M 164.5, b 112°.** Dried with $MgSO_4$ and fractionally distd. **EXTREMELY NEUROTOXIC, use appropriate precautions.**

1-Chloropropane see ***n*-propyl chloride.**

2-Chloropropane see **isopropyl chloride.**

Chloro-2-propanone see **chloroacetone.**

3-Chloropropene see **allyl chloride.**

α-Chloropropionic acid *[598-78-7]* **M 108.5, b 98°/3mm, d 1.182, n 1.4535.** Dried with P_2O_5 and fractionally distd under vacuum.

***S*-(-)-2-Chloropropionic acid** *[29617-66-1]* **M 108.5, b 77°/10mm, 80.7°/10mm, 185-188°/atm, d_4^{25} 1.2485, n_D^{25} 1.436, $[\alpha]_D^{25}$ +14.6° (neat).** Purified by twice fractionating through a 45in Podbielniak column (calcd 50 theoretical plates at atm press) using a take-off ratio of 1:5. Ths *acid chloride* is prepared by dissolving the acid in $SOCl_2$ adding a few drops of PCl_3, refluxing and then distilling through a 30 cm column, **b** 53°/100mm, $[\alpha]_D^{25}$ - 4.6° (neat), d_4^{25} 1.2689, n_D^{25} 1.4368. [Fu et al. *JACS* **76** 6954 *1954*].

β-Chloropropionic acid *[107-94-8]* **M 108.5, m 41°.** Crystd from pet ether or benzene.

γ-Chloropropyl bromide *[109-70-6]* **M 157.5, b 142-145°, n^{25} 1.4732.** Washed with conc H_2SO_4, water, 10% Na_2CO_3 soln, water again and then dried with $CaCl_2$ and fractionally distd just before use [Akagi, Oae and Murakami *JACS* **78** 4034 *1956*].

2-Chloropyrazine *[14508-49-7]* **M 114.5, b 60.5°/26mm, 62-63°/31mm, 153-154°/atm, d_4^{20} 1.302, n_D^{26} 1,5346.** Fractionally distil through a short column packed with glass helices. It has a penetrating mildly pungent odour with a high vapour pressure at room temperature. [Erickson and Spoerri *JACS* **68** 400 *1946*; *JOC* **28** 1682 *1963*].

6-Chloropurine *[87-42-3]* **M 154.6, m 179°(dec).** Crystd from water.

2-Chloropyridine *[109-09-1]* **M 113.6, b 49.0°/7mm, d 1.20, n 1.5322.** Dried with NaOH for several days, then distd from CaO under reduced pressure.

3-Chloropyridine *[626-60-8]* **M 113.6, b 148°, d 1.194, n 1.5304.** Distd from KOH pellets.

4-Chloropyridine *[626-61-9]* **M 113.6, b 85-86°/100mm, 147-148°/760mm.** Dissolved in distilled water and excess of 6M NaOH was added to give pH 12. The organic phase was separated and extracted with four volumes of ethyl ether. The combined extracts were filtered through paper to remove water and the solvent evaporated. The dark brown residual liquid was kept under high vacuum [Vaidya and Mathias *JACS* **108** 5514 *1986*]. It can be distd but readily darkens and is best kept as the *hydrochloride [7379-35-3]* M 150.1, **m** 163-165°(dec).

2-Chloropyrimidine *[1722-12-9]* **M 114.5, m 63-65°, 66°, b 91°/26mm**. It has been recrystd from C_6H_6, pet ether or a mixture of both. It sublimes at 50°/18mm and can be distd in a vacuum. [IR: Short and Thompson *JCS* 168 *1952*; Boarland and McOmie *JCS* 1218 *1951*].

Chloroquinol *[615-67-8]* **M 144.5, m 106°.** Crystd from $CHCl_3$ or toluene.

2-Chloroquinoline *[612-62-4]* **M 163.6, m 34°, b 147-148°/15mm, d^{35} 1.2351, n^{25} 1.62923.** Purified by crystn of its picrate to constant melting point (123-124°) from benzene, regenerating the base and distilling under vacuum [Cumper, Redford and Vogel *JCS* 1183 *1962*]. 2-Chloroquinoline can be crystd from EtOH. Its *picrate* has **m** 122° (from EtOH).

4-Chloroquinoline *[611-35-8]* **M 163.6, m 29-32°, 31°, b 127°/15mm, 130°/15mm, 261°/744mm.** Possible impurities include the 2-isomer. Best purified by converting to the *picrate* (**m** 212-213° dec) in EtOH and recryst from EtOH (where the picrate of the 2-chloroquinoline stays in soln) or EtOAc . The picrate is decomposed with 5% aqueous NaOH, extracted in $CHCl_3$, washed with H_2O, dried ($MgSO_4$), evapd and distd in a vacuum. It can be steam distd from slightly alkaline aqueous solns, the aqueous distillate is extracted with Et_2O, evaporated and distd. The distillate solidifies on cooling. [Bobránski *B* **71** 578 *1938*].

8-Chloroquinoline *[611-33-6]* **M 163.6, b 171-171.5°/24mm, d 1.2780, n 1.64403.** Purified by crystn of its $ZnCl_2$ complex (**m** 228°) from aqueous EtOH.

4-Chlororesorcinol *[95-88-5]* **M 144.6, m 105°.** Crystd from boiling CCl_4 (10g/L, charcoal) and air dried.

5-Chlorosalicaldehyde *[635-93-8]* **M 156.6, m 98.5-99°.** Steam distd, then crystd from aq EtOH.

***N*-Chlorosuccinimide** *[128-09-6]* **M 133.5, m 149-150°.** Rapidly crystd from benzene, or glacial acetic acid and washed well with water then dried *in vacuo*. [Phillips and Cohen *JACS* **108** 2023 *1986*].

8-Chlorotheophylline *[85-18-7]* **M 214.6, m 311°(dec).** Crystd from water.

4-Chlorothiophenol *[106-54-7]* **M 144.6, m 51-52°.** Recrystd from aqueous EtOH [D'Sousa et al. *JOC* **52** 1720 *1987*].

α–Chlorotoluene see **benzyl chloride.**

2-Chlorotoluene *[95-49-8]* **M 126.6, b 159°, d 1.083, n 1.5255.** Dried for several days with $CaCl_2$, then distd from Na using a glass helices-packed column.

4-Chlorotoluene *[106-43-4]* **M 126.6, f.p. 7.2°, b 162.4°, d 1.07, n 1.5208.** Dried with BaO, fractionally distd, then fractionally crystd by partial freezing.

2-Chlorotriethylamine hydrochloride *[869-24-9]* **M 172.1, m 208-210°.** Crystd from absolute MeOH (to remove highly coloured impurities).

Chlorotrifluoroethylene *[79-38-9]* **M 116.5, b -26 to -24°.** Scrubbed with 10% KOH soln, then 10% H_2SO_4 soln to remove inhibitors, and dried. Passed through silica gel.

Chlorotrifluoromethane *[75-72-9]* **M 104.5, m -180°, b -81.5°.** Main impurities were CO_2, O_2, and N_2. The CO_2 was removed by passage through saturated aqueous KOH, followed by conc H_2SO_4. The O_2 was removed using a tower packed with activated copper on kieselguhr at 200°, and the gas dried over P_2O_5.

Chlorotriphenylmethane *[76-83-5]* **M 278.8, m 112-113°.** Crystd from benzene soln (100ml) containing a little acetyl chloride, by addition of 200ml of pet ether and cooling. Alternatively, a soln in ethyl ether was saturated with dry HCl (by dripping conc HCl into conc H_2SO_4 and passing the gas through P_2O_5 towers) at 0°, then cooled in a Dry-ice/acetone bath. The crystals so obtained were recrystd from pet ether (b 30-60°) using Dry-ice/acetone baths [Thomas and Rochow *JACS* **79** 1843 *1957*].

5-Chlorouracil (5-chloro-2,4(6)-dihydroxypyrimidine) *[1820-81-1]* **M 146.5, m 314-418° dec, 324-325° dec.** Recrystallised from hot H_2O (4g/500ml) using charcoal. It has pKa^{25} 7.95 (7.90) and >13 in H_2O. [McOmie et al. *JCS* 3478 *1955;* West and Barrett *JACS* **76** 3146 *1954*].

4-Chloro-3,5-xylenol see **4-Chloro-3,5-dimethylphenol.**

Cholamine chloride hydrochloride see **(2-aminoethyl)trimethylammonium chloride hydrochloride.**

5-β-Cholanic acid *[546-18-9]* **M 360.6, m 164-165°, $[\alpha]_D^{14}$ +21.7° ($CHCl_3$).** Crystd from EtOH.

Cholanthrene *[479-23-2]* **M 254.3, m 173°.** Crystd from benzene/ethyl ether.

Cholestane *[481-21-0]* **M 372.7, m 80°, $[\alpha]_{546}^{20}$ +29.5° (c 2, $CHCl_3$).** Crystd from ethyl ether/EtOH.

5α-Cholestan-3ß-ol *[80-97-7]* **M 388.7, m 142-143°(monohydrate), $[\alpha]_{546}^{20}$ +28° (c 1, $CHCl_3$), $[\alpha]_D$ +27.4° (in $CHCl_3$).** Crystd from EtOH or slightly aqueous EtOH. [Mizutani and Whitten *JACS* **107** 3621 *1985*].

2-Cholestene *[102850-21-5]* **M 370.6, m 75-76°, $[\alpha]_D^{24}$ +64°.** Recrystd from MeOH or ethyl ether/acetone. [Berzbrester and Chandran *JACS* **109** *174 1987*].

Cholesterol *[57-88-5]* **M 386.7, m 148.9-149.4°, $[\alpha]_D^{25}$ -35° (hexane).** Crystd from ethyl acetate, EtOH or isopropyl ether/MeOH. [Hiromitsu and Kevan *JACS* **109** 4501 *1987*]. For extensive details of purification through the dibromide, see Fieser [*JACS* **75** 5421 *1953*] and Schwenk and Werthessen [*Arch Biochem Biophys* **40** 334 *1952*], and by repeated crystn from acetic acid, see Fieser [*JACS* **75** 4395 *1953*].

Cholesteryl acetate *[604-35-3]* **M 428.7, m 112-115°, $[\alpha]_{546}^{20}$ -51° (c 5, $CHCl_3$).** Crystd from *n*-pentanol.

Cholesteryl myristate *[1989-52-2]* **M 597.0.** Crystd from *n*-pentanol. Purified by column chromatography with MeOH and evaporated to dryness. Dissolved in water and ppted with HCl (spot 1) or passed through a cation-exchange column (spot 2). Finally, dried in vacuum over P_2O_5. [Malanik and Malat *Anal Chim Acta* **76** 464 *1975*].

Cholesteryl oleate *[303-43-5]* **M 651.1, m 48.8-49.4°.** Purified by chromatography on silica gel.

Cholic acid *[81-25-4]* **M 408.6, m 198-200°, $[\alpha]_{546}$ +41° (c 0.6, EtOH).** Crystd from EtOH. Dried under vacuum at 94°.

Choline chloride *[67-48-1]* **M 139.6.** *Extremely deliquescent.* Purity checked by $AgNO_3$ titration or by titration of free base after passage through an anion-exchange column. Crystd from absolute EtOH, or EtOH-ethyl ether, dried under vacuum and stored in a vacuum desiccator over P_2O_5 or $Mg(ClO_4)_2$.

Chromazurol S *[1667-99-8]* **M 539.3, λ_{max} 540nm, ε 7.80 x 10^4 (10M HCl).** Crude material (40g) is dissolved in water (250ml) and filtered. Then added conc HCl (50ml) to filtrate, with stirring. Ppte is filtered off, washed with HCl (2M) and dried. Redissolved in water (250ml) and pptn repeated twice more in water bath at 70°. Then dried under vacuum over solid KOH (first) then P_2O_5 [Martynov et al. *Zh Analit Khim* **32** 519 *1977*].

4-Chromanone *[491-37-2]* **M 148.2, m 35-37°, 38.5°, 39°, 41°, b 92-93°/3mm, 130-132°/15mm, 160°/50mm.** It has been recryst from pet ether, or purified by dissolving in C_6H_6 washing with H_2O, drying ($MgSO_4$), evaporate and dist in a vacuum, then recryst the residue. The liquid has a pleasant lemon-like odour. The *semicarbazone* has **m** 227°. [Loudon and Razdan *JCS* 4299 *1954*]. The *oxime* is prepared from 3g of chromanone, 3g $NH_2OH.HCl$ in EtOH (50ml), 6g K_2CO_3 and refluxed on a water bath for 6h. The soln is poured into H_2O, the solid is filtered off, dried and dissolved in hot C_6H_6 which on addition of pet ether yields the oxime as glisteneing needles **m** 140°. Decomposition of this gives very pure chromanone. The *benzal derivative* is prepared from 3g of chromanone, 4g PhCHO in 50ml EtOH, heated to boiling, 10ml of conc HCl are added dropwise and set aside for several days. The derivative separates and is recrystd from EtOH to give yellow needles, **m** 112° [*JACS* **45** 2711 *1923*]. Reaction with $Pb(OAc)_4$ yields the *3-acetoxy derivative* **m** 74° (from pet ether + trace of EtOAc, [Cavill et al. *JCS* 4573 *1954*].

Chromotropic acid *[148-25-4]* **M 120.3.** Crystd from water by addition of EtOH.

Chrysene *[218-01-9]* **M 228.3, m 255-256°.** Purified by chromatography on alumina from pet ether in a darkened room. Its soln in C_6H_6 was passed through a column of decolorizing charcoal, then crystd by concentration of the eluate. Also purified by crystn from C_6H_6 or C_6H_6-pet ether , and by zone refining. [Gorman et al. *JACS* **107** 4404 *1985*]. It was freed from *5H*-benzo[*b*]carbazole by dissolving in *N,N*-dimethylformamide and successively adding small portions of alkali and iodomethane until the fluorescent colour of the carbazole anion no longer appeared when alkali was added. The chrysene (and alkylated *5H*-benzo[*b*]carbazole) separated on addition of water. Final purification was by crystn from ethylcyclohexane and from 2-methoxyethanol [Bender, Sawicki and Wilson *AC* **36** 1011 *1964*]. It can be sublimed in a vacuum.

Chrysoidine G (4-phenylazo-1,3-benzenediamine monohydrochloride) *[532-82-1]* **M 248.7, m 118-118.5°.** Red-brown powder which is recrystd from H_2O. It gives a yellow soln in conc H_2SO_4 which turns orange on dilution. Its solubility at 15° is 5.5% (H_2O), 4.75% (EtOH), 6.0% (cellosolve), 9.5% (ethylene glycol), 0.005% (xylene) and insol in C_6H_6. The *hydroiodide* has **m** 184° (from EtOH) and the *picrate* forms red needles **m** 196°. It has pKa values of 3.32 and 5.21 in H_2O. [*Bull Chem Soc Japan* **31** 864 *1958*; *B* 10 213 *1877*].

Cinchonidine *[485-71-2]* **M 294.4, m 210.5°, $[\alpha]^{20}_{546}$ -127.5° (c 0.5, EtOH).** Crystd from aqueous EtOH.

Cinchonine *[118-10-5]* **M 294.4, m 265°, $[\alpha]^{20}_{546}$ +268° (c 0.5, EtOH).** Crystd from EtOH or ethyl ether.

Cincophen see **2-phenyl-4-quinolinecarboxylic acid.**

1,8-Cineole *[478-82-6]* **M 154.2, f.p. 1.3°, b 176.0°, d 0.9251.** Purified by dilution with an equal volume of pet ether, then saturation with dry HBr. The ppte was filtered off, washed with small portions of pet ether, and then cineole was regenerated by stirring the crystals with water. It can also be purified through its *o*-cresol or resorcinol addition compounds. Stored with sodium until required.

***trans*-Cinnamaldehyde** *[14271-10-9]* **M 132.2, m -4°, -7.5°, -9°, b 80°/0.4mm, 85.8°/1.1mm, 125-128°/11mm, 152.2°/40mm, 163.7°/60mm, 199.3°/200mm, 246°/760mm dec, d_4^{20} 1.0510, n_D^{20} 1.623.** Purified by steam distn (sol 1 in 700 parts H_2O) followed by distn *in vacuo*. The *cis*-isomer has **b** 67-69°/40mm and d_4^{20} 1.0436 and n_D^{20} 1.5937. The *trans-semicarbazone* has **m** 210° dec from $CHCl_3$-MeOH (*cis-semicarbazone* has **m** 196°); the *trans-phenylsemicarbazone* has **m** 177° from $CHCl_3$-MeOH (the *cis-phenylsemicarbazone* has **m** 146°); the *trans-2,4-dinitrophenylhydrazone* has **m** 250° dec from MeOH as the *cis*-isomer [Gamboni et al. *HCA* **38** 255 *1955*; Peine *B* **17** 2117 *1884*; *JOC* **26** 4814 *1961*; *JACS* **86** 198 *1964*].

***trans*-Cinnamic acid** *[140-10-3]* **M 148.2, m 134.5-135°.** Crystd from benzene, CCl_4, hot water, water/EtOH (3:1), or 20% aqueous EtOH. Dried at 60° under vacuum.

Cinnamic anhydride *[538-56-7]* **M 278.4, m 136°.** Crystd from benzene or toluene/pet ether (b 60-80°).

***N*-Cinnamoyl-*N*-phenylhydroxylamine** *[7369-44-0]* **M 239.3, m 158-163°.** Recrystd from EtOH.

Cinnamyl alcohol *[104-54-1]* **M 134.2, m 33°, b 143.5°/14mm, λ_{max} 251nm** (ε **18,180M^{-1} cm^{-1}**). Crystd from ethyl ether/pentane.

Cinnoline *[253-66-7]* **M 130.2, m 38°.** Crystd from pet ether. Kept under N_2 in sealed tubes in the dark at 0°.

Citraconic acid *[498-23-7]* **M 130.1, m 91°.** Steam distd and crystd from EtOH/ligroin.

Citraconic anhydride *[616-02-4]* **M 112.1, m 8-9°, b 47°/0.03mm, 213°/760mm, d_4^{20} 1.245, n_D^{20} 1.472.** Possible contamination is from the acid formed by hydrolysis. If the IR has OH bands then reflux with Ac_2O for 30 min, evaporate then distil the residue in a vacuum; otherwise distil in a vacuum. Store in a dry atmosphere. [*BJ* **191** 269 *1980*].

Citranaxanthin *[3604-90-8]* **M 456.7, m 155-156°, $\varepsilon^{1\%}_{1cm}$ 410 (349nm), 275 (466nm) in hexane.** Purified by chromatography on a column of 1:1 magnesia-HyfloSupercel. Crystd from pet ether. Stored in the dark, under inert atmosphere, at 0°.

Citrazinic acid (2,6-dihydroxyisonicotinic acid) *[99-11-6]* **M 155.1, m >300°.** Yellow powder with a greenish shade, but is white when ultra pure and turns blue on long standing. It is insoluble in H_2O but slightly soluble in hot HCl and soluble in alkali or carbonate solutions. Purified by precipitation from alkaline solutions with dilute HCl, and dry in a vacuum over P_2O_5. Its pKa values in H_2O are 3.00 and 4.76. The *ethyl ester* has **m** 232° (evacuated tube) and a pKa of 4.81 in $MeOCH_2CH_2OH$ [IR: Pitha *Coll Czech Chem Comm* **28** 1408 *1963*].

Citric acid (H_2O) *[5949-29-1]* **M 210.1, m 156-157°, 153° (anhyd).** Crystd from water.

Citronellal (3,7-dimethyloctan-6-al) *[(+): 2385-77-5] [(-): 5949-05-3]* **M 154.3, b 67°/4mm, 89°/14mm, 104-105°/21mm, 207°/760mm, $[\alpha]^{20}_{546}$ ±20°, $[\alpha]^{20}_{D}$±16.5° (neat).** Fractionally distd. Alternatively extracted with $NaHSO_3$ solution, washed with Et_2O then acidified to decompose the bisulphite adduct and extracted with Et_2O, dried (Na_2SO_4), evaporated and distd. Check for purity by hydroxylamine titration. The RD in MeOH (c 0.167) is: $[\alpha]_{700}$ +9°, $[\alpha]_{589}$ +11°, $[\alpha]_{275}$ +12° and $[\alpha]_{260}$ 12°. The *semicarbazone* has **m** 85°, and the *2,4-dinitrophenylhydrazone* has **m** 79-80°. [IR: *JCS* 3457 *1950*; ORD: Djerassi and Krakower *JACS* **81** 237 *1959*].

β-Citronellene (2,6-dimethylocta-2,7-diene) *[S-(+): 2436-90-0] [R-(-): 10281-56-8]* **M 138.3, b 153-154°/730mm, 155°/atm, d_4^{22} 0.7566, n_D^{22} 1.43070, $[\alpha]^{20}_{546}$ ±13°, $[\alpha]^{20}_{546}$ ±10° (neat).** Purified by distillation over Na three times and fractionation. [(-) Arigoni and Jeager *HCA* **37** 881 *12954*; (+) Eschenmoser and Schinz *HCA* **33** 171 *1950*].

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β–Citronellol (3,7-dimethyloctan-6-ol) *[R-(+): 11171-61-9] [S-(-): 106-22-9]* **M 156.3, b 47°/1mm, 102-104(110°)°/10mm, 112-113°/12mm, 221-224°/atm, 225-226°/atm, d_4^{24} 0.8551, n_D^{24} 1.4562, $[\alpha]_{546}^{20}$ ±6.3°, $[\alpha]_D^{20}$ ±5.4° (neat).** Purified by distn through a cannon packed (Ni) column and the main cut collected at 84°/14mm and redistd. Also purified *via* the benzoate. [IR: Eschenazi *JOC* **26** 3072 *1961*; *Bull Soc Chim France* 505 *1951*].

S-Citrulline (2-amino-5-ureidopentanoic acid) *[2436-90-0]* **M 175.2, m 222°, $[\alpha]_D^{20}$ +24.2° (in 5M HCl).** Likely impurities are arginine, and ornithine. Crystd from water by adding 5 volumes of EtOH. Also crystd from water by addn of MeOH.

β-Cocaine *[50-36-2]* **M 303.4, m 98°, $[\alpha]_D^{20}$ -15.8° ($CHCl_3$).** Crystd from EtOH.

Cocarboxylase see entry in Chapter 5.

Cofazimine *[2030-63-9]* **M 473.5.** Recrystd from acetone.

Codeine *[76-57-3]* **M 299.4, m 154-156°, $[\alpha]_D^{20}$ -138° (in EtOH).** Crystd from water or aqueous EtOH. Dried at 80°.

Coenzyme Q_0 (2,3-Dimethoxy-5-methyl-1,4-benzoquinone, 3,4-dimethoxy-2,5-toluquinone, fumigatin methyl ether) see entry in Chapter 5.

Colchicine,
Colchicoside see entries in Chapter 5.

2,4,6-Collidine see **2,4,6-trimethylpyridine.**

Coniferyl alcohol [4-hydroxy-3-methoxy-cinnamyl alcohol, 3-(4-hydroxy-3-methoxyphenyl)-2-propen-1-ol] *[458-35-5]* **M 180.2, m 73-75°, 73-75°, b 163-165°/3mm.** It is soluble in EtOH and insoluble in H_2O. It can be recrystd from EtOH and distd in a vacuum. It polymerises in dilute acid. The *benzoyl derivative* has **m** 95-96° (from pet ether), and the *tosylate* has **m** 66°. [derivatives: Freudenberg and Achtzehn *B* **88** 10 *1955*; UV: Herzog and Hillmer *B* **64** 1288 *1931*].

Conessine *[546-06-5]* **M 356.6, m 125° $[\alpha]_D^{20}$ -1.9° (in $CHCl_3$), +25.3° (in EtOH).** Crystd from acetone.

Congo Red *[573-58-0]* **M 696.7, λ_{max} 497nm.** Crystd from aq EtOH (1:3). Dried in air.

Coproporphyrin I see entry in Chapter 5.

Coprostane (5α-cholestane) *[481-20-0]* **M 372.7, m 72°, $[\alpha]_D$ +25° (c 1, $CHCl_3$).** Crystd from EtOH.

4,5-Coprosten-3-ol (cholest-4-ene-3ß-ol) *[517-10-2]* **M 386.7, m 132°.** Crystd from MeOH/ethyl ether.

Coprosterol (5α-cholestan-3ß-ol, dihydrocholesterol) *[80-97-7]* **M 388.7, m 101°, 139-140°, $[\alpha]_D^{20}$ +24° (c 1, $CHCl_3$).** Crystd from MeOH.

Coronene *[191-07-1]* **M 300.4, m 438-440°, λ_{max} 345nm (log e 4.07).** Crystd from benzene or toluene, then sublimed in vacuum.

Cortisol, corticosterone, cortisone and **cortisone-21-acetate** see entries in Chapter 5.

Coumalic acid *[500-05-0]* **M 140.1, m 205-210°(dec).** Crystd from MeOH.

Coumaran see **2,3-dihydrobenzofuran.**

4-Coumaric acid see ***p*-hydroxycinnamic acid.**

Coumarilic acid see **2-benzofurancarboxylic acid.**

Coumarin *[91-64-5]* **M 146.2, m 68-69°, b 298°.** Crystd from ethanol or water and sublimed *in vacuo* at 43° [Srinivasan and deLevie *JPC* **91** 2904 *1987*].

Coumarin-3-carboxylic acid *[531-81-7]* **M 190.2, m 188°(dec).** Crystd from water.

Coumarone see **benzofuran.**

Creatine (H_2O) and **creatinine** see entries in Chapter 5.

***o*-Cresol** *[95-48-7]* **M 108.1, m 30.9°, b 191°, n^{41} 1.53610, n^{46} 1.53362.** Can be freed from *m*- and *p*-isomers by repeated fractional distn, Crystd from benzene by addition of pet ether. Fractional crystd by partial freezing of its melt.

***m*-Cresol** *[108-39-4]* **M 108.1, f.p. 12.0°, b 202.7°, d 1.034, n 1.5438.** Separation of the *m*- and *p*-cresols requires chemical methods, such as conversion to their sulphonates [Brüchner *AC* **75** 289 *1928*]. An equal volume of H_2SO_4 is added to *m*-cresol, stirred with a glass rod until soln is complete. Heat for 3h at 103-105°. Dilute carefully with 1-1.5 vols of water, heat to boiling point and steam distil until all unsulphonated cresol has been removed. Cool and extract residue with ether. Evaporate the soln until the boiling point reaches 134° and steam distil off the *m*-cresol. Another purification involves distn, fractional crystn from the melt, then redistn. Freed from *p*-cresol by soln in glacial acetic acid and bromination by about half of an equivalent amount of bromine in glacial acetic acid. The acetic acid was distd off, then fractional distn of the residue under vac gave bromocresols from which 4-bromo-*m*-cresol was obtained by crystn from hexane. Addn of the bromocresol in glacial acetic acid slowly to a reaction mixture of HI and red phosphorus or (more smoothly) of HI and hypophosphorus acid, in glacial acetic acid, at reflux, removed the bromine. After an hour, the soln was distd at atmospheric pressure until layers were formed. Then it was cooled and diluted with water. The cresol was extracted with ether, washed with water, $NaHCO_3$ soln and again with water, dried with a little $CaCl_2$ and distd [Baltzly, Ide and Phillips *JACS* **77** 2522 *1955*].

***p*-Cresol** *[106-44-5]* **M 108.1, m 34.8°, b 201.9°, n^{41} 1.53115, n^{46} 1.52870.** Can be separated from *m*-cresol by fractional crystn of its melt. Purified by distn, by pptn from benzene soln with pet ether, and *via* its benzoate, as for phenol. Dried under vacuum over P_2O_5. Has also been crystd from pet ether (b 40-60°) and by conversion to sodium *p*-cresoxyacetate which, after crystn from water was decomposed by heating with HCl in an autoclave [Savard *Ann Chim (Paris)* **11** 287 *1929*].

***o*-Cresol Red** *[1733-12-6]* **M 382.4, m 290°(dec).** Crystd from glacial acetic acid. Air dried. Dissolved in aqueous 5% $NaHCO_3$ soln and ppted from hot soln by dropwise addition of aqueous HCl. Repeated until extinction coefficients did not increase.

***o*-Cresotic acid (methylsalicylic acid)** *[83-40-9]* **M 152.2, m 163-164°,**
***m*-Cresotic acid** *[50-85-1]* **M 152.2, m 177°,**
***p*-Cresotic acid** *[89-56-5]* **M 152.2, m 151°.** Crystd from water.

Crocetin diethyl ester *[5056-14-4]* **M 384.5, m 218-219°, $\varepsilon^{1\%}_{1cm}$ 2340 (400nm), 3820 (422nm), 3850 (450nm) in pet ether.** Purified by chromatography on a column of silica gel G. Crystd from benzene. Stored in the dark, under an inert atmosphere, at 0°.

Crotonaldehyde *[127-73-9]* **M 70.1, b 104-105°.** Fractionally distd under N_2, through a short Vigreux column. Stored in sealed ampoules.

***trans*-Crotonic acid** *[3724-65-0]* **M 86.1, m 72-72.5°.** Distd under reduced pressure. Crystd from pet ether (b 60-80°) or water, or by partial freezing of the melt.

***E*- and *Z*-Crotonitrile (mixture)** *[4786-20-3]* **M 67.1, b 120-121°, d 1.091, n 1.4595.** Separated by preparative GLC on a column using 5% FFAP on Chromosorb G. [Lewis et al. *JACS* **108** 2818 *1986*].

γ-Crotonolactone *[497-23-4]* **M 84.1, m 3-4°, 76-77°/3.5mm, 90.5-91°/11.5mm, 92-93°/14mm, 107-109°/24mm, 212-214°/760mm, d_4^{20} 1.197, n_D^{20} 1.470.** Fractionally distd under reduced pressure. IR: (CCl_4) 1784 and 1742 cm^{-1}, UV no max above 205nm (ε 1160 cm^{-1} M^{-1}) and δ (CCl_3) 2.15 (pair of triplets 1H), 3.85 (pair of triplets 1H) and 5.03 (triplet 2H) τ. [*Org Synth* Coll Vol V 255 *1973*; Smith and Jones *Canad J Chem* **37** 2007, 2092 *1959*].

Crotyl bromide *[29576-14-5]* **M 135.0, b 103-105°/740mm, n^{25} 1.4792.** Dried with $MgSO_4$, $CaCO_3$ mixture. Fractionally distd through an all-glass Todd column.

15-Crown-5 *[33100-27-5]* **M 220.3, b 93-96°/0.1mm, d 1.113, n 1.465.** Dried over 3A molecular sieves.

18-Crown-6 *[17455-13-9]* **M 264.3, m 37-39°.** Recrystd from acetonitrile and vacuum dried. Purified by pptn of 18-crown-6/nitromethane 1:2 complex with Et_2O/nitromethane (10:1 mixture). The complex is decomposed in vacuum and distilled under reduced pressure. Also recrystd from acetonitrile and vacuum dried.

Cryptopine *[482-74-6]* **M 369.4, m 220-221°.** Crystd from benzene.

Cryptoxanthin *[472-70-8]* **M 552.9, $\varepsilon_{1cm}^{1\%}$ 2370 (452nm), 2080 (480nm) in pet ether.** Purified by chromatography on MgO, $CaCO_3$ or deactivated alumina, using EtOH or ethyl ether to develop the column. Crystd from $CHCl_3$/EtOH. Stored in the dark, under inert atmosphere, at -20°.

Crystal Violet Chloride (Gentian violet, *N*-4[bis[4-(dimethylamino)phenyl)methylene)-2,5-cyclohexadien-1-ylidene)-*N*-methylmethaninium chloride) *[548-62-9]* **M 408.0.** Crystd from water (20ml/g), the crystals being separated from the chilled soln by centrifugation, then washed with chilled EtOH (sol 1g in 10 ml of hot EtOH) and ethyl ether and dried under vac. It is sol in $CHCl_3$ but insol in Et_2O. The carbinol was ppted from an aqueous soln of the HCl dye, using excess NaOH, then dissolved in HCl and recrystd from water as the chloride [UV and kinetics: Turgeon and La Mer *JACS* **74** 5988 *1952*]. The *carbinol base* has **m** 195° (needles from EtOH). The *diphthalate* (blue and turns red in H_2O) crystallises from H_2O, **m** 153-154° (dec 185-187°)[Chamberlain and Dull *JACS* **50** 3089 *1928*].

Cumene *[98-82-8]* **M 120.2, b 69-70°/41mm, 152.4°/760mm, d 0.864, n 1.49146, n^{25} 1.48892.** Usual purification is by washing with several small portions of conc H_2SO_4 (until the acid layer is no longer coloured), then with water, 10% aq Na_2CO_3, again with water, and drying with $MgSO_4$, $MgCO_3$ or Na_2SO_4, followed by fractional distn. It can then be dried with, and distd from, Na, NaH or CaH_2. Passage through columns of alumina or silica gel removes oxidation products. Has also been steam distd from 3% NaOH, and azeotropically distd with 2-ethoxyethanol (which was subsequently removed by washing out with water).

Cumene hydroperoxide *[80-15-9]* **M 152.2, b 60°/0.2mm, d 1.028, n^{24} 1.5232.** Purified by adding 100ml of 70% material slowly and with agitation to 300ml of 25% NaOH in water, keeping the temperature below 30°. The resulting crystals of the sodium salt were filtered off, washed twice with 25 ml portions of benzene, then stirred with 100ml of benzene for 20min. After filtering off the crystals and repeating the washing, they were suspended in 100ml of distilled water and the pH was adjusted to 7.5 by addn of 4M HCl. The free hydroperoxide was extracted into two 20ml portions of *n*-hexane, and the solvent was evaporated under vacuum at room temperature, the last traces being removed at 40-50° and 1mm [Fordham and Williams *Canad J Res* **27B** 943 *1949*]. Petroleum ether, **but not ethyl ether**, can be used instead of benzene, and powdered solid CO_2 can replace the 4M HCl. *The material is potentially* **EXPLOSIVE.**

Cuminaldehyde (4-isopropylbenzaldehyde) *[122-03-2]* **M 148.2, b 82-84°/3.5mm, 120°/23mm, 131-135°/35mm, 235-236°/760mm, d^{20} 0.978, n_D^{20} 1.5301.** Likely impurity is the benzoic acid. Check the IR for the presence of OH from CO_2H and the CO frequencies. If acid is present then dissolve in Et_2O, wash with 10% $NaHCO_3$ until effecrvescence ceases, then with brine, dry over $CaCl_2$, evap and distil the residual oil, preferably under vacuum. It is almost insoluble in H_2O, but soluble in EtOH and Et_2O. The *thiosemicarbazone* has **m** 147° after recrystn from aqueous EtOH, or MeOH or C_6H_6. [Crounse *JACS* **71** 1263 *1949*; Bernstein et al. *JACS* **73** *906* 1951; Gensler and Berman *JACS* **80** 4949 *1958*].

Cupferron *[135-20-6]* **M 155.2, m 162.5-163.5°.** Crystd from EtOH (charcoal), washed with ethyl ether and air dried.

Cuprein *[524-63-0]* **M 310.4, m 202°, $[\alpha]_D^7$ -176° (in MeOH).** Crystd from EtOH.

Cuproin see **2,2'-biquinolyl.**

Curcumin *[458-37-7]* **M 368.4, m 183°.** Crystd from EtOH or acetic acid.

Cyanamide *[420-04-2]* **M 42.0, m 41°.** Crystd from ethyl ether, then vacuum distd at 80° (370mm). *Hygroscopic.*

Cyanoacetamide *[107-91-5]* **M 84.1, m 119.4°.** Crystd from MeOH/dioxane (6:4), then water. Dried over P_2O_5 under vacuum.

Cyanoacetic acid *[372-09-8]* **M 85.1, m 70.9-71.1°.** Crystd to constant melting point from benzene/acetone (2:3), and dried over silica gel.

Cyanoacetic acid hydrazide *[140-87-4]* **M 99.1, m 114.5-115°.** Crystd from EtOH.

4-Cyanoacetophenone see **4-acetylbenzonitrile.**

p-**Cyanoaniline** *[873-74-5]* **M 118.1, m 85-87°.** Crystd from water, or EtOH, and dried in a vacuum for 6h at 40°. [Edidin et al. *JACS* **109** 3945 *1987*].

9-Cyanoanthracene *[1210-12-4]* **M 203.2, m 134-137°.** Purified by crystn from EtOH or toluene, and vacuum sublimed in the dark and in an inert atmosphere [Ebied et al. *JCSFT 1* **76** 2170 *1980*; Kikuchi et al. *JPC* **91** 574 *1987*].

9-Cyanoanthracene photodimer *[33998-38-8]* **M 406.4.** Purified by dissolving in the minimum amount of $CHCl_3$ followed by addition of EtOH [Ebied et al. *JCSFT 1* **75** 1111 *1979*; **76** 2170 *1980*].

p-**Cyanobenzoic acid** *[619-65-8]* **M 147.1, m 219°.** Crystd from water.

4-Cyanobenzoyl chloride *[6068-72-0]* **M 165.6, m 68-70°,69-70°, 73-74°, b 132°/8mm, 150-151°/25mm.** If the IR shows presence of OH then treat with $SOCl_2$ boil for 1h, evaporate and distil in vacuum. The distillate solidifies and can be recrystallised from pet ether. It is moisture sensitive and is an **irritant.** [Ashley et al. *JCS* 103 *1942*; Fison et al. *JOC* **16** 648 *1951*].

Cyanoguanidine *[461-58-5]* **M 84.1, m 209.5°.** Crystd from water or EtOH.

5-Cyanoindole *[15861-24-2]* **M 142.2, m 104-104°, 106-108°, 107-108°.** Dissolve in 95% EtOH boil in the presence of charcoal, filter, evaporate to a small volume and add enough H_2O to cause crystallisation and cool. Recrystd directly from aqueous EtOH and dried in a vacuum. UV: λ_{max} 276 nm (log ε 3.6) in MeOH. [Lindwall and Mantell *JOC* **18** 345 *1953*, **20** 1458 *1955*; Thesing at al. *B* **95** 2205 *1962*; NMR: Lallemend and Bernath *Bull Soc Chim France* 4091 *1970*].

p-**Cyanophenol** *[767-00-0]* **M 119.1, m 113°.** Crystd from pet ether, benzene or water and kept under vacuum over P_2O_5. [Bernasconi and Paschelis *JACS* **108** 2969 *1986*].

3-Cyanopyridine *[100-54-9]* **M 104.1, m 50°.** Crystd to constant melting point from *o*-xylene/hexane.

4-Cyanopyridine *[100-48-1]* **M 104.1, m 76-79°.** Crystd from dichloromethane/ethyl ether mixture.

Cyanuric acid *[108-80-5]* **M 120.1, m >300°.** Crystd from water. Dried at room temperature in a desiccator under vacuum.

Cyanuric chloride *[108-77-0]* **M 184.4, m 154°.** Crystd from CCl_4 or pet ether (b 90-100°), and dried under vacuum. Recrystd twice from anhydrous benzene immediately before use [Abuchowski et al. *JBC* **252** 3582 *1977*].

Cyclobutane carboxylic acid *[3721-95-7]* **M 100.1, m 3-4°, -5.4°, b 84-84.5°/10mm, 110°/25mm, 135-138°/110mm, 194°/760mm, d_4^{20} 1.0610, n_D^{20} 1.4534.** Dissolve in aqueous HCO_3^- and acidify with HCl and extract into Et_2O, wash with H_2O, dry (Na_2SO_4), concentrate to a small volume, then distil through a glass helices packed column. It has a pKa^{25} of 4.79 in H_2O. The S-*benzylthiouronium salt* has **m** *176°* (from EtOH), and the *anilide* has **m** 112.5-113°, and the *p-toluide* has **m** 123°. [Payne and Smith *JOC* **22** 1680 *1957*; Kantaro and Gunning *JACS* **73** 480 *1951*].

trans-**Cyclobutane-1,2-dicarboxylic acid** *[1124-13-6]* **M 144.1, m 131°.** Crystd from benzene.

Cyclobutanone *[1191-95-3]* **M 70.1, b 96-97°, d 0.931, n^{52} 1.4189.** Treated with dilute aqueous $KMnO_4$, dried with molecular sieves and fractionally distd. Purified *via* the semicarbazone, then regenerated, dried with $CaSO_4$, and distd in a spinning-band column. Alternatively, purified by preparative gas chromatography using a Carbowax 20-M column at 80°. (This treatment removes acetone).

Cyclobutylamine *[2516-34-9]* **M 71.1, b 82-83°/atm, 83.2-84.2°/760mm, d_4^{20} 0.839, n_D^{20} 1.437.** It has been purified by steam distn. The aqueous distillate (e.g. 2L) is acidified with 3N HCl (90ml) and evapd to dryness in a vacuum. The *hydrochloride* is treated with a few ml of H_2O, cooled in ice and a slush of KOH pellets ground in a little H_2O is added slowly in portions and keeping the soln very cold. The amine separates as an oil from the strongly alkaline soln. The oil is collected dried over solid KOH and distd using a vac jacketed Vigreux column and protected from CO_2 using a soda lime tube. The fraction boiling at 79-83° is collected, dried over solid KOH for 2 days and redistd over a few pellets of KOH (b 80.5-81.5°). Best distil in a dry N_2 atmosphere. The purity can be checked by GLC using a polyethylene glycol on Teflon column at 72°, 15 psi, flow rate of 102 ml/min of He. The sample can appear homogeneous but because of tailing it is not possible to tell if H_2O is present. The NMR in CCl_4 should show no signals less than 1 ppm from TMS. The *hydrochloride* has a multiplet at *ca* 1.5-2.6ppm (H 2,2,4,3,3,4,4), a quintet at 3.8 ppm (H 1) and a singlet at 4.75 for NH_2. It has a pKa^{25} of 9.34 in 50% aq EtOH [Roberts and Chambers *JACS* **73** 2509 *1951*]. The *benzenesulphonamide* has **m** 85-86° (from aq MeOH) and the *benzoyl derivative* has **m** 120.6-121.6° [Roberts and Mazur *JACS* **73** 2509 *1951*; Iffland et al. *JACS* **75** 4044 *1953*; *Org* Synth Coll Vol V 273 *1973*].

Cyclodecanone *[1502-06-3]* **M 154.2, m 21-24°, b 100-102°/12mm.** Purified by sublimation.

cis-**Cyclodecene** *[935-31-9]* **M 138.3, m -3°, -1°, b 73°/15mm, 90.3°/33mm, 194-195°/740mm, 197-199°/atm, d_4^{20} 0.8770, n_D^{20} 1.4854.** Purified by fractional distn. It forms an $AgNO_3$ complex which crystallises from MeOH, **m** 167-187° [Cope et al. *JACS* **77** 1628 *1955*; IR: Blomqvist et al. *JACS* **74** 3636 *1952*; Prelog et al. *HCA* **35** 1598 *1952*].

α-**Cyclodextrin** (H_2O) *[10016-20-3]* **M 972.9, m >280°(dec), $[\alpha]_{546}^{20}$ +175° (c 10, H_2O).** Recrystd from 60% aq EtOH, then twice from water, and dried for 12h in a vacuum at 80°. Also purified by pptn from water with 1,1,2-trichloroethylene. The ppte was isolated, washed and resuspended in water. This was boiled to steam distil the trichloroethylene. The soln was freeze-dried to recover the cyclodextrin. [Armstrong et al. *JACS* **108** 1418 *1986*].

β-Cyclodextrin (H_2O) *[7585-39-9]* **M 1135.0, m >300°(dec), $[\alpha]_{546}^{20}$ +170° (c 10, H_2O).** Recrystd from water and dried for 12h *in vacuo* at 110°. The purity was assessed by TLC on cellulose with a fluorescent indicator. [Taguchi, *JACS* **108** 2705 *1986*; Tabushi et al. *JACS* **108** 4514 *1986*].

***trans-cis-cis*-1,5,9-Cyclododecatriene (cyclododec-1c,5c,9t-triene)** *[2765-29-9]* **M 162.3, m -9°, -8°, b 117.5°/2mm, 237-239°/atm, 244°/760mm, d_4^{20} 0.907, n_D^{20} 1.5129.** Purified by fractional distn, preferably in a vacuum under N_2, and forms an insoluble $AgNO_3$ complex. [Breil et al. *Makromol. Chemie* **69** 28 *1963*].

Cyclododecylamine *[1502-03-0]* **M 183.3, m 27-29°, b 140-150°/*ca* 18mm, 280°/atm.** It can be purified *via* the *hydrochloride salt* **m** 274-275° (from EtOH) or the *picrate* **m** 232-234°, and the free base is distd at water-pump vacuum. Its pKa in 80% methyl cellosolve is 9.62. [Prelog et al. *HCA* **33** 365 *1950*].

1,3-Cycloheptadiene *[4054-38-0]* **M 94.2, b 55°/75mm, 71.5°/150mm, 120-121°/atm, d_4^{20} 0.868, n_D^{20} 1.4972.** It was purified by dissolving in Et_2O, wash with 5% HCl, H_2O, dry ($MgSO_4$), evap and the residue is distd under dry N_2 through a semi-micro column (some foaming occurs), [Cope et al. *JACS* **79** 6287 *1957;* UV: Pesch and Friess *JACS* **72** 5756 *1950*].

Cycloheptane *[291-64-5]* **M 98.2, b 114.4°, d 0.812, n 1.4588.** Distd from sodium, under nitrogen.

Cycloheptanone *[502-42-1]* **M 112.2, b 105°/80mm, 172.5°/760, d 0.952, n^{24} 1.4607.** Shaken with aq $KMnO_4$ to remove material absorbing around 230-240nm, then dried with Linde type 13X molecular sieves and fractionally distd.

Cycloheptatriene *[544-25-2]* **M 92.1. b 114-115°, d 0.895, n 1.522.** Washed with alkali, then fractionally distd.

Cycloheptimidazole see **1,3-diaza-azulene.**

Cycloheptylamine *[5452-35-7]* **M 113.2, b 50-52°/11mm, 60°/18mm, d_4^{20} 0.887, n_D^{20} 1.472.** It can be purified by conversion to the *hydrochloride* **m** 242-246°, and the free base is distd under dry N_2 in a vacuum. It has a pKa^{24} of 9.99 in 50% methyl cellosolve. [Cope et al. *JACS* **75** 3212 *1953*; Prelog et al. *HCA* **33** 365 *1950*].

1,3-Cyclohexadiene *[592-57-4]* **M 80.1, b 83-84°/atm. d_4^{20} 0.840, n_D^{20} 1.4707.** Distd from $NaBH_4$.

1,4-Cyclohexadiene *[628-41-1]* **80.1, b 83-86°/714mm, 88.3°/741mm, 86-88°/atm, , 88.7-89°/760mm, d_4^{20} 0.8573, n_4^{20} 1.4725.** Dry over $CaCl_2$ and distil in a vacuum under N_2. [Hückel and Wörffel **b** *88* 338 *1955*; Giovannini and Wegmüller *HCA* **42** 1142 *1959*].

Cyclohexane *[110-82-7]* **M 84.2, f.p. 6.6°, b 80.7°, d^{24} 0.77410, n 1.42623, n^{25} 1.42354.** Commonly, washed with conc H_2SO_4 until the washings are colourless, followed by water, aq Na_2CO_3 or 5% NaOH, and again water until neutral. It is next dried with P_2O_5, Linde type 4A molecular sieves, $CaCl_2$, or $MgSO_4$ then Na and distd. Cyclohexane has been refluxed with, and distd from Na, CaH_2, $LiAlH_4$ (which also removes peroxides), sodium/potassium alloy, or P_2O_5. Traces of benzene can be removed by passage through a column of silica gel that has been freshly heated: this gives material suitable for ultraviolet and infrared spectroscopy. If there is much benzene in the cyclohexane, most of it can be removed by a preliminary treatment with nitrating acid (a cold mixture of 30ml conc HNO_3 and 70ml of conc H_2SO_4) which converts benzene into nitrobenzene. The impure cyclohexane and the nitrating acid are placed in an ice bath and stirred vigorously for 15min, after which the mixture is allowed to warm to 25° during 1h. The cyclohexane is decanted, washed several times with 25% NaOH, then water dried with $CaCl_2$, and distd from sodium. Carbonyl-containing impurities can be removed as described for chloroform. Other purification procedures

include passage through columns of activated alumina and repeated crystn by partial freezing. Small quantities may be purified by chromatography on a Dowex 710-Chromosorb W gas-liquid chromatographic column.

Cyclohexane butyric acid *[4441-63-8]* **M 170.3, m 31°, 26.5-28.5°, b 136-139°/4mm. 169°/20mm, 188.8°/46mm.** Distil through a Vigreux column, and the crystalline distillate is recrystd from pet ether. It has a pKa^{25} of 4.95 in H_2O. The *S-benzylthiouronium salt* has **m** 154-155° (from EtOH) [*Acta Chem Scand* **9** 1425 *1955*; English and Dayan *JACS* **72** 4187 *1950*].

Cyclohexane-1,2-diaminetetraacetic acid (H_2O; CDTA) *[13291-61-7]* **M 364.4.** Dissolved in aq NaOH as its disodium salt, then pptd by adding HCl. The free acid was filtered off and boiled with distd water to remove traces of HCl [Bond and Jones *TFS* **55** 1310 *1959*]. Recrystd from water and dried under vacuum.

***trans*-Cyclohexane-1,2-dicarboxylic acid** *[2305-32-0]* **M 172.2, m 226-228°, 227.5-228°, 228-230.5°.** It is purified by recrystn from EtOH or H_2O. The *dimethyl ester* has **m** 95-96° (from C_6H_6-pet ether). [Abell *JOC* **22** 769 *1957*; Smith and Byrne *JACS* **72** 4406 *1950*; Linstead et al. *JACS* **64** 2093 *1942*].

(±)-*trans*-1,2-Cyclohexanediol *[1460-57-7]* **M 116.2, m 104°, 105°, 120°/14mm.** Crystd from Me_2CO and dried at 50° for several days. It can also be recrystd from CCl_4 or EtOAc and can be distilled. The *2,4-dinitrobenzoyl derivative* has **m** 179°. [Winstein and Buckles *JACS* **64** 2780 *1942*].

***trans*-1,2-Cyclohexanediol** *[1R,2R-(-): 1072-86-2] [1S,2S-(+) : 57794-08-8]* **M 116.2, m 107-109°, 109-110.5°, 109-111°, 111-112°, 113-114°, $[\alpha]_D^{22}$ ±46.5° (c 1, H_2O).** The enantiomers have been recrystd from C_6H_6 or EtOAc. The (±) diol has been resolved as the distrychnine salt of the hemisulphate [Hayward, Overton and Whitham *JCS Perkin Trans I* 2413 *1976*]; or the *1-menthoxy acetates.* {d-trans- diastereoisomer has **m** 64°, $[\alpha]_D$ -91.7° (c 1.4 EtOH) from pet ether or aqueous EtOH and yields the (-)-*trans*-diol } and {l-trans-diastereoisomer has **m** 126-127°, $[\alpha]_D$ -32.7° (c 0.8 EtOH) from pet ether or aq EtOH and yields the (+)-trans diol}. The bis-*4-nitrobenzoate* has **m** 126.5° $[\alpha]_D$ ±25.5° (c 1.1 $CHCl_3$), and the bis-*3,5-dinitrobenzoate* has **m** 160° $[\alpha]_D$ ± -83.0° (c 1.8 $CHCl_3$) [Wilson and Read *JCS* 1269 *1935*].

***cis*-1,3-Cyclohexanediol** *[931-17-9]* **M 116.2, m 86°.** Crystd from ethyl acetate and acetone.

***trans*-1,3-Cyclohexanediol** *[5515-64-0]* **M 116.2, m 117°.** Crystd from ethyl acetate.

***cis*-1,4-Cyclohexanediol** *[556-58-9]* **M 116.2, m 102.5°.** Crystd from acetone (charcoal), then dried and sublimed under vacuum.

Cyclohexane-1,3-dione *[504-02-9]* **M 112.1, m 107-108°.** Crystd from benzene.

Cyclohexane-1,4-dione *[637-88-7]* **M 112.1, m 76-77°, 78°, 79.5°, 79-80°, b 130-133°/20mm, d_4^{91} 1.0861, n_D^{102} 1.4576.** Crystd from water, then benzene. It can also be recrystd from $CHCl_3$/pet ether or Et_2O. It has been purified by distn in a vacuum and the pale yellow distillate which solidified is then recrystd from CCl_4 (14.3 g/100 ml) and has **m** 77-79°. The *di-semicarbazone* has **m** 231°, the *dioxime HCl* has **m** 150° (from MeOH-C_6H_6) and the bis-*2,4-dinitrophenylhydrazone* **m** 240° (from $PhNO_2$). [*Org Synth* Coll Vol V 288 *1973*; IR: LeFevre and LeFevre *JCS* 3549 *1956*].

Cyclohexane-1,2-dione dioxime (Nioxime) *[492-99-9]* **M 142.2, m 189-190°.** Crystd from alcohol/water and dried in a vacuum at 40°.

1,4-Cyclohexanedione monoethylene acetal (1,4-dioxa-spiro[4,5]decan-8-one) *[4746-97-8]* **M 156.2, m 70-73°, 73.5-74.5°.** Recrystd from pet ether and sublimes slowly on attempted distillation. Also purified by dissolving in Et_2O and adding pet ether (b 60-80°) until turbid and cool. [Gardner et al. *JACS* **22** 1206 *1957*; Britten and Lockwood *JCS Perkin Trans 1* 1824 *1974*].

***cis,cis*-1,3,5-Cyclohexane tricarboxylic acid** *[16526-68-4]* **M 216.2, m 214-218°, 216-218°.** Purified by recrystn from toluene + EtOH or H_2O. It forms a *1.5 hydrate* with **m** 216-218°, and a *dihydrate* at 110°. Purified also by conversion to the *triethyl ester* **b** 217-218°/10mm, 151°/1mm and distillate solidifies on cooling, **m** 36-37° and is hydrolysed by boiling in aq HCl. The *trimethyl ester* can be distd and recrystd from Et_2O, **m** 48-49°. [Newman and Lawrie *JACS* **76** 4598 *1954*, Lukes and Galik *Coll Czech Chem Comm* **19** *712* **1954**].

Cyclohexanol *[108-93-0]* **M 100.2, m 25.2°, b 161.1°, d 0.9459, n 1.466, n^{25} 1.4365, n^{30} 1.4629.** Refluxed with freshly ignited CaO, or dried with Na_2CO_3, then fractionally distd. Redistd from Na. Further purified by fractional crystn from the melt in dry air. Peroxides and aldehydes can be removed by prior washing with ferrous sulphate and water, followed by distillation under nitrogen from 2,4-dinitrophenylhydrazine, using a short fractionating column: water distils as the azeotrope. Dry cyclohexanol is *very hygroscopic.*

Cyclohexanone *[108-94-1]* **M 98.2, f.p. -16.4°, b 155.7°, d 0.947, n^{15} 1.45203. n 1.45097.** Dried with $MgSO_4$, $CaSO_4$, Na_2SO_4 or Linde type 13X molecular sieves, then distd. Cyclohexanol and other oxidisable impurities can be removed by treatment with chromic acid or dil $KMnO_4$. More thorough purification is possible by conversion to the bisulphite addition compound, or the semicarbazone, followed by decompn with Na_2CO_3 and steam distn. [For example, equal weights of the bisulphite adduct (crystd from water) and Na_2CO_3 are dissolved in hot water and, after steam distn, the distillate is saturated with NaCl and extracted with benzene which is then dried and the solvent evaporated prior to further distn].

Cyclohexanone oxime *[100-64-1]* **M 113.2, m 90°.** Crystd from water or pet ether (b 60-80°).

Cyclohexanone phenylhydrazone *[946-82-7]* **M 173.3, m 77°.** Crystd from EtOH.

Cyclohexene *[110-83-8]* **M 82.2, b 83°, d 0.810, n 1.4464, n^{25} 1.4437.** Freed from peroxides by washing with successive portions of dil acidified ferrous sulphate, or with $NaHSO_3$ soln then with distd water, dried with $CaCl_2$ or $CaSO_4$, and distd under N_2. Alternative methods of removing peroxides include passage through a column of alumina, refluxing with sodium wire or cupric stearate (then distilling from sodium). Diene is removed by refluxing with maleic anhydride before distg under vac. Treatment with 0.1moles of MeMgI in 40ml of ethyl ether removes traces of oxygenated impurities. Other purification procedures include washing with aq NaOH, drying and distg under N_2 through a spinning band column; redistg from CaH_2; storage with sodium wire; and passage through a column of alumina, under N_2, immediately before use. Stored in a refrigerator under argon. [Woon et al. *JACS* **108** 7990 *1986*; Wong et al. *JACS* **109** 3428 *1987*].

(±)-2-Cyclohexen-1-ol (3-hydroxycyclohex-1-ene) *[822-67-3]* **M 242.2, b 63-65°/12mm, 65-66°/13mm, 67°/15mm, 74°/25mm, 85[°/35mm, 166°/atm, d_4^{20} 0.9865, n_D^{20} 1.4720.** Purified by distillation through a short Vigreux column. The *2,4-dinitrobenzoyl derivative* has **m** 120.5°, and the *phenylurethane* has **m** 107°. [*Org Synth* Coll Vol **48** 18 *1968*, Cook *JCS* 1774 *1938*; Deiding and Hartman *JACS* **75** 3725 *1953*].

Cyclohexene oxide *[286-20-4]* **M 98.2, b 131-133°/atm, d_4^{20} 0.971, n_D^{20} 1.452.** Fractionated through an efficient column. The main impurity is probably H_2O. Dry over $MgSO_4$, filter and distil several times (**b** 129-134°/atm). The residue is sometimes hard to remove from the distilling flask. To avoid this difficulty, add a small amount of a mixture of ground NaCl and Celite (1:1) to help break the residue particularly if H_2O is added. [*Org Synth* Coll Vol I 185 *1948*].

Cycloheximide *[68-81-9]* **M 281.4, m 119.5-121°.** Crystd from water/MeOH (4:1), amyl acetate, isopropyl acetate/isopropyl ether or water.

Cyclohexylamine *[108-91-8]* **M 99.2, b 134.5°, d 0.866, d^{25} 0.8625, n 1.45926, n^{25} 1.4565.** Dried with $CaCl_2$ or $LiAlH_4$, then distd from BaO, KOH or Na, under N_2. Also purified by conversion to the hydrochloride, several crystns from water, then liberation of the amine with alkali and fractional distn under N_2.

Cyclohexylbenzene *[827-52-1]* **M 160.3, f.p. 6.8°, b 237-239°, d 0.950, n 1.5258.** Purified by fractional distn, and fractional freezing.

Cyclohexyl bromide *[108-85-0]* **M 156.3, b 72°/29mm, d 0.902, n^{25} 1.4935.** Shaken with 60% aqueous HBr to remove the free alcohol. After separation from excess HBr, the sample was dried and fractionally distd.

Cyclohexyl chloride *[542-18-7]* **M 118.6, b 142-142.5°, d 1.000, n 1.462.** Dried with $CaCl_2$ and distd.

1-Cyclohexyl-ethylamine *[S-(+): 17430-98-7] [R-(-): 5913-13-3]* **M 127.2, b 177-178°/atm, d_4^{20} 0.866, n_D^{20} 1.4463, $[\alpha]_D^{15}$±3.2° (neat).** Purified by conversion to the *bitartrate salt* (**m** 172°), then decomposing with strong alkali and extracting into Et_2O, drying (KOH), filtering, evaporating and distilling. The *hydrochloride salt* has **m** 242° (from EtOH-Et_2O), $[\alpha]_D^{15}$ -5.0° (c 10 H_2O; from (+) amine). The *oxalate salt* has **m** 132° (from H_2O). The *(±)-base* has **b** 176-178°/760mm, and *HCl* has **m** 237-238°. [Reihlen, Knöpfle and Sapper *A* **532** 247 *1938*; *B* **65** 660 *1932*].

Cyclohexylidene fulvene *[3141-04-6]* **M 134.2.** Purified by column chromatography and eluted with *n*-hexane [Abboud et al. *JACS* **109** 1334 *1987*].

Cyclohexyl mercaptan (cyclohexane thiol) *[1569-69-3]* **M 116.2, b 38-39°/12mm, 57°/23mm, 90°/100mm, 157°/763mm, d_4^{20} 0.9486, n_D^{20} 1.4933.** Possible impurities are the sulphide and the disulphide. Purified by conversion to the Na salt by dissolving in 10% aq NaOH, extract the sulphide and disulphide with Et_2O, and then acidify the aq soln (with cooling and under N_2) with HCl, extract with Et_2O, dry $MgSO_4$, evaporate and distil in a vacuum (**b** 41°/12mm). The *sulphide* has **b** *74°*/0.2mm, $n_D^{18.5}$ 1.5162 and the *disulphide* has **b** 110-112°/0.2mm, $n_D^{18.5}$ 1.5557. The *Hg-mercaptide* has **m** 77-78° (needles from EtOH). [Naylor *JCS* 1532 *1947*].

Cyclohexyl methacrylate *[101-43-9]* **M 168.2, b 81-86°/0.1mm, d 0.964, n 1.458.** Purification as for methyl methacrylate.

1-Cyclohexyl-5-methyltetrazole *[7707-57-5]* **M 166.2, m 124-124.5°.** Crystd from absolute EtOH, then sublimed at 115°/3mm.

Cycloleucine see **1-amino-1-cyclopentanecarboxylic acid.**

Cyclononanone *[3350-30-9]* **M 140.2, m 142.0-142.8°, b 220-222°.** Repeatedly sublimed at 0.05-0.1mm pressure.

***cis,cis*-1,3-Cyclooctadiene** *[29965-97-7]* **M 108.2; [1,3-cyclooctadiene,** *[1700-10-3]* **M 108.2], m -5°, -49°, b 55°/34mm, 142-144°/760mm, d_4^{20} 0.8690, n_D^{20} 1.48921.** Purified by GLC. Fractionally distd through a Widmer column as a mobile liquid and redistilled with a Claisen flask or through a semi-micro column (Gould, Holzman and Neiman *AC* **20** 361 *1948*]. **NB:** It has a strong characteristic disagreeable odour dectectable at low concentrations and causes headaches on prolonged exposure. [IR: Cope and Estes *JACS* **72** 1128 *1950*; UV: Cope and Baumgardner *JACS* **78** 2812 *1956*].

***cis-cis*-1,5-cyclooctadiene,** *[1552-12-1]* **M 108.2, m -69.5°, -70°, b 51-52°/25mm, 97°/144mm,150.8°/757mm, d_4^{20} 0.880, n_D^{20} 1.4935, .** Purified by GLC. It has been purified *via* the $AgNO_3$ salt. This is prepared by shaking with a soln of 50% aq $AgNO_3$ w/w several times (e.g. 3 x 50 ml and 4 x 50 ml) at 70° for *ca* 20min to get a good separation of layers. The upper layers are combined and further extracted with $AgNO_3$ at 40° (2 x 20 ml). The upper layer (19 ml) of original hydrocarbon mixture gives colourless needles $AgNO_3$ complex on cooling. The adduct is recrystd from MeOH (and cooling to 0°). The hydrocarbon is recovered by steam distilling the salt. The distillate is extracted with Et_2O, dried ($MgSO_4$), evap and distd. [Jones *JCS* 312 *1954*].

Cyclooctanone *[502-49-8]* **M 126.2, m 42°.** Purified by sublimation after drying with Linde type 13X molecular sieves.

1,3,5,7-Cyclooctatetraene *[629-20-9]* **M 104.2, b 141-141.5°, d 1.537, n^{25} 1.5350.** Purified by shaking 3ml with 20ml of 10% aqueous $AgNO_3$ for 15min, then filtering off the silver nitrate complex as a ppte. The ppte was dissolved in water and added to cold conc ammonia to regenerate the cyclooctatetraene which was fractionally distd under vacuum onto molecular sieves and stored at 0°. It was passed through a dry alumina column before use [Broadley et al. *JSCDT* **373** *1986*].

***cis*-Cyclooctene** *[931-88-4]* **M 110.2, b 32-34°/12mm, 66.5-67°/60mm, 88°/141mm, 140°/170mm, 143°/760mm, d_4^{20} 0.84843, n_D^{20} 1.4702,** . The *cis*-isomer was freed from the *trans*-isomer by fractional distn through a spinning-band column, followed by preparative gas chromatography on a Dowex 710-Chromosorb W GLC column. It was passed through a short alumina column immediately before use [Collman et al. *JACS* **108** 2588 *1986*]. It has also been distd in a dry nitrogen glove box from powdered fused NaOH through a Vigreux column and then passed through activated neutral alumina before use [Wong et al. *JACS* **109** 4328 *1987*]. Alternatively it can be purified *via* the $AgNO_3$ salt. This salt is obtained from crude cyclooctene (40 ml) which is shaken at 70-80° with 50% w/w $AgNO_3$ (2 x 15 ml) to remove cyclooctadienes (aq layer). Extraction is repeated at 40° (4 x 20 ml, of 50% $AgNO_3$). Three layers are formed each time. The middle layer contains the $AgNO_3$ adduct of cyclooctene which crystallises on cooling the layer to room temperature. The adduct (complex 2:1) is highly soluble in MeOH (at least 1g/ml) from which it crystallises in large flat needles when cooled at 0°. It is dried under slight vacuum for 1 week in the presence of $CaCl_2$ and paraffin wax soaked in the cyclooctene. It has **m** 51° and loses hydrocarbon on exposure to air. *cis*-Cyclooctene can be recovered by steam distn of the salt, collected, dried ($CaCl_2$) and distilled in vacuum. [Braude et al. *JCS* 4711 *1957*; $AgNO_3$: Jones *JCS* 1808 *1954*; Cope and Estes *JACS* **72** 1128 *1950*].

***cis*-Cyclooctene oxide {(1r,8c)-9-oxabicyclo[6.1.0]nonane}** *[286-62-4]* **M 126.7, m 56-57°, 57.5-57.8°,50-60°, b 85-88°/17mm, 82.5°/22mm, 90-93°/37mm, 189-190°/atm.** It can be distd in vacuum and the solidified distillate can be sublimed in vacuum below 50°. It has a characteristic odour. [IR: Cope et al. *JACS* **74** 5884 *1952*, **79** 3905 *1957*; Reppe et al. *A* **560** 1 *1948*].

Cyclopentadecanone *[502-72-7]* **M 224.4, m 63°.** Sublimation is better than crystn from aq EtOH.

Cyclopentadiene *[542-92-7]* **M 66.1, b 41-42°.** Dried with $Mg(ClO_4)_2$ and distd.

Cyclopentane *[287-92-3]* **M 70.1, b 49.3°, d 0.745, n 1.40645, n^{25} 1.4340.** Freed from cyclopentene by two passages through a column of carefully dried and degassed activated silica gel.

Cyclopentane carbonitrile *[4254-02-8]* **M 95.2, m -75.2°, -76°, b 43-44°/7mm, 50-62°/10mm, 67-68°/14mm, 74.5-75°/30mm, d_4^{20} 0.912, n_D^{20} 1.441.** Dissolve in Et_2O, wash thoroughly with saturated aqueous K_2CO_3, dry ($MgSO_4$) and distil through a 10 cm Vigreux column. [McElvain and Stern *JACS* **77** 457 *1955*, Bailey and Daly **81** 5397 *1959*].

Cyclopentane-1,1-dicarboxylic acid *[5802-65-3]* **M 158.1, m 184°.** Recrystd from water.

1,3-Cyclopentane-dione *[3859-41-4]* **M 98.1, m 149-150°, 151-152.5°,151-154°, 151-153°.** Purified by Soxhlet extraction with $CHCl_3$. The $CHCl_3$ is evaporated and the residue is recrystd from EtOAc and/or sublimed at 120°/4mm. It has an acidic pKa of 4.5 in H_2O. [IR: Boothe et al. *JACS* **75** 1732 *1953*; DePuy and Zaweski **81** 4920 *1959*].

Cyclopentanone *[120-92-3]* **M 84.1, b 130-130.5°, d 0.947, n 1.4370, n^{25} 1.4340.** Shaken with aq $KMnO_4$ to remove materials absorbing around 230 to 240nm. Dried with Linde type 13X molecular sieves and fractionally distd. Has also been purified by conversion to the $NaHSO_3$ adduct which, after crystallising four times from EtOH/water (4:1), was decomposed by adding to an equal weight of Na_2CO_3 in hot H_2O. The free cyclopentanone was steam distd from the soln. The distillate was saturated with NaCl and

extracted with benzene which was then dried and evaporated; the residue was distd [Allen, Ellington and Meakins *JCS* 1909 *1960*].

Cyclopentene *[142-29-0]* **M 68.1, b 45-46°, d 0.772, n 1.4228.** Freed from hydroperoxide by refluxing with cupric stearate. Fractionally distd from Na. Chromatographed on a Dowex 710-Chromosorb W GLC column. Methods for **cyclohexene** should be applicable here. Also washed with 1M NaOH soln followed by water. It was dried over anhydrous Na_2SO_4, distd over powdered NaOH under nitrogen, and passed through neutral alumina before use [Woon et al. *JACS* **108** 7990 *1986*]. It was distd in a dry nitrogen atmosphere from powdered fused NaOH through a Vigreux column, and then passed through activated neutral alumina before use [Wong et al. *JACS* **109** 3428 *1987*].

1-Cyclopentene-1,2-dicarboxylic anhydride *[3205-94-5]* **M 138.1, m 42-54°, 46-47°, b 130°/5mm, 133-135°/5mm, n_D^{20} 1.497.** If IR has OH peaks then some hydrolysis to the diacid (m 178°) must have occurred. In this case reflux with an appropriate volume of Ac_2O for 30min, evaporate the Ac_2O and distil *in vacuo*. The distillate solidifies and can be recrystd from EtOAc-hexane (1:1). The diacid distils without dec due to formation of the anhydride. The *dime ester* has **m** 120-125°/11mm. [Askain *B* **98** 2322 *1965*].

Cyclopentylamine *[1003-03-8]* **M 85.2, m -85.7°, b 106-108°/760mm, 108.5°/760mm, d_4^{20} 0.8689, n_D^{20} 1.4515.** May contain H_2O or CO_2 in the form of carbamate salt. Dry over KOH pellets and then distil from a few pellets of KOH. Store in a dark, dry CO_2-free atmosphere. It is characterised as the *thiocyanate salt* **m** 94.5°. It has a pKa^{25} in 50% aa EtOH of 4.05. The *benzenesulphonyl derivative* has **m** 68.5-69.5°. [Roberts and Chambers *JACS* **73** 5030 *1951*; Bollinger et al. *JACS* **75** 1729*1953*].

Cyclopropane *[75-19-4]* **M 42.1, b -34°.** Washed with a soln of $HgSO_4$, and dried with $CaCl_2$, then $Mg(ClO_4)_2$.

Cyclopropanecarbonyl chloride *[4023-34-1]* **M 104.5, b 117.9-118.0°/723mm, 119.5-119.6[°/760mm, d_4^{20} 1.142, n_4^{20} 1.453.** If the IR shows OH bands then some hydrolysis to the free acid must have occurred. In this case heat with oxalyl chloride at 50° for 2h or $SOCl_2$ for 30min, then evap and distil three times using a Dufton column. Store in an inert atm, preferably in sealed tubes. Strong **irritant** If it is free from OH bands then just distil *in vacuo* and store as before. [Jeffrey and Vogel *JCS* 1804 *1948*].

Cyclopropane-1,1-dicarboxylic acid *[598-10-7]* **M 130.1, m 140°.** Recrystd from $CHCl_3$.

Cyclopropylamine *[765-30-0]* **M 57.1, b 49-49.5°/760mm, 48-50°/atm, 49-50°/750mm, d_4^{20} 0.816, n_D^{20} 1.421.** It has been isolated as the *benzamide* **m** 100.6-101.0° (from aqueous EtOH). It forms a *picrate* **m** 149° (from EtOH-pet ether) from which the free base can be recovered using a basic ion exchange resin and can then be distd through a Todd column using an automatic still head which only collects products boiling below 51°/atm. Polymeric materials if present will boil above this temperature. The *hydrochloride* has **m** 85-86°. The pKa^{25} in 40% EtOH is 5.33. [Roberts and Chambers *JACS* **73** 5030 *1951*; Jones *JOC* **9** 484 *1944*; Emmons *JACS* **79** 6522 *1957*].

Cyclopropyldiphenylcarbinol *[5785-66-0]* **M 224.3, m 86-87°.** Crystd from *n*-heptane.

Cyclopropyl methyl ketone *[765-43-5]* **M 84.1, b 111.6-111.8°/752mm, d 0.850, n 1.4242.** Stored with anhydrous $CaSO_4$, distd under nitrogen. Redistd under vacuum.

***R*- and *S*- Cycloserine** see ***R*- and *S*- 4-amino-3-isoxazolidone** see entry in Chapter 5.

Cyclotetradecane *[295-17-0]* **M 192.3, m 56°.** Recrystd twice from aq EtOH then sublimed *in vacuo* [Dretloff et al. *JACS* **109** 7797 *1987*].

Cyclotetradecanone *[832-10-0]* **M 206.3, m 25°, b 145°/10mm, d 0.926, n 1.480.** It was converted to the semicarbazone which was recrystd from EtOH and reconverted to the free cyclotetradecanone by hydrolysis [Dretloff et al. *JACS* **109** 7797 *1987*].

Cyclotrimethylenetrinitramine (RDX) *[121-82-4]* **M 222.2, m 203.8°(dec).** Crystd from acetone. **EXPLOSIVE.**

***p*-Cymene** *[99-87-6]* **M 134.2, b 177.1°, d 0.8569, n 1.4909, n^{25} 1.4885.** Washed with cold, conc H_2SO_4 until there is no further colour change, then repeatedly with H_2O, 10% aqueous Na_2CO_3 and H_2O again. Dried with Na_2SO_4, $CaCl_2$ or $MgSO_4$, and distd. Further purification steps include steam distn from 3% NaOH, percolation through silica gel or activated alumina, and a preliminary refluxing for several days over powdered sulphur.

Cystamine dihydrochloride,
***S,S*-(L,L)-Cystathionine,**
Cysteamine and **Cysteamine hydrochloride,**
(±)-Cysteic acid and ***S*-Cysteic acid (H_2O),**
L-Cysteine hydrochloride (H_2O) and **(±)-Cysteine hydrochloride,**
L-Cystine,
Cytidine, see entries in Chapter 5.

Cytisine (7*R*,9*S*-7,9,10,11,12,13-hexahydro-7,9-methano-12*H*-pyrido[1,2-*a*][1,5]diazocin-8-one, Laburnine, Ulexine) *[485-35-8]* **M 190.3, m 152-153°, 155°, b 218°/2mm, $[\alpha]_D^{17}$ -120° (H_2O), $[\alpha]_D^{25}$ -115° (c 1, H_2O).** Crystd from acetone and sublimed in a vacuum. It has pKa values of 6.11 and 13.08 in H_2O. Its solubilities are: 77% (H_2O), 7.7% (Me_2CO), 28.6% (EtOH), 3.3% (C_6H_6), 50% ($CHCl_3$) but is insoluble in pet ether. The *tartrate* has **m** 206-207° $[\alpha]_D^{24}$ +45.9°, the *N-tosylate* has **m** 206-207°, and the *N-acetate* has **m** 208°. [Synthesis: Bohlmann et al. *Angew Chemie* **67** 708 *1955*; van Tamelen and Baran *JACS* **77** 4944 *1955*; Isolation: Ing *JCS* 2200 *1931*; Govindachari et al. *JCS* 3839 *1957*; Abs config: Okuda et al. *Chemistry and Industry (London)* 1751 *1961*].

Cytosine see entry in Chapter 5.

DDT see 1,1,1-trichloro-2,2-bis(*p*-chlorophenyl)ethane.

Decahydronaphthalene (mixed isomers) *[91-17-8]* **M 138.2, b 191.7°, d 0.886, n 1.476.** Stirred with conc H_2SO_4 for some hours. Then the organic phase was separated, washed with water, saturated aqueous Na_2CO_3, again with water, dried with $CaSO_4$ or CaH_2 (and perhaps dried further with Na), filtered and distd under reduced pressure (b 63-70°/10mm). Also purified by repeated passage through long columns of silica gel previously activated at 200-250°, followed by distn from $LiAlH_4$ and storage under N_2. Type 4A molecular sieves can be used as a drying agent. Storage over silica gel removes water and other polar substances.

***cis*-Decahydronaphthalene** *[493-01-6]* **M 138.2, f.p. -43.2°, b 195.7°, d 0.897, n 1.48113,**
***trans*-Decahydronaphthalene** *[493-02-7]* **M 138.2, f.p. -30.6°, b 187.3°, d 0.870, n 1.46968.** Purification methods described for the mixed isomers are applicable. The individual isomers can be separated by very efficient fractional distn, followed by fractional crystn by partial freezing. The *cis*-isomer reacts preferentially with $AlCl_3$ and can be removed from the *trans*-isomer by stirring the mixture with a limited amount of $AlCl_3$ for 48h at room temperature, filtering and distilling.

Decalin see **decahydronaphthalene.**

Decamethylene glycol see **decane-1,10-diol.**

***n*-Decane** *[124-18-5]* **M 142.3, b 174.1°, d 0.770, n 1.41189, n^{25} 1.40967.** It can be purified by shaking with conc H_2SO_4, washing with water, aqueous $NaHCO_3$, and more water, then drying with $MgSO_4$, refluxing with Na and distilling. Passed through a column of silica gel or alumina. It can also be purified by azeotropic distn with 2-butoxyethanol, the alcohol being washed out of the distillate, using water; the decane is

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Cyclotrimethylenetrinitramine (RDX) *[121-82-4]* **M 222.2, m 203.8°(dec).** Crystd from acetone. **EXPLOSIVE.**

p-**Cymene** *[99-87-6]* **M 134.2, b 177.1°, d 0.8569, n 1.4909, n^{25} 1.4885.** Washed with cold, conc H_2SO_4 until there is no further colour change, then repeatedly with H_2O, 10% aqueous Na_2CO_3 and H_2O again. Dried with Na_2SO_4, $CaCl_2$ or $MgSO_4$, and distd. Further purification steps include steam distn from 3% NaOH, percolation through silica gel or activated alumina, and a preliminary refluxing for several days over powdered sulphur.

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***S,S*-(L,L)-Cystathionine,**
Cysteamine and **Cysteamine hydrochloride,**
(±)-Cysteic acid and ***S*-Cysteic acid (H_2O),**
L-Cysteine hydrochloride (H_2O) and **(±)-Cysteine hydrochloride,**
L-Cystine,
Cytidine, see entries in Chapter 5.

Cytisine (7*R*,9*S*-7,9,10,11,12,13-hexahydro-7,9-methano-12*H*-pyrido[1,2-*a*][1,5]diazocin-8-one, Laburnine, Ulexine) *[485-35-8]* **M 190.3, m 152-153°, 155°, b 218°/2mm, $[\alpha]_D^{17}$ -120° (H_2O), $[\alpha]_D^{25}$ -115° (c 1, H_2O).** Crystd from acetone and sublimed in a vacuum. It has pKa values of 6.11 and 13.08 in H_2O. Its solubilities are: 77% (H_2O), 7.7% (Me_2CO), 28.6% (EtOH), 3.3% (C_6H_6), 50% ($CHCl_3$) but is insoluble in pet ether. The *tartrate* has **m** 206-207° $[\alpha]_D^{24}$ +45.9°, the *N-tosylate* has **m** 206-207°, and the *N-acetate* has **m** 208°. [Synthesis: Bohlmann et al. *Angew Chemie* **67** 708 *1955*; van Tamelen and Baran *JACS* **77** 4944 *1955*; Isolation: Ing *JCS* 2200 *1931*; Govindachari et al. *JCS* 3839 *1957*; Abs config: Okuda et al. *Chemistry and Industry (London)* 1751 *1961*].

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Decalin see **decahydronaphthalene.**

Decamethylene glycol see **decane-1,10-diol.**

***n*-Decane** *[124-18-5]* **M 142.3, b 174.1°, d 0.770, n 1.41189, n^{25} 1.40967.** It can be purified by shaking with conc H_2SO_4, washing with water, aqueous $NaHCO_3$, and more water, then drying with $MgSO_4$, refluxing with Na and distilling. Passed through a column of silica gel or alumina. It can also be purified by azeotropic distn with 2-butoxyethanol, the alcohol being washed out of the distillate, using water; the decane is

next dried and redistilled. It can be stored with NaH. Further purification can be achieved by preparative gas chromatography on a column packed with 30% SE-30 (General Electric methyl-silicone rubber) on 42/60 Chromosorb P at 150° and 40psig, using helium [Chu *JCP* **41** 226 *1964*]. Also purified by zone refining.

Decane-1,10-dicarboxylic acid see **1,10-dodecanedioic acid.**

Decan-1,10-diol *[112-47-0]* **M 174.3, m 72.5-74°.** Crystd from dry ethylene dichloride.

Decanoic acid see **capric acid.**

***n*-Decanol** *[112-30-1]* **M 158.3, f.p. 6.0°, b 110-119°/0.1mm, d 0.823, n 1.434.** Fractionally distd in an all-glass unit at 10mm pressure (**b** 110°), then fractionally crystd by partial freezing. Also purified by preparative GLC, and by passage through alumina before use.

Decyl alcohol see **decanol.**

***n*-Decyl bromide** *[112-29-8]* **M 221.2, b 117-118°/15.5mm, d 1.066.** Shaken with H_2SO_4, washed with water, dried with K_2CO_3, and fractionally distd.

Decyltrimethylammonium bromide *[2082-84-0]* **M 280.3.** Crystd from 50% (v/v) EtOH/ethyl ether, or from acetone and washed with ether. Dried under vacuum at 60°. Also recrystd from EtOH and dried over silica gel. [Dearden and Wooley *JPC* **91** 2404 *1987*].

(+)-Dehydroabietylamine (abieta-8,11,13-triene-18-ylamine) *[1446-61-3]* **M 285.5, m 41°, 42.5-45°, b 192-193°/1mm, 250°/12mm, n_D^{40} 1.5462.** The crude base is purified by converting 2g of base in toluene (3.3ml) into the acetate salt by heating at 65-70° with 0.46g of AcOH and the crystals are collected and dried (0.96g from two crops; **m** 141-143°). The acetate salt is dissolved in warm H_2O, basified with aqueous NaOH and extracted with C_6H_6. The dried extract ($MgSO_4$) is evaporated in vacuum leaving a viscous oil which crystallises and can be distd. [Gottstein and Cheney *JOC* **30** 2072 *1965*]. The *picrate* has **m** 234-236° (from aq MeOH), and the *formate* has **m** 147-148° (from heptane).

Dehydro-L(+)-ascorbic acid *[490-83-5]* **M 174.1, m 196°(dec), $[\alpha]_{546}^{20}$ +42.5° (c 1, H_2O),**
7-Dehydrocholesterol *[434-16-2]* **M 384.7, m 142-143°, $[\alpha]_D^{20}$ -122° (c 1, $CHCl_3$).** Crystd from MeOH.

Dehydrocholic acid *[81-23-2]* **M 402.5, m 237°, $[\alpha]_{546}^{20}$ -159° (c 1, in $CHCl_3$).** Crystd from acetone.

Dehydroepiandrosterone *[54-43-0]* **M 288.4, m 140-141° and 152-153° (dimorphic), $[\alpha]_D^{20}$ +13° (c 3, EtOH).** Crystd from MeOH and sublimed in vacuum.

Delphinine *[561-07-9]* **M 559.7, m 197-199°.** Crystd from EtOH.

3-Deoxy-D-allose *[6605-21-6]* **M 164.2, $[\alpha]_D^{20}$ +8° (c 0.25 in H_2O).** Obtained from ethyl ether as a colourless syrup.

Deoxybenzoin *[451-40-1]* **M 196.3, m 60°, b 177°/12mm, 320°/760mm.** Crystd from EtOH.

Deoxycholic acid *[83-44-3]* **M 392.6, m 171-174°, 176°, 176-178°, $[\alpha]_{546}^{20}$ +64° (c 1, EtOH), $[\alpha]_D^{20}$ +55° (c 2.5, EtOH).** Refluxed with CCl_4 (50ml/g), filtered, evaporated under vacuum at 25°, recrystd from acetone and dried under vacuum at 155° [Trenner et al. *JACS* **76** 1196 *1954*]. A soln of (cholic acid-free) material (100ml) in 500ml of hot EtOH was filtered, evaporated to less than 500ml on a hot plate, and poured into 1500ml of cold ethyl ether. The ppte, filtered by suction, was crystd twice from 1-2 parts of absolute EtOH, to give an alcoholate, **m** 118-120°, which was dissolved in EtOH (100ml for 60g) and poured into boiling water. After boiling for several hours the ppte was filtered off, dried, ground and dried to

constant weight [Sobotka and Goldberg *BJ* **26** 555 *1932*]. Deoxycholic acid was also freed from fatty acids and cholic acid by silica gel chromatography by elution with 0.5% acetic acid in ethyl acetate [Tang et al. *JACS* **107** 4058 *1985*]. It can also be recrystd from butanone. Its solubility in H_2O at 15° is 0.24g/L but in EtOH it is 22.07g/L. It has a pKa of 6.58.

11-Deoxycorticosterone *[64-85-7]* **M 330.5, m 141-142°, $[\alpha]_{546}^{20}$ +178° and $[\alpha]_{546}$ +223° (c 1, EtOH).** Crystd from ethyl ether.

2-Deoxy-β-D-galactose *[1949-89-9]* **M 164.2, m 126-128°, $[\alpha]_D^{20}$ +60° (c 4, H_2O).** Crystd from ethyl ether.

2-Deoxy-α-D-glucose *[154-17-6]* **M 164.2, m 146°, $[\alpha]_D^{20}$ +46° (c 0.5, H_2O after 45h).** Crystd from MeOH/acetone.

6-Deoxy-D-glucose (D-quinovose) *[7658-08-4]* **M 164.2, m 146°, $[\alpha]_D^{20}$ +73° (after 5 min) and +30° (final, after 3h) (c 8.3, H_2O).** It is purified by recrystn from EtOAc and is soluble in H_2O, EtOH but almost insoluble in Et_2O and Me_2CO. [Srivastava and Lerner *Carbohydrate Research* **64** 263 *1978*; NMR: Angyal and Pickles *Australian J Chem* **25** 1711 *1972*].

2-Deoxy-β-L-ribose *[18546-37-7]* **M 134.1, m 77°, 80°, $[\alpha]_D^{25}$ +91.7° (c 7, pyridine, 40° final),**
2-Deoxy-β-D-ribose *[533-67-5]* **M 134.1, m 86-87°, 87-90°, $[\alpha]_D^{20}$ -56° (c 1, H_2O after 24h).** Crystd from ethyl ether.

Desoxycholic acid see **deoxycholic acid.**

Desthiobiotin *[533-48-2]* **M 214.3, m 156-158°,**
Desyl bromide (α-bromo-desoxybenzoin, ω-bromo-ω–phenyl acetophenone) *[484-50-0]* **M 275.2, m 57.1-57.5°.** Crystd from 95% EtOH.

Desyl chloride (α-chloro-desoxybenzoin, ω-chloro-ω–phenyl acetophenone) *[447-31-4]* **M 230.7, m 62-64°, 66-67°,67.5°, 68°.** For the purification of small quantities recrystallise from pet ether (b 40-60°), but use MeOH or EtOH for larger quantities. For the latter solvent, dissolve 12.5g of chloride in 45ml of boiling EtOH (95%), filter and the filtrate yields colourless crystals (7.5g) on cooling. A further crop (0.9g) can be obtained by cooling in an ice-salt bath. It turns brown on exposure to sunlight but it is stable in sealed dark containers. [Henley and Turner *JCS* 1182 *1931, Org Synth* Coll Vol II 159 *1943*].

Dexamethasone [9-α–fluoro-16-α-methylprednisolone) *[50-02-2]* **M 392.5, m 262-264°, 268-271°, $[\alpha]_D^{25}$ +77.5° (c 1, dioxane).** It has been recrystallised from Et_2O or small volumes of EtOAc. Its solubility in H_2O in 10 mg/100ml at 25°; and is freely soluble in Me_2CO, EtOH and $CHCl_3$. [Arth et al. *JACS* **80** 3161 *1958*; for the β-methyl isomer see Taub et al. *JACS* **82** 4025 *1960*].

Dexamethasone 21-acetate [9-α–fluoro-16-α-methylprednisolone-21-acetate) *[1177-87-3]* **M 434.5, m 215-225°, 229-231°, $[\alpha]_D^{25}$ +77.6° (c 1, dioxane), +73° (c 1, $CHCl_3$).** Purified on neutral Al_2O_3 using $CHCl_3$ as eluent, fraction evaporated, and recrystd from $CHCl_3$. UV has λ_{max} at 239nm. [Oliveto et al. *JACS* **80** 4431 *1958*].

Dextrose see **D-glucose.**

Diacetamide *[625-77-4]* **M 101.1, m 75.5-76.5°, b 222-223°.** Purified by crystn from MeOH [Arnett and Harrelson *JACS* **109** 809 *1987*].

Diacetyl see **biacetyl.**

1,2-Diacetyl benzene *[704-00-7]* **M 162.2, m 39-41°, 41-42°, b 110°/0.1mm, 148°/20mm.** Purified by distn and by recrystn from pet ether. The *bis-2,4-dinitrophenyl hydrazone* has **m** 221° dec. [Halford and Weissmann *JOC* **17** 1646 *1952*; Riemschneider and Kassahn *B* **92** 1705 *1959*].

1,4-Diacetyl benzene *[1009-61-6]* **M 162.2, m 113-5-114.2°.** Crystd from benzene and vacuum dried over $CaCl_2$. Also dissolved in acetone, treated with Norit, evapd and recrystd from MeOH [Wagner et al. *JACS* **108** 7727 *1986*].

(+)-Di-*O*-acetyl-L-tartaric anhydride [(*R,R*)-2,3-diacetoxysuccinic anhydride] *[628-74-5]* **M 216.2, m 129-132°, 133-134°, 135°, 137.5°, $[\alpha]_D^{20}$ +97.2° (c 0.5, dry $CHCl_3$).** If the IR is good, i.e. no OH bands, then keep in a vacuum desiccator overnight (over P_2O_5/paraffin) before use. If OH bands are present then reflux 4g in Ac_2O (12.6ml) containing a few drops of conc H_2SO_4 for 10min (use a relatively large flask), pour onto ice, collect the crystals, wash with dry C_6H_6 (2 x 2ml), stir with 17ml of cold Et_2O, filter and dry in a vacuum desiccator as above, and store in dark evacuated ampoules under N_2 in small aliquots. It is not very stable in air; the melting point of the crystals drop one degree in the first four days then remains constant (132-134°). If placed in a stoppered bottle it becomes gummy and the m falls 100° in three days. Recrystn leads to decomposition. If good quality anhydride is required it should be prepared fresh from tartaric acid. It sublimes in a CO_2 atmosphere. [*Org Synth* Coll Vol IV 242 *1963*].

Diadzein see **4',7'-dihydroxyisoflavone.**

Diallyl amine (*N*-2-propenyl-2-propen-1-amine) *[124-02-7]* **M 97.2, b 107-111°/760mm, 112°/760mm, d_4^{20} 0.789, n_D^{20} 1.4402.** Keep over KOH pellets overnight, decant and distil from a few pellets of KOH at atm pressure (b 108-111°), then fractionate through a Vigreux column. Its pKa^{20} in H_2O is 9.42. [Vliet *JACS* **46** 1307 *1924*; *Org Synth* Coll Vol I 201 *1941*]. The *hydrochloride* has **m** 164-165° (from Me_2CO + EtOH). [Butler and Angels *JACS* **79** 3128 *1957*].

(+)-*N,N'*-Diallyl tartrimide (DATD) *[58477-85-3]* **M 228.3, m. 184°, $[\alpha]_{546}$ +141° (c 3, MeOH).** Wash with Et_2O containing 10% EtOH until the washings are clear and colourless, and dry *in vacuo*. [*FEBS LETT* **7** 293 *1970*].

Diamantane *[2292-79-7]* **M 188.3, m 234-235°.** Purified by repeated crystn from MeOH or pentane. Also dissolved in methylene dichloride, washed with 5% aq NaOH and water, and dried ($MgSO_4$). The soln was concentrated to a small volume, an equal weight of alumina was added, and the solvent evaporated. The residue was placed on an activated alumina column (*ca* 4 x weight of diamantane) and eluted with pet ether (b 40-60°). Eight sublimations and twenty zone refining experiments gave material **m** 251° of 99.99% purity by differential analysis [*TET LETT* 3877 *1970*; *JCS(C)* 2691 *1972*].

3,6-Diaminoacridine hydrochloride *[952-23-8]* **M 245.7, m 270°(dec), ε_{456} 4.3 x 10^4.** First purified by pptn of the free base by adding aq NH_3 soln to an aq soln of the hydrochloride or hydrogen sulphate, drying the ppte and subliming at 0.01mm Hg [Müller and Crothers *Eur J Biochem,* **54** 267 *1975*].

3,6-Diaminoacridine sulphate (proflavin sulphate) *[1811-28-5]* **M 516.6, λ_{max} 456nm.** An aqueous soln, after treatment with charcoal, was concentrated, chilled overnight, filtered and the ppte was rinsed with a little ethyl ether. The ppte was dried in air, then overnight in a vacuum oven at 70°.

1.3-Diaminoadamantane *[702-79-4]* **M 164.3, m 52°.** Purified by zone refining.

1,4-Diaminoanthraquinone *[128-95-0]* **M 238.3, m 268°.** Purified by thin-layer chromatography on silica gel using toluene/acetone (9:1) as eluent. The main band was scraped off and extracted with MeOH. The solvent was evaporated and the quinone was dried in a drying pistol [Land, McAlpine, Sinclair and Truscott *JCSFT 1* **72** 2091 *1976*]. Crystd from EtOH in dark violet crystals.

1,5-Diaminoanthraquinone *[129-44-2]* **M 238.3, m 319°.** Recrystd from EtOH or acetic acid [Flom and Barbara *JPC* **89** 4481 *1985*].

2,6-Diaminoanthraquinone *[131-14-6]* **M 238.3, m 310-320°.** Crystd from pyridine. Column-chromatographed on Al_2O_3 / toluene to remove a fluorescent impurity, then recrystd from EtOH.

3,3'-Diaminobenzidine tetrahydrochloride ($2H_2O$) *[7411-49-6]* **M 396.1, m >300°(dec).** Dissolved in water and ppted by adding conc HCl, then dried over solid NaOH.

3,4-Diaminobenzoic acid *[619-05-6]* **M 152.2, m 213°(dec),**
3,5-Diaminobenzoic acid *[535-87-5]* **M 152.2, m 235-240°(dec).** Crystd from water.

4,4'-Diaminobenzophenone *[611-98-3]* **M 212.3, m 242-244°, 243-245°, 246.5-247.5° (after sublimation at 0.0006 mm).** Purified by recrystn from EtOH and by sublimation in high vacuum. It has pKa^{25} values in H_2O of 1.37 and 2.92. The *dihydrochloride* has **m** 260° dec (from EtOH) and the *thiosemicarbazone* has **m** 207-207.5° dec (from aq EtOH). [Kuhn et al. *B* **75** 711 *1942*].

4,4'-Diaminobiphenyl see **benzidine.**

1,4-Diaminobutane dihydrochloride (putrescine hydrochloride) *[333-93-7]* **M 161.1, m >290°.** Crystd from EtOH/water.

1,2-Diaminocyclohexanetetraacetic acid see **cyclohexane-1,2-diaminetetraacetic acid.**

1,2-Diamino-4,5-dichlorobenzene *[5348-42-5]* **M 177.0, m 163°.** Refluxed with activated charcoal in CH_2Cl_2, followed by recrystn from ethyl ether/pet ether or pet ether [Koolar and Kochi *JOC* **52** 4545 *1987*].

2,2'-Diaminodiethylamine (diethylenetriamine) *[111-40-0]* **M 103.2, b 208°, d 0.95, n 1.483.** Dried with Na and distd, preferably under reduced pressure, or in a stream of N_2.

4,5-Diamino-2,6-dihydroxypyrimidine sulphate *[32014-70-3]* **M 382.3, m >300°.** The salt is quite insoluble in H_2O but can be converted to the free base which is recrystd from H_2O and converted to the sulphate by addition of the required amount of H_2SO_4. The *hydrochloride* has **m** 300-305° dec and can be used to prepare the sulphate by addition of H_2SO_4; It is more soluble than the sulphate. The *perchlorate* has **m** 252-254°. The free base has a pKa^{24-5} in 50% EtOH of 1.7; and λ_{max} 260nm (log ε 4.24) in 0.1M HCl. [Bogert and Davidson *JACS* **86** 1668 *1933*; Bredereck et al. *B* **86** 850 *1953*; *Org Synth* Coll Vol IV 247 *1963*].

5,6-Diamino-1,3-dimethyluracil hydrate [5,6-diamino-1,3-dimethyl-2pyrimidine-2,4-dione hydrate) *[5440-00-6]* **M 188.2, m 205-208° dec, 209° dec, 210°dec.** Recryst from EtOH. The *hydrochloride* has **m** 310° (from MeOH) and the *perchlorate* has **m** 246-248°. [UV: Bredereck et al. *B* **92** 583 *1959*; Taylor et al. *JACS* **77** 2243 *1955*].

4,4'-Diamino-3,3'-dinitrobiphenyl *[6271-79-0]* **M 274.2, m 275°.** Crystd from aqueous EtOH.

4,4'-Diaminodiphenylamine *[537-65-5]* **M 199.3, m 158°.** Crystd from water.

4,4'-Diaminodiphenylmethane *[101-77-9]* **M 198.3, m 91.6-92°.** Crystd from water or benzene.

3,3'-Diaminodipropylamine *[56-18-8]* **M 131.2, b 152°/50mm, d 0.938, n 1.481.** Dried with Na and distd under vacuum.

6,9-Diamino-2-ethoxyacridine *[442-16-0]* **M 257.3, m 226°.** Crystd from 50% EtOH.

2,7-diaminofluorene *[524-64-4]* **M 196.3, m 165°.** Recrystd from H_2O.

2,4-Diamino-6-hydroxypyrimidine *[56-06-4]* **M 126.1, m 260-270°(dec).** Recrystd from H_2O.

4,5-Diamino-6-hydroxypyrimidine hemisulphate *[102783-18-6]* **M 350.3, m 268°, 270°.** Recrystd from H_2O. The free base also recrystallises from H_2O (**m** 239°). It has pKa^{25} values of 1.34, 3.57 and 9.86. {UV: Mason *JCS* 2071 *1954*; Elion et al. *JACS* **74** 411 *1952*].

1,5-Diaminonaphthalene *[2243-62-1]* **M 158.2, m 190°.** Crystd from water.

1,8-Diaminonaphthalene *[479-27-6]* **M 158.2, m 66.5°.** Crystd from water or aqueous EtOH, and sublimed in a vacuum.

2,3-Diaminonaphthalene *[771-97-1]* **M 158.2, m 199°.** Crystd from water, or dissolved in 0.1M HCl, heated to 50°. After cooling, the soln was extracted with decalin to remove fluorescent impurities and centrifuged.

1,8-Diamino octane *[373-44-4]* **M 144.3, m 50-52°, 51-52°, 52-53°, b 121°/18mm, 120°/24mm.** Distil under vacuum in an inert atmosphere(N_2, Ar), cool and store distillate in an inert atmosphere in the dark. The *dihydrochloride* has **m** 273-274°. [Nae and Le *HCA* **15** 55 *1955*].

2,4-Diamino-5-phenylthiazole *[490-55-1]* **M 191.3, m 163-164°(dec).** Crystd from aqueous EtOH or water. Stored in the dark under N_2.

1,5-Diaminopentane *[462-94-2]* **M 102.2, m 14-16°, b 78-80°/12mm, 101-103°/35mm, 178-180°/750mm, d_4^{20} 0.869, n_D^{20} 1.458.** Purified by distn, after standing over KOH pellets (at room temp; i.e. liquid form). It has pKa^{20} values of 10.02 and 10.96 in H_2O. Its *dihydrochloride* has **m** 275°(sublimes in vac), and its *tetraphenyl boronate* has **m** 164°. [Schwarzenbach et al. *HCA* **35** 2333 *1952*].

***d,l*-2,6-Diaminopimelic acid** *[2577-62-0]* **M 190.2, m 313-315°(dec).** Crystd from water.

1,3-Diaminopropane dihydrochloride *[10517-44-9]* **M 147.1, m 243°.** Crystd from EtOH/water.

1,3-Diaminopropan-2-ol *[616-29-5]* **M 90.1, m 38-40°.** Dissolved in an equal amount of water, shaken with charcoal and vacuum distd at 68°/0.1mm. It is too viscous to be distd through a packed column.

L(*S*)-2,3-Diaminopropionic acid monohydrochloride (3-amino-L-alanine hydrochloride) *[1482-97-9]* **M 140.6, m 132-133°dec, 237°dec, $[\alpha]_D^{25}$ +26.1° (c 5.8, M HCl).** Forms needles from H_2O and can be recrystd from aqueous EtOH. [Gmelin et al. *Z Physiol Chem.* **314** 28 *1959*; IR: Koegel et al. *JACS* **77** 5708 *1977*].

2,3-Diaminopyridine *[452-58-4]* **M 109.1, m 116°,**
2,6-Diaminopyridine *[141-86-6]* **M 109.1, m 121.5°.** Crystd from benzene and sublimed *in vacuo*.

3,4-Diaminopyridine *[54-96-6]* **M 109.1, m 218-219°.** Crystd from benzene and stored under H_2 because it is deliquescent and absorbs CO_2.

***meso*-2,3-Diaminosuccinic acid** *[50817-04-4]* **M 148.1, m 305-306°(dec, and sublimes).** Crystd from water.

Diaminotoluene see **toluenediamine.**

3,5-Diamino-1,2,4-triazole *[1455-77-2]* **M 99.1, m 206°.** Crystd from water or EtOH.

2,5-Di-*tert*-amylhydroquinone *[79-74-3]* **M 250.4, m 185.8-186.5°.** Crystd under N_2 from boiling glacial acetic acid (7ml/g) plus boiling water (2.5ml/g) [Stolow and Bonaventura *JACS* **85** 3636 *1963*].

Di-n-amyl phthalate *[131-18-0]* **M 306.4, b 204-206°/11mm, d^{25} 1.0230, n 1.4885.** Washed with aqueous Na_2CO_3, then distilled water. Dried with $CaCl_2$ and distd under reduced pressure. Stored in a vacuum desiccator over P_2O_5.

1,3-Diaza-azulene *[275-94-5]* **M 130.1, m 120°.** Recrystd repeatedly from de-aerated cyclohexane in the dark.

1,5-Diazabicyclo[4.3.0]non-5-ene (DBN, 2,3,4,,6,7,8-hexahydropyrrolo[1,2-*a*]-pyrimidine) *[3001-72-7]* **M 124.2, b 96-98°/11mm, 100-102°/12mm, 118-121°/32mm, d_4^{20} 1.040, n_D^{20} 1.5196.** Distd from BaO. It forms a *hydroiodide* by addn of 47% HI, dry and dissolve in MeCN, evaporate and repeat, recrystallise from EtOH then dry at 25°/1mm for 5h, then at 80°/0.03mm for 12h and store and dispense in a dry box, **m** 154-156° [Jaeger et al. *JACS* **101** 717 *1979*]. The *methiodide* is recrystd from $CHCl_3$ + Et_2O, **m** 248-250°, and *hydrogen fumarate* has **m** 159-160° and is crystd from *iso*-PrOH [Rokach et al. *J Med Chem* **22** 237 *1979*; Oediger et al. *B* **99** 2012 *1966*; Reppe et al. *A* **596** 210 *1955*].

1,4-Diazabicyclo[2.2.2]octane (Dabco, TED) see **triethylenediamine.**

1,8-Diazabiphenylene *[259-84-7]* **M 154.2,**
2,7-Diazabiphenylene *[31857-42-8]* **M 154.2.** Recrystd from cyclohexane, then sublimed in a vacuum.

Diazoaminobenzene *[27195-22-8]* **M 197.2, m 99°.** Crystd from pet ether (b 60-80°), 60% MeOH/water or 50% aqueous EtOH (charcoal) containing a small amount of KOH. Also purified by chromatography on alumina/toluene and toluene-pet ether. Stored in the dark.

6-Diazo-5-oxo-L-norleucine *[157-03-9]* **M 171.2, m 145-155°(dec), $[\alpha]_D^{20}$ (c 5, EtOH).** Crystd from EtOH.

Dibenzalacetone *[538-58-9]* **M 234.3, m 112°.** Crystd from hot ethyl acetate (2.5ml/g) or EtOH.

Dibenz[*a*,*h*]anthracene *[53-70-3]* **M 278.4, m 266-267°.** The yellow-green colour (due to other pentacyclic impurities) has been removed by crystn from benzene or by selective oxidation with lead tetraacetate in acetic acid [Moriconi et al. *JACS* **82** 3441 *1960*].

Dibenzo-18-crown-6 *[14187-32-7]* **M 360.4, m 163-164°.** Crystd from benzene, *n*-heptane or toluene and dried under vacuum at room temperature for several days. [Szezygiel *JPC* **91** 1252 *1987*].

Dibenzo-18-crown-8 *[14174-09-5]* **M 448.5, m 103-106°.** Recrystd from EtOH, and vacuum dried at 60° over P_2O_5 for 16hours. [Delville et al. *JACS* **109** 7293 *1987*].

Dibenzofuran *[132-64-9]* **M 168.2, m 82.4°.** Dissolved in ethyl ether, then shaken with two portions of aqueous NaOH (2M), washed with water, separated and dried ($MgSO_4$). After evaporating the ether, dibenzofuran was crystd from aq 80% EtOH and dried under vacuum. [Cass et al. *JCS* 1406 *1958*]. High purity material was obtained by zone refining.

Dibenzopyran (xanthene) *[92-83-1]* **M 182.2, m 100.5°, b 310-312°.** Crystd from 95% EtOH.

Dibenzothiophene *[132-65-0]* **M 184.3, m 99°.** Purified by chromatography on alumina with pet ether, in a darkened room. Crystd from water or EtOH.

***trans*-1,2-Dibenzoyl ethylene** *[959-28-4]* **M 236.3, m 109-112°, 111°.** Recrystd from MeOH or EtOH as yellow needles [Koller et al. *HCA* **29** 512 *1946*]. The *dioxime* has **m** 210-211°dec from AcOH. [IR: Kuhn et al. *JACS* **72** 5058 *1950*; Yates *JACS* **74** 5375 *1952*; Erickson et al. *JACS* **73** 5301 *1951*].

Dibenzoylmethane *[120-46-7]* **M 224.3, m 80°.** Crystd from pet ether or MeOH.

Dibenzoyl peroxide see **benzoyl peroxide.**

Di-*O*-benzoyl-*R*-tartaric acid (H_2O) *[17026-42-5]* **M 376.3, $[\alpha]_{546}^{20}$ +136° (c 2, EtOH), $[\alpha]_D^{20}$ +117° (c 5, EtOH),**
Di-*O*-benzoyl-*S*-tartaric acid (H_2O) *[2743-38-6]* **M 376.3, $[\alpha]_{546}^{20}$ -136° (c 2, EtOH), $[\alpha]_D^{20}$ -117° (c 5, EtOH).**
Crystd from water (18g from 400 ml boiling H_2O) and stir vigorously while cooling in order to obtain crystals; otherwise an oil will separate which solidifies on cooling. Dry in a vacuum desiccator over KOH-H_2SO_4 - yield 16.4g) as monohydrate, **m** 88-89°. It crystallises from xylene as the anhydrous acid, **m** 173° (150-153°). It does not cryst from C_6H_6, toluene, C_6H_6-pet ether (oil), or $CHCl_3$-pet ether. [Butler and Cretcher *JACS* **55** 2605 *1933*; *TET* **41** 2465 *1085*].

2,3,6,7-Dibenzphenanthrene *[222-93-5]* **M 276.3, m 257°.** Crystd from xylene.

Dibenzyl amine *[103-49-1]* **M 197.3, m -26°, b 113-114°/0.1mm, 174-175°/6mm, 270°/250mm, 300° (partial dec), d_4^{20} 1.0270, n_D^{20} 1.5757.** Purified by distn in a vacuum. **It causes burns to the skin.** The *dihydrochloride* has **m** 265-266° after recrystn from MeOH-HCl, and the *tetraphenyl boronate* has **m** 129-133°. [Bradley and Maisey *JCS* 247 *1954*; Hall *JPC* **60** 63 *1956*; Donetti and Bellora *JOC* **37** 3352 *1972*].

Dibenzyl disulphide *[150-60-7]* **M 246.4, m 71-72°.** Crystd from EtOH.

1,3,4,6-Di-*O*-benzylidene-D-mannitol *[28224-73-9]* **M 358.4, m 192-195°, 193°, $[\alpha]_D^{20}$ -11.9.0° (c 0.7, Me_2CO).** Recryst from Et_2O in long fine needles. λmax 256nm (ε 435) in 95% EtOH, R_F 0.21 (1:1 CCl_4-EtOAc) on TLC Silica Gel G. [Sinclair *Carbohydrate Research* **12** 150 *1970*; ORD, CD, NMR, IR, MS: Brecknell et al. *Australian J Chem* **29** 1749 *1976*].

Dibenzyl ketone *[102-04-5]* **M 210.3, m 34.0°.** Fractionally crystd from its melt, then crystd from pet ether. Stored in the dark.

Dibenzyl malonate *[15014-25-2]* **M 284.3, b 188-190°/0.2mm, 193-196°/1mm, d_4^{20} 1.158, n_D^{20} 1.5452.** Dissolve in toluene, wash with aqueous $NaHCO_3$, H_2O, dry over $MgSO_4$, filter, evaporate and distil. [Ginsburg and Pappo *JACS* **75** 1094 *1953*; Baker et al. *JOC* **17** 77 *1952*].

Dibenzyl sulphide *[528-74-9]* **M 214.3, m 48.5°.** Crystd from EtOH/water (10:1), or repeatedly from purified hot ethyl ether. Vacuum dried at 30° over P_2O_5, fused under nitrogen and re-dried.

2,4'-Dibromoacetophenone see ***p*-bromophenacyl bromide.**

2,4-Dibromoaniline *[615-57-6]* **M 250.9, m 79-80°.** Crystd from aqueous EtOH.

9,10-Dibromoanthracene *[523-27-3]* **M 336.0, m 226°.** Recrystd from xylene and vacuum sublimed [Johnston et al. *JACS* **109** 1291 *1987*].

***p*-Dibromobenzene** *[106-37-6]* **M 235.9, m 87.8°.** Steam distd, crystd from EtOH or MeOH and dried in the dark under vacuum. Purified by zone melting.

2,5-Dibromobenzoic acid *[610-71-9]* **M 279.9, m 157°.** Crystd from water or EtOH.

4,4'-Dibromobiphenyl *[92-86-4]* **M 312.0, m 164°, b 355-360°/760mm.** Crystd from MeOH.

***trans*-1,4-Dibromobut-2-ene** *[821-06-7]* **M 213.9, m 54°, b 85°/10mm.** Crystd from ligroin.

Dibromodeoxybenzoin *[15023-99-1]* **M 354.0, m 111.8-112.7°.** Crystd from acetic acid.

Dibromodichloromethane *[594-18-3]* **M 242.7, m 22°.** Crystd repeatedly from its melt, after washing with aqueous $Na_2S_2O_3$ and drying with BaO.

1,3-Dibromo-5,5-dimethylhydantoin *[77-48-5]* **M 285.9, m 190-192°dec, 190-193°dec.** Recrystd from H_2O. Solubility in CCl_4 is 0.003 mol/L at 25° and 0.024 mol/L at 76.5°.

1,2-Dibromoethane *[106-93-4]* **M 187.9, f 10.0°, b 29.1°/10mm, 131.7°/760mm, d 2.179, n^{15} 1.54160.** Washed with conc HCl or H_2SO_4, then water, aqueous $NaHCO_3$ or Na_2CO_3, more water, and dried with $CaCl_2$. Fractionally distd. Alternatively, kept in daylight with excess bromine for 2hours, then extracted with aqueous Na_2SO_3, washed with water, dried with $CaCl_2$, filtered and distd. It can also be purified by fractional crystn by partial freezing. Stored in the dark.

4',5'-Dibromofluorescein *[596-03-2]* **M 490.1, m 285°.** Crystd from aqueous 30% EtOH.

5,7-Dibromo-8-hydroxyquinoline *[521-74-4]* **M 303.0, m 196°.** Crystd from acetone/EtOH. It can be sublimed.

Dibromomaleic acid *[608-37-7]* **M 273.9, m 123.5°, 125°dec.** It has been recrystd from Et_2O or Et_2O-$CHCl_3$. It is slightly soluble in H_2O, soluble also in AcOH but insoluble in C_6H_6 and $CHCl_3$. [Salmony and Simonis *B* **38** 2583 *1905*; Ruggli *HCA* **3** 566 *1929*].

2,5-Dibromonitrobenzene *[3460-18-4]* **M 280.9, m 84°.** Crystd from acetone.

2,6-Dibromo-4-nitrophenol *[99-28-5]* **M 280.9, m 143-144°.** Crystd from aqueous EtOH.

2,4-Dibromophenol *[615-58-7]* **M 251.9, m 37°, 41-42°, b 154°/10mm, 239°/atm.** Crystd from $CHCl_3$ at -40°. pKa^{25} 7.8 in water.

2,6-Dibromophenol *[608-33-3]* **M 251.9, m 56-57°, b 138°/10mm, 255-256°/740mm.** Vacuum distd (at 18mm), then crystd from cold $CHCl_3$ or from EtOH/water. pKa^{25} 6.6 in water.

1,3-Dibromopropane *[109-64-8]* **M 201.9, f -34.4°, b 63-63.5°/26mm, 76-77°/40mm, 90°/80mm, 165°/atm, d 1.977, n 1.522.** Washed with dilute aqueous Na_2CO_3, then water. Dried and fractionally distd under reduced pressure.

2,6-Dibromopyridine *[626-05-1]* **M 236.9, m 117-119°, 118.5-119°, b 249°/757.5°.** Purified by steam distn then twice recrystd from EtOH. Does not form an $HgCl_2$ salt. [den Hertog and Wibaut *Rec Trav Chim Pays Bas* **51** 381 *1932*].

5,7-Dibromo-8-quinolinol see **5,7-dibromo-8-hydroxyquinoline.**

***meso*-2,3-Dibromosuccinic acid** *[526-78-3]* **M 275.9, m 288-290° (sealed tube, dec).** Crystd from distilled water, keeping the temperature below 70°.

1,2-Dibromotetrafluoroethane *[124-73-2]* **M 259.8, b 47.3°/760mm.** Washed with water, then with weak alkali. Dried with $CaCl_2$ or H_2SO_4 and distd. [Locke et al. *JACS* **56** 1726 *1934*]. Also purified by gas chromatography on a silicone DC-200 column.

α,α'-Dibromo-*o*-xylene *[91-13-4]* **M 264 0, m 95°, b 129-130°/4.5mm.** Crystd from $CHCl_3$

α,α'-Dibromo-*m*-xylene *[626-15-3]* **M 264.0, m 77°, b 156-160°/12mm.** Crystd from acetone.

α,α'-Dibromo-*p*-xylene *[623-24-5]* **M 264.0, m 145-147°, b 155-158°/12-15mm, 245°/760mm.** Crystd from benzene or chloroform.

Di-*n*-butylamine *[111-92-2]* **M 129.3, b 159°, n 1.41766, d 0.761.** Dried with $LiAlH_4$, CaH_2 or KOH pellets, filtered and distd from BaO or CaH_2.

α-Dibutylamino-α-(*p*-methoxyphenyl)acetamide *[519-88-0]* **M 292.4, m 134°.** Crystd from EtOH containing 10% ethyl ether.

2,5-Di-*tert*-butyl aniline *[21860-03-7]* **M 205.4, m 103-104°, 103-106°, 103-104°.** Recrystd from EtOH in fine needles after steam distn. It has a pKa^{25} of 3.58 (50% aq EtOH) and 3.34 (90% aq MeOH). The *tosylate* has **m** 164° (from AcOH). [Bell and Wilson *JCS* 2340 *1956*; Carpenter et al. *JOC* **16** 586 *1951*; Bartlett et al. *JACS* **76** 2349 *1954*].

***p*-Di-*tert*-butylbenzene** *[1571-86-4]* **M 190.3, m 80°.** Crystd from ethyl ether, EtOH and dried under vacuum over P_2O_5 at 55°. [Tanner et al. *JOC* **52** 2142 *1987*].

3,5-Di-*tert*-butyl-*o*-benzoquinone *[3383-21-9]* **M 220.3, m 112-114°, 113-114°.** It can be recrystd from MeOH or pet ether, and forms fine red plates or rhombs. [Flaig et al. *A* **597** 196 *1955*; IR: Ley and Müller *B* **89** 1402 *1956*].

Di-*n*-butyl *n*-butylphosphonate *[78-46-6]* **M 250.3, b 150-151°/10mm, 160-162°/20mm, n^{25} 1.4302.** Purified by three crystns of its compound with uranyl nitrate, from hexane. For method, see *tributyl phosphate*.

3,5-Di-*tert*-butyl catechol *[1020-31-1]* **M 222.3, m 97-100°, 99°, 99-100°.** Recrystd from pet ether. [Ley and Müller *B* **89** 1402 *1956*; UV Flaig et al. *Z Naturforschung* **10b** 668 *1955*]. Also crystd three times from pentane [Funabiki et al. *JACS* **108** 2921 *1986*].

Dibutylcarbitol *[112-73-2]* **M 218.3, b 125-130°/0.1mm, d 0.883, n 1.424.** Freed from peroxides by slow passage through a column of activated alumina. The eluate was shaken with Na_2CO_3 (to remove any remaining acidic impurities), washed with water, and stored with $CaCl_2$ in a dark bottle [Tuck *JCS* 3202 *1957*].

2,6-Di-*tert*-butyl-*p*-cresol (BHT) *[128-37-0]* **M 230.4, m 71.5°.** Dissolved in *n*-hexane at room temperature, then cooled with rapid stirring, to -60°. The ppte was separated, redissolved in hexane, and the process was repeated until the mother liquor was no longer coloured. The final product was stored under N_2 at 0° [Blanchard *JACS* **82** 2014 *1960*]. Also crystd from EtOH, MeOH, benzene, *n*-hexane, methylcyclohexane or pet ether (b 60-80°), and dried under vacuum.

2,6-Di-*tert*-butyl-4-dimethylaminomethylphenol *[88-27-7]* **M 263.4, m 93-94°, b 172°/30mm.** Crystd from *n*-hexane.

Di-*tert*-butyldiperphthalate *[2155-71-7]* **M 310.3.** Crystd from ethyl ether. Dried over H_2SO_4.

Di-*n*-butyl ether see ***n*-butyl ether.**

2,6-Di-*tert*-butyl-4-ethylphenol *[4130-42-1]* **M 234.4, m 42-44°.** Cryst from aqueous EtOH or *n*-hexane.

***N,N*-Dibutyl formamide** *[761-65-9]* **M 157.3, b 63°/0.1mm, 118-120°/15mm, 244-246°/760mm, 241-243°/atm, d_4^{20} 0.878, n_D^{20} 1.445.** Purified by fractn distn [Mandel and Hill *JACS* **76** 3981 *1954*].

2,5-Di-*tert*-butylhydroquinone *[88-58-4]* **M 222.3, m 222-223°.** Crystd from benzene or glacial acetic acid.

2,4-Di-*tert*-butyl-4-isopropylphenol *[5427-03-2]* **M 248.4, m 39-41°.** Crystd from *n*-hexane or aq EtOH.

2,6-Di-*tert*-butyl-4-methylphenol see **2,6-di-*tert*-butyl-*p*-cresol.**

2,6-Di-*tert*-butyl-4-methylpyridine *[38222-83-2]* **M 205.4, m 31-32°, 33-36°, b 148-153°/95mm, 223°/760mm, n_4^{20} 1.476.** Possible impurity is 2,6-di-*tert*-butyl-4-neopentylpyridine. Attempts to remove coloured impurities directly by distn, acid-base extraction or treatment with activated charcoal were unsuccessful. Pure material can be obtained by dissolving 0.3mole of the alkylpyridine in pentane (150ml) and introducing it at the top of a water jacketed chromatographic column (40 x 4.5cm, the cooling is necessary because the base in pentane reacts exothermically with alumina) containing activated and acidic alumina (300g). The column is eluted with pentane using a 1L constant pressure funnel fitted at the top of the column to provide slight press. All the pyridine is obtained in the first two litres of eluent (the progress of elution is monitored by spotting a fluorescent TLC plate and examining under short wave UV light - a dark blue spot is evidence for the presence of the alkylpyridine. Elution is complete in 1h. Pentane is removed on a rotovap with 90-93% recovery yielding a liquid which solidifies on cooling, **m** 31-32°, and the base can be distilled. The *$HPtCl_6$ salt* has **m** 213-314° (dec), and the *CF_3SO_3H salt* has **m** 202.5-203.5° (from CH_2Cl_2). [*Org Synth* **60** 34 *1981*].

Di-*tert*-butyl peroxide (*tert*-butyl peroxide) *[110-05-4]* **M 146.2, d 0.794, n 1.3889.** Washed with aqueous $AgNO_3$ to remove olefinic impurities, water and dried ($MgSO_4$). Freed from *tert*-butyl hydroperoxide by passage through an alumina column [Jackson et al. *JACS* **107** 208 *1985*], and if necessary two high vacuum distns from room temp to a liquid-air trap [Offenbach and Tobolsky *JACS* **79** 278 *1957*]. *The necessary protection from* **EXPLOSION** *should be used.*

2,6-Di-*tert*-butylphenol *[128-39-2]* **M 206.3, m 37-38°.** Crystd from aqueous EtOH or *n*-hexane.

Dibutyl phthalate *[84-74-2]* **M 278.4, b 206°/20mm, 340°/760mm, d 1.4929, d^5 1.0426, n^{25} 1.4901.** Washed with dilute NaOH (to remove any butyl hydrogen phthalate), aqueous $NaHCO_3$ (charcoal), then distd water. Dried with $CaCl_2$, distd under vacuum, and stored in a desiccator over P_2O_5.

2,6-Di-*tert*-butylpyridine, *[585-48-8]* **M 191.3, b 100-101°/23mm, d 0.852, n 1.474.** Redistd from KOH pellets.

Di-*n*-butyl sulphide *[544-40-1]* **M 146.3, α-form b 182°, β-form 190-230°(dec).** Washed with aq 5% NaOH, then water. Dried with $CaCl_2$ and distd from sodium.

Di-*n*-butyl sulphone *[598-04-9]* **M 162.3, m 43.5°.** Purified by zone melting.

***N,N'*-Di-*tert*-butylthiourea** *[4041-95-6]* **M 188.3, m 174-175° (evac capillary).** Recrystd from H_2O [Bortnick et al. *JACS* **78** 4358 *1956*].

3,5-Dicarbethoxy-1,4-dihydrocollidine *[632-93-9]* **M 267.3, m 131-132°.** Crystd from hot EtOH/water.

Dichloramine-T *[473-34-7]* **M 240.1, m 83°.** Crystd from pet ether (b 60-80°) or $CHCl_3$/pet ether. Dried in air.

Dichloroacetic acid *[79-43-6]* **M 128.9, m 13.5°, b 95.0-95.5°/17-18mm, d 1.5634, n 1.4658.** Crystd from benzene or pet ether. Dried with $MgSO_4$ and fractionally distd. [Bernasconi et al. *JACS* **107** 3612 *1985*].

***sym*-Dichloroacetone (1,3-dichloropropan-2-one)** *[534-07-6]* **M 127.0, m 41-43°, 45°, b 86-88°/12mm, 75-77°/22mm, 172-172.5°/atm, 173°/atm, 170-175° /atm, d 1.383.** Crystd from CCl_4, $CHCl_3$ and benzene. Distd under vacuum. [Conant and Quayle *Org Synth* Coll Vol 211 *1941*; Hall and

Sirel *JACS* **74** 836 *1952*]. It is dimorphic [Daasch and Kagarise *JACS* **77** 6156 *1955*]. The *oxime* has **m** 130-131°, **b** 106°/25mm [*Arzneimittel-Forsch* **8** 638 *1958*].

Dichloroacetonitrile *[3018-12-0]* **M 110.0.** Purified by gas chromatography.

2,4-Dichloroaniline *[554-00-7]* **M 162.0, m 63°.** Crystd from EtOH/water. Also crystd from EtOH and dried *in vacuo* for 6h at 40° [Moore et al. *JACS* **108** 2257 *1986*; Edidin et al. *JACS* **109** 3945 *1987*].

3,4-Dichloroaniline *[95-76-1]* **M 162.0, m 71.5°.** Crystd from MeOH.

9,10-Dichloroanthracene *[605-49-1]* **M 247.1, m 214-215°.** Purified by crystn from MeOH or EtOH, followed by sublimation under reduced pressure. [Masnori and Kochi *JACS* **107** 7880 *1985*].

2,4-Dichlorobenzaldehyde *[874-42-0]* **M 175.0, m 72°.** Crystd from EtOH or ligroin.

2,6-Dichlorobenzaldehyde *[83-38-5]* **M 175.0, m 70.5-71.5°.** Crystd from EtOH/water or pet ether (b 30-60°).

***o*-Dichlorobenzene** *[95-50-1]* **M 147.0, b 81-82°/31-32mm, 180.5°/760mm, d 1.306, n 1.55145, n^{25} 1.54911.** Contaminants may include the *p*-isomer and trichlorobenzene [Suslick et al. *JACS* **106** 4522 *1984*]. It was shaken with conc or fuming H_2SO_4, washed with water, dried with $CaCl_2$, and distd from CaH_2 or sodium in a glass-packed column. Low conductivity material (*ca* 10^{-10} mhos) has been obtained by refluxing with P_2O_5, fractionally distilled and passed through a column packed with silica gel or activated alumina: it was stored in a dry-box under N_2 or with activated alumina.

***m*-Dichlorobenzene** *[541-77-1]* **M 147.0, b 173.0°, d 1.289, n 1.54586, n^{25} 1.54337.** Washed with aqueous 10% NaOH, then with water until neutral, dried and distd. Conductivity material (*ca* 10^{-10} mhos) has been prepared by refluxing over P_2O_5 for 8h, then fractionally distilling, and storing with activated alumina. *m*-Dichlorobenzene dissolves rubber stoppers.

***p*-Dichlorobenzene** *[106-46-7]* **M 147.0, m 53.0°, b 174.1°, d 1.241, n^{60} 1.52849.** *o*-Dichlorobenzene is a common impurity. Has been purified by steam distn, crystn from EtOH or boiling MeOH, air-dried and dried in the dark under vacuum. Also purified by zone refining.

2,2'-Dichlorobenzidine *[84-68-4]* **M 253.1, m 165°.** Crystd from EtOH.

3,3'-Dichlorobenzidine *[91-94-1]* **M 253.1, m 132-133°.** Crystd from EtOH or benzene. **CARCINOGEN.**

2,4-Dichlorobenzoic acid *[50-84-0]* **M 191.0, m 163-164°.** Crystd from aqueous EtOH (charcoal), then benzene (charcoal). It can also be recrystd from water.

2,5-Dichlorobenzoic acid *[50-79-3]* **M 191.0, m 154°, b 301°/760mm.** Crystd from water.

2,6-Dichlorobenzoic acid *[50-30-6]* **M 191.0, m 141-142°.** Crystd from EtOH and sublimed *in vacuo*.

3,4-Dichlorobenzoic acid *[51-44-5]* **M 191.0, m 206-207°.** Crystd from aqueous EtOH (charcoal) or acetic acid.

3,5-Dichlorobenzoic acid *[51-36-5]* **M 191.0, m 188°.** Crystd from EtOH and sublimed in a vacuum.

2,6-Dichlorobenzonitrile *[1194-65-6]* **M 172.0, m 145°.** Crystd from acetone.

4,4'-Dichlorobenzophenone *[90-98-2]* **M 251.1, m 145-146°.** Recrystd from EtOH [Wagner et al. *JACS* **108** 7727 *1986*].

2,5-Dichloro-1,4-benzoquinone *[615-93-0]* **M 177.0, m 161-162°.** Recrystd twice from 95% EtOH as yellow needles [Beck et al. *JACS* **108** 4018 *1986*].

2,6-Dichloro-1,4-benzoquinone *[697-91-6]* **M 177.0.** Recrystd from pet ether (b 60-70°) [Carlson and Miller *JACS* **107** 479 *1985*].

3,4-Dichlorobenzyl alcohol *[1805-32-9]* **M 177.0, m 38-39°.** Crystd from water.

2,3-Dichloro-1:3-butadiene *[1653-19-6]* **M 123.0, b 41-43°/85mm, 98°/760mm.** Crystd from pentane to constant melting point about -40°. A mixture of *meso* and *d,l* forms was separated by gas chromatography on an 8m stainless steel column (8mm i.d.) with 20% DEGS on Chromosorb W (60-80 mesh) at 60° and 80ml He/min. [Su and Ache *JPC* **80** 659 *1976*].

(+) and (-) (8,8-Dichlorocamphorylsulphonyl)oxaziridine *[127184-05-8]* **M 298.2, m 178-180°, 183-186°, $[\alpha]_D^{20}$ ±88.3° (c 1.3, $CHCl_3$), ±91° (c 5, $CHCl_3$).** Recrystd from EtOH [Davis and Weismiller *JOC* **55** 3715 *1990*].

1,1-Dichloro-2,2-bis-(*p*-chlorophenyl)ethane *[72-54-8]* **M 320.1, m 109-111°.** Purity checked by TLC.

4,6-Dichloro-*o*-cresol see **2,4-dichloro-6-methylphenol**.

***cis*-3,4-Dichlorocyclobutene** *[2957-95-1]* **M 123.0, b 70-71°/55mm, 74-76°/55mm, d_4^{20} 1.297, n_D^{20} 1.499.** Distd at 55mm through a 36-in platinum spinning band column, a fore-run b 58-62°/55mm is mainly 1,4-dichlorobutadiene. When the temperature reaches 70° the reflux ratio is reduced to 10:1 and the product is collected quickly. It is usually necessary to apply heat frequently with a sun lamp to prevent any dichlorobutadiene from clogging the exit in the early part of the distn [Pettit and Henery *Org Synth* **50** 36 *1970*].

2,3-Dichloro-5,6-dicyano-*p*-benzoquinone (DDQ) *[84-58-2]* **M 227.0, m 203° (dec).** Crystd from $CHCl_3$, $CHCl_3$/benzene (4:1), or benzene and stored at 0°. [Pataki and Harvey *JOC* **52** 2226 *1987*].

ß,ß'-Dichlorodiethyl ether *[111-44-4]* **M 143.0, b 79-80°/20mm, 176-177.0°/743mm, n 1.457, d 1.219.** Peroxide formation occurs rapidly, especially if distn is attempted at atmospheric pressure. After drying with NaOH pellets for 2 days, the ether was distd under N_2 at reduced pressure. The distillate was made 10^{-6}M in catechol to diminish peroxide formation, and was redistd immediately before use.

1,2-Dichloro-1,2-difluoroethane *[431-08-7]* **M 134.9.** For purification of diastereoisomeric mixture, with resolution into *meso* and *rac* forms, see Machulla and Stocklin [*JPC* **78** 658 *1974*].

Dichlorodifluoromethane *[75-71-8]* **M 120.9, b -25°.** Passage through saturated aqueous KOH then conc H_2SO_4, and a tower packed with activated copper on kielselguhr at 200° removed CO_2 and O_2. A trap cooled to -29° removed a trace of high boiling material.

2,5-Dichloro-3,6-dihydroxy-*p*-benzoquinone see **chloranilic acid**.

1,3-Dichloro-5,5'-dimethylhydantoin *[118-52-5]* **M 197.0, m 132-134°, 136°.** Purified by dissolving in conc H_2SO_4 and diluting with ice H_2O, dry and rerystd from $CHCl_3$. It sublimes at 100° in a vacuum. Exhibits time dependent hydrolysis at pH 9. [Petterson and Grzeskowiak *JOC* **24** 1414 *1959*].

4,5-Dichloro-3*H*-1,2-dithiol-3-one *[1192-52-5]* **M 187.1, m 52-56°, 61°, b 87°/0.5mm, 125°/11mm.** Distd *in vacuo* and then recrystd from pet ether. IR: ν 1650 cm^{-1} [Boberg *A* **693** 212 *1966*].

1,1-Dichloroethane *[75-34-3]* **M 99.0, b 57.3°, d^{15} 1.18350, d 1.177, n^{15} 1.41975.** Shaken with conc H_2SO_4 or aqueous $KMnO_4$, then washed with water, saturated aqueous $NaHCO_3$, again with water, dried with K_2CO_3 and distd from CaH_2 or $CaSO_4$. Stored over silica gel.

1,2-Dichloroethane *[107-06-2]* **M 99.0, b 83.4°, d 1.256, n^{15} 1.44759.** Usually prepared by chlorinating ethylene, so that likely impurities include higher chloro derivatives and other chloro compounds depending on the impurities originally present in the ethylene. It forms azeotropes with water, MeOH, EtOH, trichloroethylene, CCl_4 and isopropanol. Its azeotrope with water (containing 8.9% water, and **b** 77°) can be used to remove gross amounts of water prior to final drying. As a preliminary purification step, it can be steam distd, and the lower layer was treated as below.
Shaken with conc H_2SO_4 (to remove alcohol added as an oxidation inhibitor), washed with water, then dilute KOH or aqueous Na_2CO_3 and again with water. After an initial drying with $CaCl_2$, $MgSO_4$ or by distn, it is refluxed with P_2O_5, $CaSO_4$ or CaH_2 and fractionally distd. Carbonyl-containing impurities can be removed as described for chloroform.

1,2-Dichloroethylene M 96.9, b 60° (*cis*), d 1.284, b 48° (*trans*), d 1.257. Shaken successively with conc H_2SO_4, water, aqueous $NaHCO_3$ and water. Dried with $MgSO_4$ and distn separated the *cis*- and *trans*-isomers.

***cis*-1,2-Dichloroethylene** *[156-59-2]* **M 96.9, b 60.4°, d 1.2830, n^{15} 1.44903, n 1.4495.** Purified by careful fractional distn, followed by passage through neutral activated alumina. Also by shaking with mercury, drying with K_2CO_3 and distn. from $CaSO_4$.

***trans*-1,2-Dichloroethylene** *[156-60-5]* **M 96.9, b 47.7°, n^{15} 1.45189, n 1.4462, d 1.2551.** Dried with $MgSO_4$, and fractionally distd under CO_2. Fractional crystn at low temperatures has also been used.

5,7-Dichloro-8-hydroxyquinoline *[773-76-2]* **M 214.1, m 180-181°.** Crystd from acetone/EtOH.

2,3-Dichloromaleic anhydride *[1122-17-4]* **M 167.0, m 105-115°, 120°, 121-121.5°.** Purified by sublimation *in vacuo* [Katakis et al. *JCSDT* 1491 *1986*]. It has also been purified by Soxhlet extraction with hexane, recrystd from $CHCl_3$ and sublimed [MS, Relles *JOC* **37** 3630 *1972*].

Dichloromethane *[75-09-2]* **M 84.9, b 40.0°, d 1.325, n 1.42456, n^{25}1.4201.** Shaken with portions of conc H_2SO_4 until the acid layer remained colourless, then washed with water, aqueous 5% Na_2CO_3, $NaHCO_3$ or NaOH, then water again. Pre-dried with $CaCl_2$, and distd from $CaSO_4$, CaH_2 or P_2O_5. Stored away from bright light in a brown bottle with Linde type 4A molecular sieves, in an atmosphere of dry N_2. Other purification steps include washing with aq $Na_2S_2O_3$, passage through a column of silica gel, and removal of carbonyl-containing impurities as described under **Chloroform**. It has also been purified by treatment with basic alumina, distd, and stored over molecular sieves under nitrogen [Puchot et al. *JACS* 108 2353 *1986*].
Dichloromethane from Japanese sources contained MeOH as stabiliser which is not removed by distn. It can, however, be removed by standing over activated 3A Molecular Sieves (note that 4A Sieves cause the development of pressure in bottles), passed through activated Al_2O_3 and distd [Gao et al. *JACS* **109** 5771 *1987*]. It has been fractionated through a platinum spinning band column, degassed, and distd onto degassed molecular sieves {Linde 4A, heated under high vacuum at over 450° until the pressure readings reached the low values of 10^{-6} mm — ~1-2h) [Mohammad and Kosower *JACS* **93** 2713 *1971*].

3,9-Dichloro-7-methoxyacridine *[86-38-4]* **M 278.1, m 160-161°.** Crystd from benzene.

5,7-Dichloro-2-methyl-8-hydroxyquinoline *[72-80-0]* **M 228.1, m 114-115°.** Crystd from EtOH.

2,4-Dichloro-6-methylphenol *[1570-65-6]* **M 177.0, m 55°, b 129-132°/40mm.** Crystd from water.

2,4-Dichloro-1-naphthol *[2050-76-2]* **M 213.1, m 106-107°.** Crystd from MeOH.

2,3-Dichloro-1,4-naphthoquinone *[117-80-6]* **M 227.1, m 193°.** Crystd from EtOH.

2,5-Dichloro-4-nitroaniline *[6627-34-5]* **M 207.0, m 157-158°.** Crystd from EtOH, then sublimed.

2,6-Dichloro-4-nitroaniline *[99-30-9]* **M 207.0, m 193°.** Crystd from aq EtOH or benzene/EtOH.

2,5-Dichloro-1-nitrobenzene *[89-61-2]* **M 192.0, m 56°,**
3,4-Dichloro-1-nitrobenzene *[99-54-7]* **M 192.0, m 43°.** Crystd from absolute EtOH.

2,4-Dichloro-6-nitrophenol *[609-89-2]* **M 208.0, m 122-123°.** Crystd from acetic acid.

2,6-Dichloro-4-nitrophenol *[618-00-4]* **M 208.0, m 125°.** Crystd from EtOH and dried *in vacuo* over anhydrous $MgSO_4$.

4,6-Dichloro-5-nitropyrimidine *[4316-93-2]* **M 194.0, m 100-103°, 101-102°.** If too impure then dissolve in Et_2O, wash with H_2O, dry over $MgSO_4$, evaporate to dryness and recrystallise from pet ether (b 85-105°) as a light tan solid. It is sol in *ca* 8 parts of MeOH [Boon et al, *JCS* 96 *1951*; Montgomery et al. in *Synthetic Procedures in Nucleic Acid Chemistry* (Zorbach and Tipson eds) Wiley & Sons, NY, p76 *1968*].

Dichlorophen [2,2'-methylenebis(4-chlorophenol)] *[97-23-4]* **M 269.1, b 177-178°.** Crystd from toluene.

2,3-Dichlorophenol *[576-24-9]* **M 163.0, m 57°.** Crystd from ether.

2,4-Dichlorophenol *[120-83-2]* **M 163.0, m 42-43°.** Crystd from pet ether (b 30-40°). Purified by repeated zone melting, using a P_2O_5 guard tube to exclude moisture. Very *hygroscopic* when dry.

2,5-Dichlorophenol *[583-78-8]* **M 163.0, m 58°, b 211°/744mm.** Crystd from ligroin and sublimed.

3,4-Dichlorophenol *[95-77-2]* **M 163.0, m 68°, b 253.5°/767mm,**
3,5-Dichlorophenol *[591-35-5]* **M 163.0, m 68°, b 122-124°/8mm, 233-234°/760mm.** Crystd from pet ether/benzene mixture.

2,6-Dichlorophenol-indophenol sodium salt ($2H_2O$) *[620-45-1]* **M 326.1, ε = 2.1 x 10^4 at 600nm and pH 8.** Dissolved in 0.001M phosphate buffer, pH 7.5 (alternatively, about 2g of the dye was dissolved in 80ml of M HCl), and extracted into ethyl ether. The extract was washed with water, extracted with aqueous 2% $NaHCO_3$, and the sodium salt of the dye was ppted by adding NaCl (30g/100ml of $NaHCO_3$ soln), then filtered off, washed with dilute NaCl soln and dried.

2,4-Dichlorophenoxyacetic acid (2,4-D) *[94-75-7]* **M 221.0, m 146°,**
α-(2,4-Dichlorophenoxy)propionic acid (2,4-DP) *[120-36-5]* **M 235.1, m 117°,** Crystd from MeOH. **TOXIC.**

2,4-Dichlorophenylacetic acid *[19719-28-9]* **M 205.0, m 131°,**
2,6-Dichlorophenylacetic acid *[6575-24-2]* **M 205.0, m 157-158°.** Crystd from aqueous EtOH.

3-(3,4-Dichlorophenyl)-1,1-dimethyl urea (Diuron) *[330-54-1]* **M 233.1.** Crystd four times from 95% EtOH [Beck et al. *JACS* **108** 4018 *1986*].

4,5-Dichloro-*o*-phenylenediamine *[5348-42-5]* **M 177.1.** Dried over Na_2SO_4. Recrystd from hexane.

4,5-Dichlorophthalic acid *[56962-08-4]* **M 235.0, m 200° (dec to anhydride).** Crystd from water.

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3,6-Dichlorophthalic anhydride *[4466-59-5]* **M 189-191°, 191-191.5°, b 339°.** Boil in xylene (allowing any vapours which would contain H_2O to be removed, e.g. Dean and Stark trap), which causes the acid to dehydrate to the anhydride and cool. Recryst from xylene [Villiger *B* **42** 3539 *1909*; Fedoorow *Izv Akad SSSR Otd Chem* 397 *1948*, *Chem Abstr* 1585 *1948*].

1,2-Dichloropropane *[78-87-5]* **M 113°, b 95.9-96.2°, d 1.158, n 1.439.** Distd from CaH_2.

2,2-Dichloropropane *[594-20-7]* **M 113.0, b 69.3°, d 1.090, n 1.415.** Washed with aqueous Na_2CO_3 soln, then distilled water, dried over $CaCl_2$ and fractionally distd.

1,3-Dichloro-2-propanone see ***sym*-dichloroacetone.**

2,6-Dichloropurine *[5451-40-1]* **M 189.0, m 180-181.5°, 181°, 185-195°(dec), 188-189°.** It can be recrystd from 150 parts of boiling H_2O and dried at 100° to constant weight. Soluble in EtOAc. The $HgCl_2$ salt separates from EtOH soln. UV: λmax 275nm (ε 8.9K) at pH 1; and 280nm (ε 8.5K) at pH 11 [Elion and Hitchings *JACS* **78** 3508 *1956*; Schaeffer and Thomas *JACS* **80** 3738 *1958*; Beaman and Robins *J Appl Chem* **12** 432 *1962*; Montgomery *JACS* **78** 1928 *1956*].

2,6-Dichloropyridine *[2402-78-0]* **M 148.0, m 87-88°**,
3,5-Dichloropyridine *[2457-47-8]* **M 148.0, m 64-65°.** Crystd from EtOH.

4,7-Dichloroquinoline *[86-98-6]* **M 198.1, m 86.4-87.4°, b 148°/10mm.** Crystd from MeOH or 95% EtOH.

5,7-Dichloro-8-quinolinol see **5,7-dichloro-8-hydroxyquinoline.**

2,3-Dichloroquinoxaline *[2213-63-0]* **M 199.0, m 152-153°, 152-154°.** Recrystd from C_6H_6 and dried in a vacuum [Cheeseman *JCS* 1804 *1955*].

2,6-Dichlorostyrene *[28469-92-3]* **M 173.0, b 72-73°/2mm, d 1.4045, n 1.5798.** Purified by fractional crystn from the melt and by distn.

***p*-*a*-Dichlorotoluene** see ***p*-chlorobenzyl chloride.**

2,4-Dichlorotoluene *[95-73-8]* **M 161.1, m -13.5°, b 61-62°/3mm, d 1.250, n 1.5513,**
2,6-Dichlorotoluene *[118-69-4]* **M 161.1, b 199-200°/760mm, d 1.254, n 1.548,**
3,4-Dichlorotoluene *[95-75-0]* **M 161.1, m -16°, b 205°/760mm, d 1.2541, n 1.549.** Recrystd from EtOH at low temperature or fractionally distd.

α,α'-Dichloro-*p*-xylene *[623-25-6]* **M 175.1, m 100°.** Crystd from benzene and dried under vacuum.

Dicinnamalacetone *[622-21-9]* **M 314.4, m 146°.** Crystd from benzene/isooctane (1:1).

Dicumyl peroxide *[80-43-3]* **M 270.4, m 39-40°.** Crystd from 95% EtOH (charcoal). Stored at 0°. *Potentially* **EXPLOSIVE.**

9,10-Dicyanoanthracene *[1217-45-4]* **M 228.2.** Recrystd twice from pyridine [Mattes and Farid *JACS* **108** 7356 *1986*].

1,2-Dicyanobenzene *[91-15-6]* **M 128.1, m 141°.** Recrystd from hot toluene.

1,4-Dicyanobenzene *[623-26-7]* **M 128.1, m 222°.** Crystd from EtOH.

Dicyanodiamide see **cyanoguanidine.**

1,4-Dicyanonaphthalene *[3029-30-9]* **M 178.2, m 206°.** Purified by crystn and sublimed *in vacuo*.

1,3-Dicyclohexyl carbodimide *[538-75-0]* **M 206.3, m 34-35°, b 95-97°/0.2mm, 120-121°/0.6mm, 155°/11mm.** It is sampled as a liquid after melting in warm H_2O. It is sensitive to air and *it is a potent* ***skin irritant.*** It can be distd in a vacuum and stored in a tightly stoppered flask in a freezer. It is very soluble in CH_2Cl_2 and pyridine where the reaction product with H_2O, after condensation, is dicyclohexyl urea which is insoluble and can be removed by filtration. Alternatively dissolve in CH_2Cl_2 add powdered anhyd $MgSO_4$ shake 4h, filter, evaporate and distil at 0.6 mm press and oil bath temperature 145°. [*Biochem Prep* **10**, 122 *1963*; *A* **571** 83 *1951*; *A* **612** 11 *1958*].

Dicyclohexyl-18-crown-6 *[16069-36-6]* **M 372.5.** Purified by chromatography on neutral alumina and eluting with an ether/hexane mixture [see *Inorg Chem* **14** 3132 *1975*]. Dissolved in ether at *ca* 40°, and spectroscopic grade MeCN was added to the soln which was then chilled. The crown ether ppted and was filtered off. It was dried *in vacuo* at room temperature [Wallace *JPC* **89** 1357 *1985*].

Di-*n*-decylamine *[1120-49-6]* **M 297.6, m 34°. b 153°/1mm, 359°/760mm.** Dissolved in benzene and ppted as its bisulphate by shaking with 4M H_2SO_4. Filtered, washed with benzene, separating by centrifugation, then the free base was liberated by treating with aqueous NaOH [McDowell and Allen *JPC* **65** 1358 *1961*].

Didodecylamine *[3007-31-6]* **M 353.7, m 51.8°.** Crystd from EtOH/benzene under N_2.

Didodecyldimethylammonium bromide *[3282-73-3]* **M 463.6.** Recrystd from acetone, acetone/ether mixture, then from ethyl acetate, washed with ether and dried in a vacuum oven at 60° [Chen et al. *JPC* **88** 1631 *1984*; Rupert et al. *JACS* **107** 2628 *1985*; Halpern et al. *JACS* **108** 3920 *1986*; Allen et al. *JPC* **91** 2320 *1987*].

Dienestrol [4,4'-(diethylidene-ethlene)diphenol, Dienol] *[84-17-37]* **M 266.3, m 227-228°, 231-233°.** Crystd from EtOH or dilute EtOH, sublimes at 130°/1mm. The *diacetate* has **m** 119-120° (from EtOH) [Hobday and Short *JCS* 609 *1943*].

Diethanolamine *[111-42-2]* **M 105.1, m 28°, b 154-155°/10mm, 270°/760mm.** Fractionally distd twice, then fractionally crystd from its melt.

3,4-Diethoxy-3-cyclobutene-1,2-dione (diethyl squarate) *[5321-87-8]* **M 170.2, b 89-91°/0.4mm, 88-92°/0.4mm, d_4^{20} 1.162, n_D^{25} 1.5000.** Dissolve in Et_2O, wash with Na_2CO_3, H_2O and dry (Na_2SO_4), filter, evaporate and distil using a Kugelrohr or purify by chromatography . Use a Keiselgel column and elute with 20% Et_2O-Pet ether (b 40-60°) then with Et_2O-pet ether (1:1), evaporate and distil *in vacuo*. [Dehmlow and Schell *B* **113** 1 *1980*; Perri and Moore *JACS* **112** 1897 *1990*; IR: Cohen and Cohen *JACS* **88** 1533 *1966*]. **It can cause severe dermatitis** [Foland et al. *JACS* **111** 975 *1989*].

1,2-Diethoxyethane see **ethylene glycol diethyl ether.**

***N,N*-Diethylacetamide** *[2235-46-3]* **M 157.2, b 86-88°, n 1.474, d 0.994.** Dissolved in cyclohexane, shaken with anhydrous BaO and then filtered. The procedure was repeated three times, and the cyclohexane was distd off at 1 atmosphere pressure. The crude amide was also fractionally distd three times from anhydrous BaO.

Diethyl acetamidomalonate *[1068-90-2]* **M 217.2, m 96°.** Crystd from benzene/pet ether.

Diethyl acetylenedicarboxylate *[762-21-0]* **M 170.2, b 60-62°/0.3mm, 107-110°/11mm, 118-120°/20mm, d_4^{20} 1.0735, n_D^{20} 1.4428.** Dissolve in C_6H_6, wash with $NaHCO_3$, H_2O, dry over Na_2SO_4, filter, evaporate and distil in a vacuum [IR: Walton and Hughes *JACS* **79** 3985 *1957*; Truce and Kruse *JACS* **81** 5372 *1959*].

Diethylamine *[109-89-7]* **M 73.1, b 55.5°, d 0.707, n 1.38637.** Dried with $LiAlH_4$ or KOH pellets. Refluxed with, and distd from, BaO or KOH. Converted to the *p*-toluenesulphonamide and crystd to constant melting point from dry pet ether (b 90-120°), then hydrolysed with HCl, excess NaOH was added, and the amine passed through a tower of activated alumina, redistd and dried with activated alumina before use [Swift *JACS* **64** 115 *1942*].

Diethylamine hydrochloride *[660-68-4]* **M 109.6, m 223.5°.** Crystd from absolute EtOH. Also crystd from dichloroethane/MeOH. *Hygroscopic.*

***trans*-4-(Diethylamino)azobenzene** *[3588-91-8]* **M 320.5, m 171°.** Purified by column chromatography [Flamigni and Monti *JPC* **89** 3702 *1985*].

***N,N*-Diethylaniline** *[91-66-7]* **M 149.2, b 216.5°, d 0.938, n 1.5409.** Refluxed for 4h with half its weight of acetic anhydride, then fractionally distd under reduced pressure (**b** 92°/10mm).

Diethyl azodicarboxylate (DEAD) *[1972-28-7]* **M 174.2, b 104.5°/12mm, 211-213°/atm, d_4^{20} 1.110, n_D^{20} 1.420.** Dissolve in toluene, wash with 10% $NaHCO_3$ till neutral (may require several washes if too much hydrolysis had occurred (check IR for OH bands), then wash with H_2O (2 x), dry over Na_2SO_4, filter, evaporate the toluene and distil through a short Vigreux column. Main portion boils at 107-111°/15mm [*Org Synth* Coll Vol III 376 *1955*].

5,5-Diethylbarbituric acid *[57-44-3]* **M 184.2, m 188-192°.** Crystd from water or EtOH. Dried in a vacuum over P_2O_5.

Diethyl bromomalonate *[685-87-0]* **M 239.1, b 116-118°/10mm, 122-123°/20mm, d_4^{20} 1.420, n_D^{20} 1.4507.** Purified by fractional distn in a vacuum. IR: 1800 and 1700cm^{-1} [Abramovitch *Canad J Chem* **37** 1146 *1959*; Bretschneider and Karpitschka *M* **84** 1091 *1053*].

Diethyl *tert*-butylmalonate *[759-24-0]* **M 216.3, b 40-42°/0.03, 102-104°/11mm, 109.5-110.5°/17mm, 205-210°/760mm, d_4^{20} 0.980, n_D^{20} 1.425.** Dissolve in Et_2O, wash with aqueous $NaHCO_3$, H_2O, dry ($MgSO_4$), filter, evaporate and distil residue. Identified by hydrolysis to the acid and determining the neutralisation equiv (theor: 80.0). The *acid* has **m** 155-157° efferv [Hauser, Abramovitch and Adams *JACS* **64** 2715 *1942*; Bush and Beauchamp *JACS* **75** 2949 *1953*].

***N,N'*-Diethylcarbanilide** *[611-92-7]* **M 240.3, m 79°.** Crystd from EtOH.

Diethyl carbitol see **Diethylene glycol diethyl ether.**

Diethyl carbonate *[105-58-8]* **M 118.1, b 126.8°, d 0.975, n^{25} 1.38287.** It was washed (100ml) with an aqueous 10% Na_2CO_3 (20ml) solution, saturated $CaCl_2$ (20ml), then water (30ml). After drying by standing over solid $CaCl_2$ for 1h (note that prolonged contact should be avoided because slow combination with $CaCl_2$ occurs), it should be fractionally distd.

1,1'-Diethyl-2,2'-cyanine iodide *[977-96-8]* **M 454.4, m 274°(dec).** Crystd from EtOH and dried in a vacuum oven at 80° for 4h.

***N,N*-Diethylcyclohexylamine** *[91-65-6]* **M 155.3, b 193°/760mm, d 0.850, n 1.4562.** Dried with BaO and fractionally distd.

***sym*-Diethyldiphenylurea** see ***N,N*-diethylcarbanilide.**

Diethylene glycol *[111-46-6]* **M 106.1, f.p. -10.5°, b 244.3°, d 1.118, n^{15} 1.4490, n 1.4475.** Fractionally distd under reduced pressure (**b** 133°/14mm), then fractionally crystd by partial freezing.

Diethylene glycol diethyl ether *[112-36-7]* **M 162.2, b 85-86°/10mm, 188.2-188.3°/751mm, d 0.909.** Dried with $MgSO_4$, then CaH_2 or $LiAlH_4$, under N_2. If sodium is used the ether should be redistd alone to remove any products which may be formed by the action of sodium on the ether. As a preliminary purification, the crude ether (2L) can be refluxed for 12h with 25ml of conc HCl in 200ml of water, under reduced pressure, with slow passage of N_2 to remove aldehydes and other volatile substances. After cooling, addn of sufficient solid KOH pellets (slowly and with shaking until no more dissolve) gives two liquid phases. The upper of these is decanted, dried with fresh KOH pellets, decanted, then refluxed over, and distd from, sodium.

Diethylene glycol dimethyl ether see **diglyme.**

Diethylene glycol ditosylate *[7460-82-4]* **M 414.5, m 86-87°, 87-88°, 88-89°.** Purified by recrystn from Me_2CO and dried in a vacuum.

Diethylene glycol mono-*n*-butyl ether *[112-34-5]* **M 162.2, b 69-70°/0.3mm, 230.5°/760, d 0.967, n 1.4286.** Dried with anhydrous K_2CO_3 or $CaSO_4$, filtered and fractionally distd. Peroxides can be removed by refluxing with stannous chloride or a mixture of $FeSO_4$ and $KHSO_4$ (or, less completely, by filtration under slight pressure through a column of activated alumina).

Diethylene glycol monoethyl ether *[111-90-0]* **M 134.2, b 201.9°, d 0.999, n 1.4273, n^{25} 1.4254.** Ethylene glycol can be removed by extracting 250g in 750ml of benzene with 5ml portions of water, allowing for phase separation, until successive aqueous portions show the same volume increase. Dried, and freed from peroxides, as described for diethylene glycol mono-*n*-butyl ether.

Diethylene glycol monomethyl ether *[111-77-3]* **M 120.2, b 194°, d 1.010, n 1.423.** Purified as for diethylene glycol mono-*n*-butyl ether.

Diethylenetriamine see **2,2'-diaminodiethylamine.**

Diethylenetriaminepenta-acetic acid *[67-43-6]* **M 393.4, m 219-220°.** Crystd from water. Dried under vacuum or at 110°. [Bielski and Thomas *JACS* **109** 7761 *1987*].

Diethyl ether see **ethyl ether.**

Diethyl ethoxymethylene malonate *[87-13-8]* **M 216.2, b 014°/0.2mm, 109°/0.5mm, 279-283°/atm, d_4^{20} 1.079, n_D^{20} 1.4623.** Likely impurity is diethyl diethoxymethylene malonate which is difficult to separate from diethyl ethoxymethylene malonate by distn and it is necessary to follow the course of the distn by the change in refractive index instead of boiling point. After a low boiling fraction is collected, there is obtained an intermediate fraction (n_D^{20} 1.414—1.4580) the size of which depends on the amount of diethoxymethylene compound. This fraction is fractionated through a 5-inch Vigreux column at low pressure avoiding interruption in heating. Fraction **b** 108-110°/0.25mm was *ca* 10° lower than the submitters' (**b** 97.2°/0.25mm (n_D^{20} 1.4612—1.4623) [*Org Synth* Coll Vol III 395 *1955*; Fuson et al. *JOC* **11** 197 *1946*; Duff and Kendal *JCS* 893 *1948*].

***N,N'*-Diethylformamide** *[617-84-5]* **M 101.2, b 29°/0.5mm, 61-63°/10mm, 176-179°/758mm, 178.3-178.5°/760mm d_4^{20} 0.906, n_D^{25} 1.4313.** Distd under reduced pressure then at atmospheric pressure [Wintcler et al. *HCA* **37** 2370 *1954*; NMR: Hoffmann *Z anal Chem* **170** 177 *1959*].

Diethyl fumarate *[623-91-6]* **M 172.2, b 218°, d 1.052, n 1.441.** Washed with aqueous 5% Na_2CO_3, then with saturated $CaCl_2$ soln, dried with $CaCl_2$ and distd.

Di-(2-ethylhexyl)phthalate ('di-iso-octyl' phthalate) *[117-81-7]* **M 390.6, b 384°, 256-257°/1mm, d 0.9803, n 1.4863.** Washed with Na_2CO_3 soln, then shaken with water. After the resulting emulsion had been broken by adding ether, the ethereal soln was washed twice with water, dried

($CaCl_2$), and evaporated. The residual liquid was distd several times under reduced pressure, then stored in a vacuum desiccator over P_2O_5 [French and Singer *JCS* 1424 *1956*]

Diethyl ketone (3-pentanone) *[96-22-0]* **M 86.1, b 102.1°, d 0.8099, n 1.392.** Dried with anhydrous $CaSO_4$ or $CuSO_4$, and distd from P_2O_5 under N_2 or under reduced pressure. Further purification by conversion to the semicarbazone (recrystd to constant **m** 139°, from EtOH) which, after drying under vacuun over $CaCl_2$ and paraffin wax, was refluxed for 30min with excess oxalic acid, then steam distd and salted out with K_2CO_3. Dried with Na_2SO_4 and distd [Cowan, Jeffrey and Vogel *JCS* 171 *1940*].

Diethyl phenyl orthoformate (diethoxy phenoxy ethane) *[14444-77-0]* **M 196.3, b 111°/11mm, 122°/13mm, d_4^{20} 1.0099, n_D^{20} 1.4799.** Fractionated through an efficient column under vacuum [Smith *Acta Chem Scand* **10** 1006 *1956*].

Diethyl phthalate *[84-66-2]* **M 222.2. b 172°/12mm, b 295°/760mm, d^{25} 1.1160, n 1.5022.** Washed with aqueous Na_2CO_3, then distilled water, dried ($CaCl_2$), and distd under reduced pressure. Stored in a vacuum desiccator over P_2O_5.

Diethyl phthalimido malonate *[56680-61-5]* **M 305.3, m 72-74°, 73-74°.** Dissolve in xylene and when the temperature is 30° add pet ether (b 40-60°) and cool to 20° whereby the malonate separates as a pale brown powder [Booth et al. *JCS* 666 *1944*]. Alternatively, dissolve in C_6H_6, dry over $CaCl_2$, filter, evaporate and the residual oil solidifies. This is ground with Et_2O, filter and wash with Et_2O until white in colour, and dry in a vacuum. It has a pKa of 9.17 (H_2O) and the anion has λmax 254nm (ε 18.5K) [Clark and Murray *OrgSynth* Coll Vol I 271 *1941*; UV of Na salt: Nnadi and Wang *JACS* **92** 4421 *1970*].

2,2-Diethyl-1,3-propanediol *[115-76-4]* **M 132.2, m 61.4-61.8°.** Crystd from pet ether (b 65-70°).

Diethyl pyrocarbonate (DEP) *[1609-47-8]* **M 162.1, b 38-40°/12mm, 160-163°/atm, d_4^{20} 1.119, n_D^{20} 1.398.** Dissolve in Et_2O, wash with dilute HCl, H_2O, dry over Na_2SO_4, filter, evaporate and distil the residue first *in vacuo* then at atmospheric pressure. It is soluble in alcohols, esters, ketones and hydrocarbon solvents. A 50% w/w soln is usually prepared for general use. **Treat with great CAUTION as DEP irritates the eyes, mucous membranes and skin.** [Boehm and Mehta *B* **71** 1797 *1938*; Thoma and Rinke *A* **624** 30 *1959*].

Diethylstilboesterol *[56-25-1]* **M 268.4, m 169-172°.** Crystd from benzene.

Diethyl succinate *[123-25-1]* **M 174.2, b 105°/15mm, d 1.047, n 1.4199.** Dried with $MgSO_4$, and distd at 15mm pressure.

Diethyl sulphate *[64-67-5]* **M 154.2, b 96°/15mm, 118°/40mm, d 1.177, n 1.399.** Washed with aqueous 3% Na_2CO_3 (to remove acidic material), then distilled water, dried ($CaCl_2$), filtered and distd. *Causes blisters to the skin.*

Diethyl disulphide *[110-81-6]* **M 122.3, b 154-155°, d 0.993, n 1.506.** Dried with silica gel or $MgSO_4$ and distd under reduced pressure (optionally from $CaCl_2$).

Diethyl sulphide *[352-93-2]* **M 90.2, m 0°/15mm, 90.1°/760mm, d 0.837, n 1.443.** Washed with aq 5% NaOH, then water, dried with $CaCl_2$ and distd from sodium. Can also be dried with $MgSO_4$ or silica gel. Alternative purification is *via* the Hg(II) chloride complex [$(Et)_2S.2HgCl_2$] (see dimethyl sulphide).

Diethyl (-)-D- (from the non-natural) *[13811-71-7]* **and (+)-L- (from the natural acid)** *[89-91-2]* **tartrate M 206.2, m 17°, 80°/0.5mm, 150°/11mm, 162°/19mm, 278-282°/atm, d_4^{20} 1.204, n_D^{20} 1.4476, $[\alpha]_D^{20} \pm 26.5°$ (c 1, H_2O) and ±8.5° (neat), $[\alpha]_{546}^{20} \pm 30°$ (c 1, H_2O).** Distd under high vacuum and stored under vacuum or in an inert atm in a desiccator in round bottomed flasks equiped with a vac stopcock. Have also been dist by Kügelrohr distn and by wiped-film molecular distn. Slightly sol in H_2O but miscible in EtOH and Et_2O. [Gao et al. *JACS* **109** 5770 *1987*; IR: Pristera *AC* **25** 844 *1953*].

Diethyl terephthalate *[636-09-0]* **M 222.2, m 44°, 142°/2mm, 302°/760mm.** Crystd from toluene and distd under reduced pressure.

***sym*-Diethylthiourea** *[105-55-5]* **M 132.2, m 76-77°.** Crystd from benzene.

Difluoroacetic acid *[496-16-2]* **M 96.0, m -0.35°, b 67-70°/20mm, 134°/760mm, d_4^{20} 1.530, n_D^{20} 1.3428.** Purified by distilling over P_2O_5. The *acid chloride* is a fuming liquid **b** 25°, and the *amide* has **b** 108.6°/35mm, **m** 52° (from C_6H_6) [Henne and Pelley *JACS* **74** 1426 *1952*, Coffman et al. *JOC* **14** 749 *1949*; NMR: Meyer et al. *JACS* **75** 4567 *1953*]. It has a Ka value of 5.72 x 10^{-2} [Wegscheider *ZPC* **69** 614 1909].

4,4'-Difluoro-3,3'-dinitrophenylsulphone see **Bis-(4-fluoro-3-nitrophenyl)sulphone.**

Digitonin *[11024-24-1]* **M 1229.3, m >270°(dec), $[\alpha]_{546}^{20}$ -63° (c 3, MeOH).** Crystd from aqueous 85% EtOH or MeOH/ethyl ether.

Digitoxigenin *[142-62-4]* **M 374.5, m 253°, $[\alpha]_{546}^{20}$ +21° (c 1, MeOH).** Crystd from aqueous 40% EtOH.

D(+)-Digitoxose *[527-52-6]* **M 148.2, m 112°, $[\alpha]_{546}^{20}$ +57° (c 1, H_2O).** Crystd from MeOH/ethyl ether, or ethyl acetate.

Diglycolic acid *[110-99-6]* **M 134.1, m 148° (monohydrate).** Crystd from water.

Diglycyl glycine *[556-33-2]* **M 189.2, m 246°(dec).** Crystd from H_2O or H_2O/EtOH and dried at 110°.

Diglyme *[111-46-6]* **M 134.2, b 62°/17mm, 75°/35mm, 160°/760mm, d 0.917, n 1.4087.** Dried with NaOH pellets or CaH_2, then refluxed with, and distd (under reduced pressure) from Na, CaH_2, $LiAlH_4$, $NaBH_4$ or NaH. These operations were carried out under N_2. The amine-like odour of diglyme has been removed by shaking with a weakly acidic ion-exchange resin (Amberlite IR-120) before drying and distn. Addn of 0.01% $NaBH_4$ to the distillate inhibits peroxidation. Purification as for dioxane. Also passed through a 12-in column of molecular sieves to remove water and peroxides.

Digoxin *[20830-75-5]* **M 781.0, m 265°(dec), $[\alpha]_{546}^{20}$ +14.0° (c 10, pyridine).** Crystd from aqueous EtOH or aqueous pyridine.

4,4'-Di-*n*-heptyloxyazoxybenzene *[2635-26-9]* **M 426.6, m 75°, 95° (smectic → nematic) and 127° (nematic → liquid).** Purified by chromatography on Al_2O_3 (benzene), recrystd from hexane or 95% EtOH and dried by heating under vacuum. The liquid crystals can be sublimed *in vacuo*. [Mellifiori et al. *Spectrochim Acta A* **37(A)** 605 *1981*; Dewar and Schroeder *JACS* **86** 5235 *1964*; Weygand and Glaber *J prakt Chemie* **155** 332 *1940*].

9,10-Dihydroanthracene *[613-31-0]* **M 180.3, m 110-110.5°.** Crystd from EtOH [Rabideau et al. *JACS* **108** 8130 *1986*].

2,3-Dihydrobenzofuran (coumaran) *[496-16-2]* **M 120.2, m -21.5°, 72-73°/12mm, 78-81°/15mm. 84°/17mm, 188°/atm, d_4^{20} 1.065, n_D^{20} 1.5524.** Suspend in aqueous NaOH and steam distil. Saturate the distillate with NaCl and extract with Et_2O, dry extract ($MgSO_4$), filter, evap and distil the residue. It gives a strong violet colour with $FeCl_3$ + H_2SO_4 and forms a yellow *picrate*, **m** 76°, from EtOH or C_6H_6 which loses coumaran in a desiccator [Bennett and Hafez *JCS* 287 *1941*; Baddeley et al. *JCS* 2455 *1956*].

Dihydrochloranil *[1198-5-6]* **M 247.9.** Crystd from EtOH [Rabideau et al. *JACS* **108** 8130 *1986*].

Dihydrocholesterol see **cholestanol.**

Dihydrocinnamic acid *[501-52-0]* **M 150.2, m 48-49°.** Crystd from pet ether (b 60-80°).

3,4-Dihydro-3,4-dioxo-1-naphthlene sulphonic acid sodium salt (1,2-naphthoquinone-4-sulphonic acid sodium salt) *[521-24-4]* **M 260.2.** Yellow crystals from aqueous EtOH and dry at 80° *in vacuo*. Solubility in H_2O is 5% [*Org Synth* Coll Vol III 633 *1955*; Danielson *JBC* **101** 507 *1933*; UV: Rosenblatt et al. *AC* **27** 1290 *1955*].

1,4-Dihydro-1,4-epoxynaphthalene *[573-57-9]* **M 144.2, m 53-54.5°, 53-56°, 55-56°.** Dissolve in Et_2O, wash with H_2O, dry over K_2CO_3, filter, evaporate and dry the residue at 15mm, then recrystallise from pet ether (b 40-60°), dry at 25°/0.005mm and sublime (sublimes slowly at room temp)[Wittig and Pohmer *B* 89 1334 *1956*; Gilman and Gorsich *JACS* **79** 2625 *1957*].

Dihydropyran (3,4-dihydro-2*H*-pyran) *[110-87-2]* **M 84.1, b 84.4°/742mm, 85.4-85.6°/760mm, d_4^{20} 0.9261, n_D^{20} 1.4423.** Partially dried with Na_2CO_3, then fractionally distd. The fraction **b** 84-85°, was refluxed with Na until hydrogen was no longer evolved when fresh Na was added. It was then dried, and distd again through a 60 x 1.2cm column packed with glass rings [Brandon et al. *JACS* **72** 2120 *1950*; UV: Elington at al. *JCS* 2873 *1952*, NMR: Bushweller and O'Neil *TET LETT* 4713 *1969*]. It has been characterised as the *2,3,5-dinitrobenzoyloxy-tetrahydrofuran* derivative, **m** 103° which forms pale yellow crystals from dihydropyran-Et_2O [Woods and Kramer *JACS* **69** 2246 *1947*].

3,4-Dihydro-2*H*-pyrido[1,2*a*]-pyrimidin-2-one *[5439-14-5]* **M 148.2, m 185-187°, 187-188°, 191-191.5°.** Dissolve in $CHCl_3$, filter, evaporate then recrystallise the residue from EtOH-Me_2CO (needles) which can be washed with Et_2O and dried. It can also be recrystd from $CHCl_3$-pet ether or $CHCl_3$-hexane. The *hydrochloride* has **m** 295-295° (dec, from EtOH or MeOH-Et_2O), the *hydrobromide* has **m** 299-300°(dec, from MeOH-Et_2O) and the *picrate* has **m** 224-226°(corr), **m** 219-220° from EtOH. [Adams and Pachter *JACS* **74** 4906 *1952*; Lappin *JOC* **23** 1358 *1958*; Hurd and Hayao *JACS* **77** 115 *1955*].

Dihydrotachysterol *[67-96-9]* **M 398.7, m 125-127°, $[\alpha]_D^{20}$ +97° ($CHCl_3$).** Crystd from 90% MeOH.

1,2-Dihydroxyanthraquinone see **alizarin.**

1,4-Dihydroxyanthraquinone see **quinizarin.**

1,5-Dihydroxyanthraquinone see **anthrarufin.**

1,8-Dihydroxyanthraquinone *[117-10-2]* **M 240.1, m 193-197°.** Crystd from EtOH and sublimed in a vacuum.

2,4-Dihydroxyazobenzene *[2051-85-6]* **M 214.2, m 228°.** Crystd from hot EtOH (charcoal).

2,3-Dihydroxybenzaldehyde *[24677-78-9]* **M 138.1, m 135-136°,**
2,4-Dihydroxybenzoic acid *[95-01-2]* **M 154.1, m 226-227°(dec).** Crystd from water.

2,5-Dihydroxybenzoic acid *[490-79-9]* **M 154.1, m >200°(dec).** Crystd from benzene/acetone. Dried in a vacuum desiccator over silica gel.

2,6-Dihydroxybenzoic acid *[303-07-1]* **M 154.1, m 167°(dec).** Dissolved in aqueous $NaHCO_3$ and the soln was washed with ether to remove non-acidic material. The acid was ppted by adding H_2SO_4, and recrystd from water. Dried under vacuum and stored in the dark [Lowe and Smith *JCSFT 1* **69** 1934 *1973*].

2,4-Dihydroxybenzophenone *[131-56-6]* **M 214.2, m 145.5-147°.** Recrystd from MeOH.

2,5-Dihydroxybenzyl alcohol *[495-08-9]* **M 140.1, m 100°.** Crystd from $CHCl_3$. Sublimed.

2,2'-Dihydroxybiphenyl *[1806-29-7]* **M 186.2, m 108.5-109.5°.** Repeatedly crystd from toluene, then sublimed at 60°/10^{-4}mm.

3α,7α-Dihydroxycholanic acid *[474-25-9]* **M 239.6, m 143°, $[\alpha]^{20}_{546}$ +14° (c 2, EtOH).** Crystd from ethyl acetate.

6,7-Dihydroxycoumarin (esculetin) *[305-01-1]* **M 178.2, m 268-270°(dec).** Crystd from glacial acetic acid. See also esculetin.

7,8-Dihydroxycoumarin *[486-35-1]* **M 178.2, m 256°(dec).** Crystd from aqueous EtOH. Sublimed.

3,4-Dihydroxy-3-cyclobutene-1,2-dione see **squaric acid.**

2,2'-Dihydroxy-6,6'-dinaphthyl disulphide *[6088-51-3]* **M 350.5, m 220-223°.** Recryst from hot glacial acetic acid. [Barnett and Seligman *Science* **116** 323 *1952*].

***trans*-2,3-Dihydroxy-1,4-dioxane** *[4845-50-5]* **M 120.1, m 91-95°, 100°.** Recryst from Me_2CO. With phenylhydrazine it gives *glyoxal phenylhydrazone* **m** 175° (from Me_2CO-pet ether). The *diacetyl* derivative has **m** 105-106° [Head *JCS* 1036 *1955*, Raudnitz *Chemistry & Industry (London)* 166 *1956*].

2,5-Dihydroxy-1,4-dithiane *[40018-26-6]* **M 152.2, m (142-147° ?) 150-152°, 151°.** Recrystd from EtOH. The *2,5-diethoxy-dithiane* has **m** 91° (92-93°) crystallises from pet ether and can be sublimed at 60°/0.001mm [Hormatka and Haber *M* **85** 1088 *1954*; Thiel et al. *A* **611** 121 *1958*; Hesse and Jøeder *B* **85** 924 *1952*].

(*N,N*-Dihydroxyethyl)glycine *[150-25-4]* **M 163.2, m 193°(dec).** Dissolved in a small volume of hot water and ppted with EtOH, twice. Repeated once more but with charcoal treatment of the aqueous soln, and filtered before addition of EtOH.

2,4-Dihydroxyimidazole see **hydantoin.**

3,4-Dihydroxyisoflavone *[578-86-9]* **M 256.3, m 234-236°.** Crystd from aqueous 50% EtOH.

2,6-Dihydroxyisonicotinic acid see **citrazinic acid.**

Dihydroxymaleic acid (dihydroxyfumaric acid hydrate) *[133-38-0]* **M 148.1, m 155°(dec).** Crystd from water.

5,7-Dihydroxy-4'-methoxyflavone *[491-80-5]* **M 284.3, m 261°.** Crystd from 95% EtOH.

1,8-Dihydroxy-3-methylanthraquinone (chrysophanic acid) *[481-74-3]* **M 245.3, m 196°.** Crystd from EtOH or benzene and sublimed in a vacuum.

1,5-Dihydroxynaphthalene *[83-56-7]* **M 160.2, m 165°(dec).** Crystd from nitromethane.

1,6-Dihydroxynaphthalene *[575-44-0]* **M 160.2, m 138-139° (with previous softening).** Crystd from benzene/EtOH after treatment with charcoal.

5,8-Dihydroxy-1,4-naphthoquinone see **naphthazarin.**

2,5-Dihydroxyphenylacetic acid (homogentisic acid) *[451-13-8]* **M 168.2, m 152°.** Crystd from EtOH/$CHCl_3$.

***S*-β-(3,4-Dihydroxyphenyl)alanine (DOPA)** *[59-92-7]* **M 197.2, m 285.5°(dec), $[\alpha]^{20}_{D}$ -12.0° (1M HCl).** Likely impurities are vanillin, hippuric acid, 3-methoxytyrosine and 3-aminotyrosine. Crystd by

dissolving in dilute HCl and adding dilute ammonia to give pH 5, under N_2. Alternatively, crystd from aqueous EtOH. Unstable in aqueous alkali.

2,3-Dihydroxytoluene *[452-86-8]* **M 124.1, m 65-66°.** Crystd from C_6H_6. Purity checked by TLC.

1,3-Diiminoisoindoline *[3468-11-9]* **M 145.2, m 193-194° (dec), 196° (dec), ~ 197° (dec).** It crystallises from H_2O, MeOH or MeOH-Et_2O (charcoal) in colourless prisms that become green on heating. [Elvidge and Linstead *JCS* 5000 *1952*]. It has pKa 8.27, IR (nujol): 3150 and 690 cm^{-1}, and UV: λmax 251nm (ε 12.5K), 256nm (ε 12.5K) and 303nm (ε 4.6K) [Elvidge and Golden *JCS* 700 *1957*; Clark et al. *JCS* 3593 *1953*]. The *thiocyanate* has **m** 250-255° (dec), the *monohydrochloride* has **m** 300-301° (turns green) and the *dihydrochloride* has **m** 326-328° (turns green) and the *picrate* cryst from EtHO has **m** 299° (dec).

p-**Diiodobenzene** *[624-38-4]* **M 329.9, m 132-133°.** Crystd from EtOH or boiling MeOH, then air dried.

1,2-Diiodoethane *[624-73-7]* **M 281.9, m 81-84°, d 2.134.** Dissolved in ether, washed with satd aq $Na_2S_2O_3$, drying it over $MgSO_4$ and evaporating the ether *in vacuo* [Molander et al. *JACS* **109** 453 *1987*].

5,7-Diiodo-8-hydroxyquinoline *[83-73-8]* **M 397.0, m 214-215°(dec).** Crystd from xylene and dried at 70° in a vacuum.

Diiodomethane *[75-11-6]* **M 267.8, m 6.1°, b 66-70°/11-12mm, d 3.325.** Fractionally distd under reduced pressure, then fractionally crystd by partial freezing, and stabilized with silver wool if necessary. It has also been purified by drying over $CaCl_2$ and fractionally distd from Cu powder.

5,7-Diiodo-8-quinolinol see **5,7-diiodo-8-hydroxyquinoline.**

S-3,5-Diiodotyrosine (iodogorgoic acid) *[300-39-0]* **M 469.0, m 204°(dec), $[\alpha]_D$ +1.5° (in 1M HCl).** Likely impurities are tyrosine, 3-iodotyrosine and iodide ions. Crystd from cold dilute ammonia by adding acetic acid to give pH 6. It can also be crystd from aq 70% EtOH.

Diisopropanolamine *[110-97-4]* **M 133.2, m 41-44°, d 1.004.** Repeatedly crystd from dry ethyl ether.

(-)-2,3:4,6-Di-*O*-isopropylidene-2-keto-L-gulonic acid monohydrate (- DAG) *[18467-77-1]* **M 292.3, m 100-101°, 103°, $[\alpha]_D^{25}$ -21.6° (c 2.3, MeOH).** Dissolve in Et_2O, filter, dry ($MgSO_4$), filter, evaporate to give a yellow oil. Addition of one drop of H_2O induces crystn to the monohydrate, which also forms rhombic crystals by recrystn from 95% EtOH-H_2O at room tempereture. [Flatt et al. *S* 815 *1979*; Reichstein and Grussner *HCA* **17** 311 *1934*; Takagi and Jeffrey *Acta Cryst Sect B 34* 2932 *1978*; cf *Org Synth* **55** 80 *1976*].

1,2:5,6-Di-*O*-isopropylidene-D-mannitol *[1707-77-3]* **M 262.3, m 121-125°, 122°, $[\alpha]_D^{25}$ +1.2° (c 3, H_2O).** Although quite soluble in H_2O it gives a purer product from this solvent, forming needles [Baer *JACS* **67** 338 *1945*; NMR: Curtis et al. *JCS Perkin Trans 1* 1756 *1977*].

Diisopropylamine *[108-18-9]* **M 101.2, b 83.5°/760mm, n 1.39236, d 0.720.** Distd from NaOH, or refluxed over Na wire or NaH for three minutes and distd into a dry receiver under N_2.

Diisopropyl ether see **isopropyl ether.**

Diisopropylethylamine *[7087-68-5]* **M 129.3, b 127°.** Distd from ninhydrin, then from KOH [Dryland and Sheppard, *JCSFT 1* 125 *1986*].

Diisopropyl ketone *[565-80-0]* **M 114.2, b 123-125°, d 0.801, n 1.400.** Dried with $CaSO_4$, shaken with chromatographic alumina and fractionally distd.

Diketene *[674-82-8]* **M 84.1, m -7°, b 66-68°/90mm, d 1.440, n 1.4376, n^{25} 1.4348.** Diketene polymerizes violently in the presence of alkali. Distd at reduced pressure, then fractionally crystd by partial freezing (using as a cooling bath a 1:1 soln of $Na_2S_2O_3$ in water, cooled with Dry-ice until slushy, and stored in a Dewar flask). Freezing proceeds slowly, and takes about a day for half completion. The crystals are separated and stored in a refrigerator under N_2.

2,2'-Diketospirilloxanthin *[24009-17-4]* **M 624.9, m 225-227°, $\varepsilon^{1\%}_{1cm}$ 550(349nm), 820(422nm), 2125(488nm), 2725(516nm), 2130(551nm) in hexane.** Purified by chromatography on a column of partially deactivated alumina. Crystd from acetone/pet ether. Stored in the dark, in an inert atmosphere at 0°.

Dilauroyl peroxide *[105-74-8]* **M 398.6, m 53-55°.** Crystd from *n*-hexane. *Potentially* **EXPLOSIVE.**

Dilituric acid see **5-*N*-nitrobarbituric acid.**

Dimedone *[126-81-8]* **M 140.2, m 148-149°.** Crystd from acetone (*ca* 8ml/g), water or aqueous EtOH. Dried in air.

1,2-Dimercapto-3-propanol *[59-52-9]* **M 124.2, b 82-84°/0.8mm, d 1.239, n 1.5732,**
1,3-Dimercapto-2-propanol *[584-04-3]* **M 124.2, b 82°/1.5mm.** Ppted as the mercury mercaptide (see Bjöberg *B* **75** 13 *1942*], regenerated with H_2S, and distd at 2.7mm [Rosenblatt and Jean *AC* 951 *1955*].

***meso*-2,3-Dimercaptosuccinic acid** *[304-55-2]* **M 182.2, m 191-192° (dec), 210° (dec), 210-211° (dec).** Purified by dissolving in NaOH and precipitating with dilute HCl, dry and recrystallise from MeOH. It has pKa values of 3.0 and 3.9, and the IR has ν at 2544 (SH) and 1689 (CO_2H) cm^{-1}. The *bis-S-acetyl* deriv has **m** 183-185° (from EtOAc or Me_2CO) and its *Me ester* has **m** 119-120° (from pet ether) [Gerecke et al. *HCA* **44** 957 *1961*; Owen and Sultanbawa *JCS* 3112 *1949*].

4,4'-Dimethoxyazobenzene *[2396-60-3]* **M 242.3, m 162.7-164.7°.** Chromatographed on basic alumina, eluted with benzene. Crystd from 2:2:1 (v/v) methanol/ethanol/benzene.

4,4'-Dimethoxyazoxybenzene *[1562-94-3]* **M 258.3, m 165°.** Crystd from hot 95% EtOH, dried, then sublimed in a vacuum onto a cold finger.

3,4-Dimethoxybenzaldehyde see **veratraldehyde.**

***o*-Dimethoxybenzene (veratrole)** *[91-16-7]* **M 137.2, m 23°, b 208.5-208.7, d 1.085, n^{25} 1.53232.** Steam distd. Fractionally distd from BaO, CaH_2 or Na. Crystd from benzene or low-boiling pet ether at 0°. Fractionally crystd from its melt. Stored over anhydrous Na_2SO_4.

***m*-Dimethoxybenzene** *[151-10-0]* **M 137.2, b 212-213°, d 1.056, n 1.5215.** Extracted with aqueous NaOH, and water, then dried. Fractionally distd from BaO or Na.

***p*-Dimethoxybenzene** *[150-78-7]* **M 137.2, m 57.2-57.8°.** Steam distd. Crystd from benzene, MeOH or EtOH. Dried under vacuum. Also sublimes under vacuum.

2,4-Dimethoxybenzoic acid *[91-52-1]* **M 182.2, m 109°,**
2,6-Dimethoxybenzoic acid *[1466-76-8]* **M 182.2, m 186-187°.** Crystd from water.

3,4-Dimethoxybenzoic acid *[93-07-2]* **M 182.2, m 181-182°.** Crystd from water or aq acetic acid.

3,5-Dimethoxybenzoic acid *[1132-21-4]* **M 182.2, m 185-186°.** Crystd from water, EtOH or aq acetic acid.

Diketene *[674-82-8]* **M 84.1, m -7°, b 66-68°/90mm, d 1.440, n 1.4376, n^{25} 1.4348.** Diketene polymerizes violently in the presence of alkali. Distd at reduced pressure, then fractionally crystd by partial freezing (using as a cooling bath a 1:1 soln of $Na_2S_2O_3$ in water, cooled with Dry-ice until slushy, and stored in a Dewar flask). Freezing proceeds slowly, and takes about a day for half completion. The crystals are separated and stored in a refrigerator under N_2.

2,2'-Diketospirilloxanthin *[24009-17-4]* **M 624.9, m 225-227°, $\varepsilon^{1\%}_{1cm}$ 550(349nm), 820(422nm), 2125(488nm), 2725(516nm), 2130(551nm) in hexane.** Purified by chromatography on a column of partially deactivated alumina. Crystd from acetone/pet ether. Stored in the dark, in an inert atmosphere at 0°.

Dilauroyl peroxide *[105-74-8]* **M 398.6, m 53-55°.** Crystd from *n*-hexane. *Potentially* **EXPLOSIVE.**

Dilituric acid see **5-*N*-nitrobarbituric acid.**

Dimedone *[126-81-8]* **M 140.2, m 148-149°.** Crystd from acetone (*ca* 8ml/g), water or aqueous EtOH. Dried in air.

1,2-Dimercapto-3-propanol *[59-52-9]* **M 124.2, b 82-84°/0.8mm, d 1.239, n 1.5732,**
1,3-Dimercapto-2-propanol *[584-04-3]* **M 124.2, b 82°/1.5mm.** Ppted as the mercury mercaptide (see Bjöberg *B* **75** 13 *1942*], regenerated with H_2S, and distd at 2.7mm [Rosenblatt and Jean *AC* 951 *1955*].

***meso*-2,3-Dimercaptosuccinic acid** *[304-55-2]* **M 182.2, m 191-192° (dec), 210° (dec), 210-211° (dec).** Purified by dissolving in NaOH and precipitating with dilute HCl, dry and recrystallise from MeOH. It has pKa values of 3.0 and 3.9, and the IR has ν at 2544 (SH) and 1689 (CO_2H) cm^{-1}. The *bis-S-acetyl* deriv has **m** 183-185° (from EtOAc or Me_2CO) and its *Me ester* has **m** 119-120° (from pet ether) [Gerecke et al. *HCA* **44** 957 *1961*; Owen and Sultanbawa *JCS* 3112 *1949*].

4,4'-Dimethoxyazobenzene *[2396-60-3]* **M 242.3, m 162.7-164.7°.** Chromatographed on basic alumina, eluted with benzene. Crystd from 2:2:1 (v/v) methanol/ethanol/benzene.

4,4'-Dimethoxyazoxybenzene *[1562-94-3]* **M 258.3, m 165°.** Crystd from hot 95% EtOH, dried, then sublimed in a vacuum onto a cold finger.

3,4-Dimethoxybenzaldehyde see **veratraldehyde.**

***o*-Dimethoxybenzene (veratrole)** *[91-16-7]* **M 137.2, m 23°, b 208.5-208.7, d 1.085, n^{25} 1.53232.** Steam distd. Fractionally distd from BaO, CaH_2 or Na. Crystd from benzene or low-boiling pet ether at 0°. Fractionally crystd from its melt. Stored over anhydrous Na_2SO_4.

***m*-Dimethoxybenzene** *[151-10-0]* **M 137.2, b 212-213°, d 1.056, n 1.5215.** Extracted with aqueous NaOH, and water, then dried. Fractionally distd from BaO or Na.

***p*-Dimethoxybenzene** *[150-78-7]* **M 137.2, m 57.2-57.8°.** Steam distd. Crystd from benzene, MeOH or EtOH. Dried under vacuum. Also sublimes under vacuum.

2,4-Dimethoxybenzoic acid *[91-52-1]* **M 182.2, m 109°,**
2,6-Dimethoxybenzoic acid *[1466-76-8]* **M 182.2, m 186-187°.** Crystd from water.

3,4-Dimethoxybenzoic acid *[93-07-2]* **M 182.2, m 181-182°.** Crystd from water or aq acetic acid.

3,5-Dimethoxybenzoic acid *[1132-21-4]* **M 182.2, m 185-186°.** Crystd from water, EtOH or aq acetic acid.

p,p'-**Dimethoxybenzophenone** *[90-96-0]* **M 242.3, m 144.5°.** Crystd from absolute EtOH.

2,6-Dimethoxybenzoquinone *[530-55-2]* **M 168.1, m 256°.** Crystd from acetic acid. Sublimes in a vacuum.

1,1-Dimethoxyethane (acetaldehyde dimethyl acetal) *[534-15-6]* **M 90.1, b 212°/760mm, d 0.828, n 1.4140.** Purified by GLC.

1,2-Dimethoxyethane (glyme) *[110-71-4]* **M 90.1, b 84°, d 0.867, n 1.380.** Traces of water and acidic materials have been removed by refluxing with Na, K or CaH_2, decanting and distilling from Na, K, CaH_2 or $LiAlH_4$. Reaction has been speeded up by using vigorous high-speed stirring and molten potassium. For virtually complete elimination of water, 1,2-dimethoxyethane has been dried with Na-K alloy until a characteristic blue colour was formed in the solvent at Dry-ice/cellosolve temperatures: the solvent was kept with the alloy until distd for use [Ward *JACS* **83** 1296 *1961*]. Alternatively, glyme, refluxed with benzophenone and Na-K, was dry enough if, on distn, it gave a blue colour of the ketyl immediately on addition to benzophenone and sodium [Ayscough and Wilson *JCS* 5412 *1963*]. Also purified by distn under N_2 from sodium benzophenone ketyl (see above).

3,5-Dimethoxy-4-hydroxybenzaldehyde see **syringaldehyde.**

3,5-Dimethoxy-4-hydroxycinnamic acid see **3-(4-hydroxy-3,5-dimethoxyphenyl)acrylic acid.**

5,6-Dimethoxy-1-indanone *[2107-69-9]* **M 192.2, m 118-120°.** Crystd from MeOH, then sublimed in a vacuum.

Dimethoxymethane (methylal) *[109-87-5]* **M 76.1, b 42.3°, d 0.860, n^{15} 1.35626, n 1.35298.** The main impurity is MeOH, which can be removed by treatment with sodium wire, followed by fractional distn from sodium. The solvent is kept dry by storing in contact with molecular sieves. Alternatively, technical dimethoxymethane was stood with paraformaldehyde and a few drops of H_2SO_4 for 24h, then distd. It could also be purified by shaking with an equal volume of 20% NaOH, leaving for 30min, and distilling. Methods of purification used for acetal are probably applicable to methylal.

2,3-Dimethoxy-5-methyl-1,4-benzoquinone see **Coenzyme Q_0** entry in Chapter 5.

1,4-Dimethoxynaphthalene *[10075-62-4]* **M 188.2, m 87-88°,**
1,5-Dimethoxynaphthalene *[10075-63-5]* **M 188.2, m 183-184°.** Crystd from EtOH.

2,6-Dimethoxyphenol *[91-10-1]* **M 154.2, m 54-56°.** Purified by zone melting or sublimation in a vacuum.

3,4-Dimethoxyphenyl acetic acid (homoveratric acid) *[93-40-3]* **M 196.2, m 97-99°.** Crystd from water or benzene/ligroin.

3,5-Dimethoxyphenylacetonitrile *[13388-75-5]* **M 177.1.** Crystd from MeOH. [Sankaraman et al. *JACS* **109** 5235 *1987*].

4,4'-Dimethoxythiobenzophenone *[958-80-5]* **M 258.3, m 120°.** Recrystd from a mixture of cyclohexane/dichloromethane (4:1).

2,6-Dimethoxytoluene *[5673-07-4]* **M 152.2, m 39-41°.** Sublimed *in vacuo* [Sankaraman et al. *JACS* **109** 5235 *1987*].

4,4'-Dimethoxytrityl chloride (DMT) *[40615-36-9]* **M 338.8, m 114°.** Crysts from cyclohexane-acetyl chloride as the hydrochloride and dry over KOH pellets in a desiccator. When dissolved in C_6H_6 and air is blown through, HCl is removed. It crystallises from Et_2O. [*A* **370** 142 *1909*; *B* **36** 2774 *1903*; Smith

et al. *JACS* **84** 430 *1962*; Smith et al. *JACS* **85** 3821 *1963*]. If it had hydrolysed considerably (see OH in IR) then repeat the crystallisation from cyclohexane-acetyl chloride — excess of AcCl is removed in vac over KOH.

Dimethyl acetal see **1,1-dimethoxyethane.**

***N,N*-Dimethylacetamide** *[127-19-5]* **M 87.1, b 58.0-58.5°/11.4mm, d 0.940, n 1.437.** Shaken with BaO for several days, refluxed with BaO for 1h, then fractionally distd under reduced pressure, and stored over molecular sieves.

ß,ß-Dimethylacrylic acid (senecioic acid) *[541-47-9]* **M 100.1, m 68°.** Crystd from hot water or pet ether (b 60-80°).

Dimethyl adipate *[627-93-0]* **M 174.2, m 9-11°, b 109°/10mm, 121-123°/20mm, 235°/760mm, d_4^{20} 1.0642, n_D^{20} 1.4292.** Dissolve in Et_2O, wash with $NaHCO_3$, H_2O, dry over $MgSO_4$, filter, evaporate and distil several times until the IR and NMR are consistent with the structure [Lorette and Brown *JOC* **24** 261 *1959*; Hoffmann and Weiss *JACS* **79** 4759 *1957*].

Dimethyl adipimidate dihydrochloride *[14620-72-5]* **M 245.1, m 218-220°, 222-224°.** If the salt smells of HCl then wash with MeOH and dry Et_2O (1:3) under N_2 until the HCl is completely removed. Recryst from MeOH-Et_2O (it is very important that the solvents are super dry) [Hartman and Wold *Biochemistry* **6** 2439 *1967*; McElvain and Shroeder *JACS* **71** 40 *1949*].

Dimethylamine *[124-40-4]* **M 45.1, fp -92.2°, b 0°/563mm, 6.9°/760mm.** Dried by passage through a KOH-filled tower, or using sodium at 0° during 18h.

Dimethylamine hydrochloride *[506-59-2]* **M 81.6, m 171°.** Crystd from hot $CHCl_3$ or abs EtOH. Also recrystd from MeOH/ether soln. Dried in a vacuum desiccator over H_2SO_4, then P_2O_5. *Hygroscopic.*

***p*-Dimethylaminoazobenzene (Methyl Yellow)** *[60-11-7]* **M 225.3, m 118-119°(dec).** Crystd from acetic acid or isooctane, or from 95% EtOH by adding hot water and cooling. Dried over KOH under vacuum at 50°. **CARCINOGEN.**

***p*-Dimethylaminobenzaldehyde (Ehrlich's Reagent)** *[100-10-7]* **M 149.2, m 74-75°.** Crystd from water, hexane, or from EtOH (2ml/g), after charcoal treatment, by adding excess of water. Also dissolved in aqueous acetic acid, filtered, and ppted with ammonia. Finally recrystd from EtOH.

***p*-Dimethylaminobenzoic acid** *[619-84-1]* **M 165.2, m 242.5-243.5°(dec).** Crystd from EtOH/water.

***p*-Dimethylaminobenzophenone** *[530-44-9]* **M 225.3, m 92-93°.** Crystd from EtOH.

***N,N*-Dimethylamino-*p*--chlorobenzene (ß,-chloro-*N,N*-dimethylaniline)** *[698-69-1]* **M 155.6, m 32-33.5°, 35.5°, b 231°/atm.** Purified by vacuum sublimation [Guarr et al. *JACS* **107** 5104 *1985*]. The picrate has m 126-128° (from methanol).

2*S*,3*R*-(+)-4-Dimethylamino-1,2-diphenyl-3-methyl-2-butanol *[38345-66-3]* **M 283.4, m 55-57°, $[\alpha]_{546}^{20}$ +9.3 (c 9.6, EtOH), $[\alpha]_D^{20}$ +7.7 (c 9.6, EtOH).** Purification of the hydrochloride by dissolving 1.5g in 13.5 ml of 5N HCl heating to boiling and evaporate in a vacuum. Recrystn of the 'HCl three times from MeOH-EtOAc gives **m** 189-190°, $[\alpha]_D$ -33.7° (c 1, H_2O) {enantiomer has +34.2°}. The 'HCl in the minimum volume of water is basified with aqueous 5N NaOH and extracted with Et_2O. The extract is dried (K_2CO_3) and evap leaving a residue which is stored in a desiccator over solid KOH as a low melting solid. It can be recovered with these procedures from asymmetric reductions with LAH, and reused. [*JACS* **77** 3400 *1955*; *JOC* **28** 2381 2483 *1963*].

***dl*-4-Dimethylamino-2,2-diphenylvaleramide** *[5985-87-5]* **M 296.4, m 183-184°.** Crystd from aqueous EtOH.

(-)-L-4-Dimethylamino-2,2-diphenylvaleramide *[6078-64-4]* **M 296.4, 136.5-137.5°.** Crystd from pet ether or EtOH.

2-Dimethylaminoethanol *[108-01-0]* **M 89.1, b 134.5-135.5°, d 1.430, n 1.4362.** Dried with anhydrous K_2CO_3 or KOH, and fractionally distd.

6-Dimethylaminopurine *[938-55-6]* **M 163.1, m 257°, 257.5-258.5°, 259-262°, 263-264°.** It is purified by recrystn from H_2O, EtOH (0.32g in 10ml) or $CHCl_3$. It has pKa values of 3.87 and 10.5 (H_2O, 25°) [Albert and Brown *JCS* 2060 *1954*; UV: Mason *JCS* 2071 *1954*]. The *monohydrochloride* crystallises from EtOH-Et_2O, **m** 253° (dec) [Elion et al. *JACS* **74** 411 *1952*], the *dihydrochloride* has **m** 225° (dec) and the *picrate* has **m** 245° (235-236.5°) [Fryth et al. *JACS* **80** 2736 *1958*].

4-Dimethylaminopyridine *[1122-58-3]* **M 122.2, m 108-109°, b 191°.** Recrystd from toluene [Sadownik et al. *JACS* **108** 7789 *1986*].

***N,N*-Dimethylaniline** *[121-69-7]* **M 121.2, f.p.2°, b 84°/15mm, 193°/760mm, d 0.956, n^{25} 1.5556.** Primary and secondary amines (including aniline and monomethylaniline) can be removed by refluxing for some hours with excess acetic anhydride, and then fractionally distilling. Crocker and Jones (*JCS* 1808 *1959*) used four volumes of acetic anhydride, then distd off the greater part of it, and took up the residue in ice-cold dil HCl. Non-basic materials were removed by ether extraction, then the dimethylaniline was liberated with ammonia, extracted with ether, dried, and distd under reduced pressure. Metzler and Tobolsky (*JACS* **76** 5178 *1954*) refluxed with only 10% (w/w) of acetic anhydride, then cooled and poured into excess 20% HCl, which, after cooling, was extracted with ethyl ether. (The amine hydrochloride, remains in the aqueous phase.) The HCl soln was cautiously made alkaline to phenolphthalein, and the amine layer was drawn off, dried over KOH and fractionally distd under reduced pressure, under nitrogen. Suitable drying agents for dimethylaniline include NaOH, BaO, $CaSO_4$, and CaH_2.
Other purification procedures include the formation of the picrate, prepared in benzene soln and crystd to constant melting point, then decomposed with warm 10% NaOH and extracted into ether: the extract was washed with water, and distd under reduced pressure. The oxalate has also been used. The base has been fractionally crystd by partial freezing and also from aq 80% EtOH then from absolute EtOH. It has been distd from zinc dust, under nitrogen.

2,6-Dimethylaniline *[87-62-7]* **M 121.2, f.p. 11°, b 210-211°/736mm, d 0.974, n 1.5604.** Converted to its hydrochloride which, after recrystn, was decomposed with alkali to give the free base. Dried over KOH and fractionally distd.

3,4-Dimethylaniline *[95-64-7]* **M 121.2, m 51°, b 116-118°/25mm, b 226°/760mm.** Crystd from ligroin and distilled under vacuum.

9,10-Dimethylanthracene *[781-43-1]* **M 206.3, m 180-181°.** Crystd from EtOH, and by recrystn from the melt.

1,3-Dimethylbarbituric acid *[769-42-6]* **M 156.1, m 123°.** Crystd from water and sublimed in a vacuum. Also purified by dissolving 10g in 100ml of boiling $CCl_4/CHCl_3$ (8:2) (1g charcoal), filtered and cooled to 25°. Dried *in vacuo* [Kohn et al. *AC* **58** 3184 *1986*].

7,12-Dimethylbenz[*a*]anthracene *[57-97-6]* **M 256.4, m 122-123°.** Purified by chromatography on alumina/toluene or benzene. Crystd from acetone/EtOH.

5,6-Dimethylbenzimidazole *[582-60-5]* **M 146.2, m 205-206°.** Crystd from ethyl ether. Sublimed at 140°/3mm.

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2,3-Dimethylbenzoic acid *[603-79-21]* **M 150.2, m 146°.** Crystd from EtOH and is volatile in steam.

2,4-Dimethylbenzoic acid *[611-01-8]* **M 150.2, m 126-127°, b 267°/727mm.** Crystd from EtOH, and sublimed in a vacuum.

2,5-Dimethylbenzoic acid *[610-72-0]* **M 150.2, m 134°, b 268°/760mm,**
2,6-Dimethylbenzoic acid *[632-46-2]* **M 150.2, m 117°.** Steam distd, and crystd from EtOH.

3,4-Dimethylbenzoic acid *[619-04-5]* **M 150.2, m 166°.** Crystd from EtOH and sublimed *in vacuo*.

3,5-Dimethylbenzoic acid *[419-06-9]* **M 150.2, m 170°.** Distd in steam, crystd from water or EtOH and sublimed in a vacuum.

4,4'-Dimethylbenzophenone *[54323-31-8]* **M 210.3, m 95°, b 333-334°/725mm.** Purified by zone refining.

2,5-Dimethyl-1,4-benzoquinone *[137-18-8]* **M 136.1, m 124-125°.** Crystd from EtOH.

2,6-Dimethyl-1,4-benzoquinone *[527-61-7]* **M 136.1, m 72° (sealed tube).** Crystd from water/EtOH (8:1).

2,3-Dimethylbenzothiophene *[31317-17-6]* **M 212.3, b 123-124°/10mm, n^{19} 1.6171.** Fractionated through a 90cm Monel spiral column.

***N,N*-Dimethylbenzylamine** *[103-83-3]* **M 135.2, b 66-67°/15mm, 181°/760mm, d 0.900, n 1.501.** Refluxed with acetic anhydride for 24h, then fractionally distd. The middle fraction was dried with KOH, distd under reduced pressure, and stored under vacuum. Distn of the amine with zinc dust, at reduced pressure, under nitrogen, has also been used.

4,4'-Dimethyl-2,2'-bipyridine *[1134-35-6]* **M 184.2, m 175-176°.** Crystd from ethyl acetate. [Elliott et al. *JACS* **107** 4647 *1985*].

1,1'-Dimethyl-4,4'-bipyridylium dichloride ($3H_2O$; Methyl Viologen Dichloride, paraquat dichloride) *[1910-42-5]* **M 311.2, m >300°(dec).** Recrystd from MeOH/acetone mixture. Also crystd three times from absolute EtOH [Bancroft et al. *AC* **53** 1390 *1981*]. Dried at 80° in a vacuum.

***N,N*-Dimethylbiuret** *[7710-35-2]* **M 131.1.** Purified by repeated crystn from the melt.

2,3-Dimethyl-1,3-butadiene *[513-81-5]* **M 82.2, m -69-70°, b 68-69°/760mm, d 0.727, n 1.4385.** Distd from $NaBH_4$, and purified by zone melting.

1,3-Dimethylbutadiene sulphone *[10033-92-8]* **M 145.2, m 40.4-41.0°.** Crystd from ethyl ether.

2,2-Dimethylbutane *[75-83-2]* **M 86.2, b 49.7°, d 0.649, n^{25} 1.36595.** Distd azeotropically with MeOH, then washed with water, dried and distd.

2,3-Dimethylbutane *[79-29-8]* **M 86.2, b 58.0°, d 1.375, n^{25} 1.37231.** Distd from sodium, passed through a column of silica gel (activated by heating in nitrogen to 350° before use) to remove unsaturated impurities, and again distd from sodium. Also distilled azeotropically with MeOH, then washed with water, dried and redistd.

2,3-Dimethylbut-2-ene *[563-79-1]* **M 84.2, b 72-73°/760mm, d 0.708, n 1.41153.** Purified by GLC on a column of 20% squalene on chromosorb P at 50° [Flowers and Rabinovitch *JPC* **89** 563 *1985*]. Also washed with 1M NaOH soln followed by H_2O. Dried over Na_2SO_4, distd over powdered KOH under

nitrogen and passed through activated alumina before use. [Woon et al. *JACS* **108** 7990 *1986*; Wong et al. *JACS* **109** 3428 *1987*].

Dimethylcarbamoyl chloride *[79-44-7]* **M 107.5, m -33°, b 34°/0.1mm, d 1.172, n 1.4511.** Must distil under high vacuum to avoid decomposition.

3,3'-Dimethylcarbanilide *[620-50-8]* **M 240.3, m 225°.** Crystd from ethyl acetate.

Dimethyl carbonate *[616-38-5]* **M 90.1, m 4.65°, b 90-91°, d 1.070, n 1.369.** Contains small amounts of water and alcohol which form azeotropes. Stood for several days in contact with Linde type 4A molecular sieves, then fractionally distd. The middle fraction was frozen slowly at 2°, several times, retaining 80% of the solvent at each cycle.

***cis-and trans*-1,4-Dimethylcyclohexane** *[589-90-2]* **M 112.2, b 120°, d 0.788, n 1.427.** Freed from olefines by shaking with conc H_2SO_4, washing with water, drying and fractionally distilling.

5,5-Dimethyl-1,3-cyclohexanedione see **dimedone.**

1,2-Dimethylcyclohexene *[1674-10-8]* **M 110.2, b 135-136°/760mm, d 0.826, n 1.4591.** Passed through a column of basic alumina and distd.

1,5-Dimethyl-1,5-diazaundecamethylene polymethobromide (Hexadimethrene, polybrene) *[28728-55-4]*. Purified by chromatography on Dowex 50 and/or by filtration through alumina before use [Frank *Hoppe-Seyler's Z Physiol Chemie* **360** 997 *1979*].

Dimethyldihydroresorcinol see **dimedone**.

2,9-Dimethyl-4,7-diphenyl-1,10-phenanthroline *[4733-39-5]* **M 360.5, m >280°.** Purified by recrystn from benzene.

Dimethyl disulphide *[624-92-0]* **M 94.2, f.p. -98°, b 40°/12mm, 110°/760mm, d 1.0605, n 1.5260.** Passed through neutral alumina before use.

Dimethyl ether see **methyl ether.**

2,2-Dimethylethyleneimine *[2658-24-4]* **M 71.1, b 70.5-71.0°.** Freshly distd from sodium before use.

***N,N*-Dimethyl formamide (DMF)** *[68-12-2]* **M 73.1, b 76°/39mm, 153°/760mm, d 0.948, n^{25} 1.4269.** Decomposes slightly at its normal boiling point to give small amounts of dimethylamine and carbon monoxide. The decomposition is catalysed by acidic or basic materials, so that even at room temperature DMF is appreciably decomposed if allowed to stand for several hours with solid KOH, NaOH or CaH_2. If these reagents are used as dehydrating agents, therefore, they should not be refluxed with the DMF. Use of $CaSO_4$, $MgSO_4$, silica gel or Linde type 4A molecular sieves is preferable, followed by distn under reduced pressure. This procedure is adequate for most laboratory purposes. Larger amounts of water can be removed by azeotropic distn with benzene (10% v/v, previously dried over CaH_2), at atmospheric pressure: water and benzene distil below 80°. The liquid remaining in the distn flask is further dried by adding $MgSO_4$ (previously ignited overnight at 300-400°) to give 25g/L. After shaking for one day, a further quantity of $MgSO_4$ is added, and the DMF distd at 15-20mm pressure through a 3-ft vacuum-jacketed column packed with steel helices. However, $MgSO_4$ is an inefficient drying agent, leaving about 0.01M water in the final DMF. More efficient drying (to around 0.001-0.007M water) is achieved by standing with powdered BaO, followed by decanting before distn, with alumina powder (50g/L; previously heated overnight to 500-600°), and distilling from more of the alumina; or by refluxing at 120-140° for 24h with triphenylchlorosilane (5-10g/L), then distilling at *ca* 5mm pressure [Thomas and Rochow JACS 79 1843 1957]. Free amine in DMF can be detected by colour reaction with 1-fluoro-2,4-dinitrobenzene. It has also been purified by drying overnight over KOH pellets and then distd

from BaO through a 10 cm Vigreux column {*Experimental Cell Research* **100** 213 *1976*]. [For efficiency of desiccants in drying dimethyl formamide see Burfield and Smithers [*JOC* **43** 3966 *1978*, and for a review on purification, tests of purity and physical properties, see Juillard *PAC* **49** 885 *1977*].
It has been purified by distilling from K_2CO_3 under high vac and fractionated in an all-glass apparatus. The middle fraction is collected, degassed (seven or eight freeze-thaw cycles) and redistd under as high a vacuum as possible [Mohammad and Kosower *JACS* **93** 2713 *1971*].

***d,l*-2,4-Dimethylglutaric acid** *[2121-67-7]* **M 160.2, m 144-145°.** Distd in steam and crystd from ether/pet ether.

3,3-Dimethylglutaric acid *[4839-46-7]* **M 160.2, m 103-104°, b 89-90°/2mm, 126-127°/4.5mm.** Crystd from water, benzene or ether/pet ether. Dried in a vacuum.

3,3-Dimethylglutarimide *[1123-40-6]* **M 141.2, m 144-146°.** Recrystd from EtOH [Arnett and Harrelson *JACS* **109** 809 *1987*].

***N,N*-Dimethylglycinehydrazide hydrochloride** *[539-64-0]* **M 153.6, m 181°.** Crystd by adding EtOH to a conc aqueous soln.

Dimethylglyoxime *[95-45-4]* **M 116.1, m 240°.** Crystd from EtOH (10ml/g) or aqueous EtOH.

2,5-Dimethyl-2,4-hexadiene *[764-13-6]* **M 110.2, f.p. 14.5°, b 132-134°, d 0.773, n 1.4796.** Distd, then repeatedly fractionally crystd by partial freezing. Immediately before use, the material was passed through a column containing Woelm silica gel (activity I) and Woelm alumina (neutral) in separate layers.

2,2-Dimethylhexane *[590-73-8]* **M 114.2, m -121.2°, b 107°, d 0.695,**
2,5-Dimethylhexane *[592-13-2]* **M 114.2, m -91.2°, b 109°, d 0.694.** Dried over type 4A molecular sieves and distd.

2,5-Dimethylhexane-2,5-diol *[110-03-2]* **M 146.2, m 88-90°.** Purified by fractional crystn. Then the diol was dissolved in hot acetone, treated with activated charcoal, and filtered while hot. The soln was cooled and the diol was filtered off and washed well with cold acetone. The crystn process was repeated several times and the crystals were dried under a vac in a freeze-drying apparatus [Goates et al. *JCSFT 1* **78** 3045 *1982*].

5,5-Dimethylhydantoin *[77-71-4]* **M 128.1, m 177-178°.** Crystd from EtOH and sublimed *in vacuo.*

1,1-Dimethylhydrazine *[57-14-7]* **M 60.1, b 60.1°/702mm, d 0.790, n 1.408.** Fractionally distd through a 4-ft column packed with glass helices. Ppted as its oxalate from ethyl ether soln. After crystn from 95% EtOH, the salt was decomposed with aqueous saturated NaOH, and the free base was distd, dried over BaO and redistd [McBride and Kruse *JACS* **79** 572 *1957*]. Distn and storage should be under nitrogen.

4,6-Dimethyl-2-hydroxypyrimidine *[108-79-2]* **M 124.1, m 198-199°.** Crystd from absolute EtOH (charcoal).

1,2-Dimethylimidazole *[1739-84-0]* **M 96.1, b 206°/760mm, d 1.084.** Crystd from benzene and stored at 0-4°. [Gorun et al. *JACS* **109** 4244 *1987*].

1,1-Dimethylindene *[18636-55-0]* **M 144.2.** Purified by gas chromatography.

Dimethyl itaconate *[617-52-7]* **M 158.2, m 38°, b 208°, d 1.124.** Crystd from MeOH by cooling to -78°.

Dimethylmaleic anhydride *[766-39-2]* **M 126.1, m 96°, b 225°/760mm.** Distd from benzene/ligroin and sublimed in a vacuum.

Dimethylmalonic acid *[595-46-0]* **M 132.1, m 192-193°.** Crystd from benzene/pet ether and sublimed in a vacuum with slight decomposition.

1,5-Dimethylnaphthalene *[571-61-9]* **M 156.2, m 81-82°, b 265-266°.** Crystd from 85% aq EtOH.

2,3-Dimethylnaphthalene *[581-40-8]* **M 156.2, m 104-104.5°,**
2,6-Dimethylnaphthalene *[581-42-0]* **M 156.2, m 110-111°, b 122.5-123.5°/10mm, 261-262°/760mm.** Distd in steam and crystd from EtOH.

3,3'-Dimethylnaphthidine (4,4'-diamino-3,3'-dimethyl-1,1'-binaphthyl) *[13138-48-2]* **M 312.4, m 213°.** Recrystd from EtOH or pet ether (b 60-80°).

***N,N*-Dimethyl-*m*-nitroaniline** *[619-31-8]* **M 166.1, m 60°.** Crystd from EtOH.

***N,N*-Dimethyl-*p*-nitroaniline** *[100-23-2]* **M 166.1, m 164.5-165.2°.** Crystd from EtOH or aqueous EtOH. Dried under vacuum.

***N,N*-Dimethyl-*p*-nitrosoaniline** *[138-89-6]* **M 150.2, m 85.8-86.0°.** Crystd from pet ether or $CHCl_3/CCl_4$. Dried in air.

***N,N*-Dimethyl-*p*-nitrosoaniline hydrochloride** *[42344-05-8]* **M 186.7, m 177°.** Crystd from hot water in the presence of a little HCl.

2,6-Dimethyl-2,4,6-octatriene *[7216-56-0]* **M 136.2, b 80-82°/15mm, ε_{278nm} 42,870.** Repeated distn at 15mm through a long column of glass helices, the final distn being from sodium under nitrogen.

Dimethylolurea *[140-95-4]* **M 120.1, m 123°.** Crystd from aqueous 75% EtOH.

Dimethyl oxalate *[553-90-2]* **M 118.1, m 54°, b 163-165°, d 1.148.** Crystd repeatedly from EtOH. Degassed under nitrogen high vacuum and distd.

3,3-Dimethyloxetane *[6921-35-3]* **M 86.1, b 79.2-80.3°/760mm.** Purified by gas chromatography using a 2m silicone oil column.

2,3-Dimethylpentane *[565-59-3]* **M 100.2, b 89.8°, d 0.695, n 1.39197, n^{25} 1.38946.** Purified by azeotropic distn with EtOH, followed by washing out the EtOH with water, drying and distn [Streiff et al. *J Res Nat Bur Stand* **37** 331 *1946*].

2,4-Dimethylpentane *[108-08-7]* **M 100.2, b 80.5°, d 0.763, n 1.3814, n^{25} 1.37882.** Extracted repeatedly with conc H_2SO_4, washed with water, dried and distd. Percolated through silica gel (previously heated in nitrogen to 350°). Purified by azeotropic distn with EtOH, followed by washing out the EtOH with water, drying and distn.

4,4-Dimethyl-1-pentene *[762-62-9]* **M 98.2, b 72.5°/760mm, d 0.6827, n 1.3918.** Purified by passage through alumina before use [Traylor et al. **109** 3625 *1987*].

Dimethyl peroxide *[690-02-8]* **M 62.1, b 13.5°/760mm, d 0.8677, n 1.3503.** Purified by repeated trap-to-trap fractionation until no impurities could be detected by gas IR spectroscopy [Haas and Oberhammer *JACS* **106** 6146 *1984*]. *All necessary precautions should be taken in case of* **EXPLOSION.**

2,9-Dimethyl-1,10-phenanthroline *[484-11-7]* **M 208.3, m 162-164°.** Purified as hemihydrate from water, and as anhydrous from benzene.

***R*-(+)-*N,N'*-Dimethyl-1-phenethylamine** *[19342-01-9]* **M 149.2, b 81°/16mm, $[\alpha]_D^{20}$ +50.2° (c 1, MeOH), $[\alpha]_D^{26}$ +61.8° (neat *l* 1), d 0.908,**
***S*-(-)-*N,N'*-Dimethyl-1-phenethylamine** *[17279-31-1]* **M 149.2, b 81°/16mm, $[\alpha]_D^{20}$ -50.2° (c 1, MeOH), $[\alpha]_D^{26}$ -64.4° (neat *l* 1), d 0.908.** The amine is mixed with aqueous 10N NaOH and extracted with toluene. The extract is washed with saturated aqueous NaCl and dried over K_2CO_3, and transfered to fresh K_2CO_3 until the soln is clear, and filtered. The filtrate is distd. If a short column packed with glass helices is used, the yield is reduced but a purer product is obtained. [*Org Synth* **25** 89 *1945*; *JACS* **71** 291 4165 3929 3931, *1949*]. The (-)-*picrate* has **m** 140-141° (cryst from EtOH). The *racemate [1126-71-2]* has **b** 88-89°/16mm, 92-94°/30mm, 194-195°/atm, d_4^{20} 0.908.

2,3-Dimethylphenol *[526-75-0]* **M 122.2, m 75°, b 120°/20mm, 218°/760mm.** Crystd from aqueous EtOH.

2,5-Dimethylphenol *[95-87-1]* **M 122.2, m 73°, b 211.5°/762mm.** Crystd from EtOH/ether.

2,6-Dimethylphenol *[576-26-1]* **M 122.2, m 49°, b 203°/760mm.** Fractionally distd under nitrogen, crystd from benzene or hexane, and sublimed at 38°/10mm.

3,4-Dimethylphenol *[95-65-8]* **M 122.2, m 65°, b 225°/757mm,**
3,5-Dimethylphenol *[108-68-9]* **M 122.2, m 68°, b 219°.** Heated with an equal weight of conc H_2SO_4 at 103-105° for 2-3h, then diluted with four volumes of water, refluxed for 1h, and either steam distd or extracted repeatedly with ethyl ether after cooling to room temperature. The steam distillate was also extracted and evaporated to dryness. (The purification process depends on the much slower sulphonation of 3,5-dimethylphenol than most of its likely contaminants.) [Kester *IEC* **24** 770 *1932*]. It can also be crystd from water, hexane or pet ether, and vacuum sublimed. [Bernasconi and Paschalis *JACS* **108** *1986*].

***N,N*-Dimethyl-*p*-phenylazoaniline** see ***p*-dimethylaminoazobenzene.**

1,2-Dimethyl-3-phenyl-5-pyrazolone see **antipyrine.**

***N,N*-Dimethyl-2-(α-phenyl-*o*-tolyloxy)ethylamine hydrochloride** see **phenyltoloxamine hydrochloride.**

Dimethyl phthalate *[131-11-3]* **M 194.2, b 282°, n 1.5149, d 1.190, d^{25} 1.1865.** Washed with aqueous Na_2CO_3, then distilled water, dried ($CaCl_2$) and distd under reduced pressure (**b** 151-152°/0.1mm).

2,2-Dimethyl-1,3-propanediol *[126-30-7]* **M 104.2, m 128.4-129.4°, b 208°/760mm.** Crystd from benzene or acetone/water (1:1).

2,2-Dimethyl-1-propanol (neopentyl alcohol) *[75-84-3]* **M 88.2, m 52°, b 113.1°/760mm.** Difficult to distil because it is a solid at ambient temperatures. Purified by fractional crystallisation and sublimation.

***N,N*-Dimethylpropionamide** *[758-96-3]* **M 101.2, b 175-178°, d 0.920, n 1.440.** Shaken over BaO for 1-2 days, then distd at reduced pressure.

2,5-Dimethylpyrazine *[123-32-0]* **M 108.1, b 156°, d 0.990, n 1.502.** Purified *via* its picrate (**m** 150°)[Wiggins and Wise *JCS* 4780 *1956*].

3,5-Dimethylpyrazole *[67-51-6]* **M 96.1, m 107-108°.** Crystd from cyclohexane or water. [Barszez et al. *JCSDT* 2025 *1986*].

Dimethylpyridine see **lutidine.**

2,3-Dimethylquinoxaline *[2379-55-7]* **M 158.2, m 106°.** Crystd from distilled water.

2,4-Dimethylresorcinol *[634-65-1]* **M 138.1, m 149-150°.** Crystd from pet ether (b 60-80°).

***meso*-α,β-Dimethylsuccinic acid** *[608-40-2]* **M 146.1, m 211°.** Crystd from EtOH/ether or EtOH/chloroform.

2,2-Dimethylsuccinic acid *[597-43-3]* **M 146.1, m 141°.** Crystd from EtOH/ether or EtOH/chloroform.

(±)-2,3-Dimethylsuccinic acid *[13545-04-5]* **M 146.1, m 129°.** Crystd from water.

Dimethyl sulphide *[75-18-3]* **M 62.1, f.p. -98.27°, b 0°/172mm, 37.5-38°/760mm, d^{21} 0.8458, n^{25} 1.4319.** Purified *via* the Hg(II) chloride complex by dissolving 1 mole of $Hg(II)Cl_2$ in 1250ml of EtOH and slowly adding the boiling alcoholic soln of dimethyl sulphide to give the right ratio for $2(CH_3)_2S.3HgCl_2$. After recrystn of the complex to constant melting point, 500g of complex is heated with 250ml conc HCl in 750ml of water. The sulphide is separated, washed with water, and dried with $CaCl_2$ and $CaSO_4$. Finally, it is distd under reduced pressure from sodium.

2,4-Dimethylsulpholane *[1003-78-7]* **M 148.2, b 128°/77mm, d^{25} 1.1314.** Vacuum distd.

Dimethyl sulphone *[67-71-0]* **M 94.1, m 109°.** Crystd from water. Dried over P_2O_5.

Dimethyl sulphoxide (DMSO) *[67-68-5]* **M 78.1, m 18.0-18.5°, b 75.6-75.8°/12mm, 190°/760mm, d 1.100, n 1.479.** Colourless, odourless, very *hygroscopic* liquid, synthesised from dimethyl sulphide. The main impurity is water, with a trace of dimethyl sulphone. The Karl-Fischer test is applicable. It is dried with Linde types 4A or 13X molecular sieves, by prolonged contact and passage through a column of the material, then distd under reduced pressure. Other drying agents include CaH_2, CaO, BaO and $CaSO_4$. It can also be fractionally crystd by partial freezing. More extensive purification is achieved by standing overnight with freshly heated and cooled chromatographic grade alumina. It is then refluxed for 4h over CaO, dried over CaH_2, and then fractionally distd at low pressure. For efficiency of desiccants in drying dimethyl sulphoxide see Burfield and Smithers [*JOC* **43** 3966 *1978*; Sato et al. *JCSDT* 1949 *1986*].

Dimethyl terephthalate *[120-61-6]* **M 194.2, m 150°.** Purified by zone melting.

***N,N*-Dimethylthiocarbamoyl chloride** *[16420-13-6]* **M 123.6, m 42-43°, b 64-65°/0.1mm.** Crystd twice from pentane.

***N,N*-Dimethyl-*o*-toluidide** *[609-72-3]* **M 135.2, b 68°/10mm, 211-211.5°/760mm, d 0.937, n 1.53664.** Isomers and other bases have been removed by heating in a water bath for 100h with two equivalents of 20% HCl and two and a half volumes of 40% aq formaldehyde, then making the soln alkaline and separating the free base. After washing well with water it was distd at 10mm pressure and redistd at ambient pressure [von Braun and Aust *B* **47** 260 *1914*]. Other procedures include drying with NaOH, distilling from zinc in an atmosphere of nitrogen under reduced pressure, and refluxing with excess of acetic anhydride in the presence of conc H_2SO_4 as catalyst, followed by fractional distn under vacuum.

***N,N*-Dimethyl-*m*-toluidide** *[121-72-2]* **M 135.2, b 211.5-212.5°, d 0.93,**
***N,N*-Dimethyl-*p*-toluidide** *[99-97-8]* **M 135.2, b 93-94°/11mm, b 211°, d 0.937, n 1.5469.** Methods described for *N,N*-dimethylaniline are applicable. Also dried over BaO, distd and stored over KOH.

1,3-Dimethyluracil *[874-14-6]* **M 140.1, m 121-122°.** Crystd from EtOH/ether.

***sym*-Dimethylurea** *[96-31-1]* **M 88.1, m 106°.** Crystd from acetone/ethyl ether by cooling in an ice bath. Also crystd from EtOH and dried at 50° and 5mm for 24h [Bloemendahl and Somsen *JACS* **107** 3426 *1985*].

Di-β-naphthol *[41024-90-21]* **M 286.3, m 218°.** Crystd from toluene or benzene (10ml/g).

β,β'-Dinaphthylamine *[532-18-3]* **M 269.3,m 170.5°.** Crystd from benzene.

2,4-Dinitroaniline *[97-02-9]* **M 183.1, m 180°, ε_{348} 12,300 in dil aq $HClO_4$.** Crystd from boiling EtOH by adding one-third volume of water and cooling slowly. Dried in a steam oven.

2,6-Dinitroaniline *[606-22-4]* **M 183.1, m 139-140°.** Purified by chromatography on alumina, then crystd from benzene or EtOH.

2,4-Dinitroanisole *[119-27-7]* **M 198.1, m 94-95°.** Crystd from aq EtOH.

3,5-Dinitroanisole *[5327-44-6]* **M 198.1, m 105-106°.** Purified by repeated crystn from water.

1,2-Dinitrobenzene *[528-29-0]* **M 168.1, m 116.5°.** Crystd from EtOH.

1,3-Dinitrobenzene *[99-65-0]* **M 168.1, m 90.5-91°.** Crystd from alkaline EtOH soln (20g in 750ml 95% EtOH at 40°, plus 100ml of 2M NaOH) by cooling and adding 2.5L of water. The ppte, after filtering off, washing with water and sucking dry, was crystd from 120ml, then 80ml of absolute EtOH [Callow, Callow and Emmens *BJ* **32** 1312 *1938*]. Has also been crystd from MeOH, CCl_4 and ethyl acetate. Can be sublimed in a vacuum. [Tanner *JOC* **52** 2142 *1987*].

1,4-Dinitrobenzene *[100-25-4]* **M 168.1, m 173°.** Crystd from EtOH or ethyl acetate. Dried under vacuum over P_2O_5. Can be sublimed in a vacuum.

2,4-Dinitrobenzenesulphenyl chloride *[528-76-7]* **M 234.6, m 96°.** Crystd from CCl_4.

2,4-Dinitrobenzenesulphonyl chloride *[1656-44-6]* **M 266.6, m 102°.** Crystd from benzene or benzene/pet ether.

3,3'-Dinitrobenzidine see **4,4'-diamino-3,3'-dinitrobiphenyl.**

2,4-Dinitrobenzoic acid *[610-30-3]* **M 212.1, m 183°.** Crystd from aqueous 20% EtOH (10ml/g), dried at 100°.

2,5-Dinitrobenzoic acid *[610-28-6]* **M 212.1, m 179.5-180°.** Crystd from distd water. Dried in a vacuum desiccator.

2,6-Dinitrobenzoic acid *[603-12-3]* **M 212.1, m 202-203°.** Crystd from water.

3,4-Dinitrobenzoic acid *[528-45-0]* **M 212.1, m 166°.** Crystd from EtOH by addition of water.

3,5-Dinitrobenzoic acid *[99-34-3]* **M 212.1, m 205°.** Crystd from distilled water or 50% EtOH (4ml/g). Dried in a vacuum desiccator or at 70° over BaO under vacuum for 6h.

4,4'-Dinitrobenzoic anhydride *[902-47-6]* **M 406.2, m 189-190°.** Crystd from acetone.

3,5-Dinitrobenzoyl chloride *[99-34-3]* **M 230.6, m 69.5°.** Crystd from CCl_4 or pet ether (b 40-60°). It reacts readily with water, and should be kept in sealed tubes or under dry pet ether.

2,2'-Dinitrobiphenyl *[2436-96-6]* **M 244.2, m 123-124°,**
2,4'-Dinitrobiphenyl *[606-81-5]* **M 244.2, m 92.7-93.7°.** Crystd from EtOH.

4,4'-Dinitrobiphenyl *[1528-74-1]* **M 244.2, m 240.9-241.8°.** Crystd from benzene, EtOH (charcoal) or acetone. Dried under vacuum over P_2O_5.

2,4-Dinitrochlorobenzene *[97-00-7]* **M 202.6, m 51° (stable form), 43° (unstable form), b 315°/760mm.** Crystd from EtOH (stable form), or from ether (unstable form).

4,6-Dinitro-*o*-cresol *[534-52-1]* **M 198.1, m 85-86°,**
2,4-Dinitrodiphenylamine *[961-68-2]* **M 259.2, m 157°.** Crystd from aqueous EtOH.

4,4'-Dinitrodiphenylurea *[587-90-6]* **M 302.2, m 312°(dec).** Crystd from EtOH. Sublimes in vac.

2,4-Dinitrofluorobenzene (Sanger's reagent) *[70-34-8]* **M 186.1, m 25-27°, b 133°/2mm, 140-141°/5mm. d 1.483.** Crystd from ether or EtOH. Vacuum distd through a Todd Column. If it is to be purified by distn *in vacuo*, the distn unit must be allowed to cool before air is allowed into the apparatus otherwise the residue carbonizes spontaneously and an **EXPLOSION** may occur. The material is a **skin irritant** and may cause serious dermatitis.

3,5-Dinitro-2-hydroxybenzoic acid see **3,5-dinitrosalicylic acid.**

3,4-Dinitro-2-methylbenzoic acid see **3,5-dinitro-*o*-toluic acid.**

1,8-Dinitronaphthalene *[602-38-0]* **M 218.2, m 170-171°.** Crystd from benzene.

2,4-Dinitro-1-naphthol (Martius Yellow) *[605-69-6]* **M 234.2, m 81-82°.** Crystd from benzene or aqueous EtOH.

2,4-Dinitrophenetole *[610-54-8]* **M 240.2, m 85-86°.** Crystd from aqueous EtOH.

2,4-Dinitrophenol *[51-28-5]* **M 184.1, m 114°.** Crystd from benzene, EtOH, EtOH/water or water acidified with dil HCl, then recrystd from CCl_4. Dried in an oven and stored in a vac desiccator over $CaSO_4$.

2,5-Dinitrophenol *[329-71-5]* **M 184.1, m 108°.** Crystd from water containing a little EtOH.

2,6-Dinitrophenol *[573-56-8]* **M 184.1, m 63.0-63.7°.** Crystd from benzene/cyclohexane, aqueous EtOH, water or benzene/pet ether (b 60-80°, 1:1).

3,4-Dinitrophenol *[577-71-9]* **M 184.1, m 138°.** Steam distd and crystd from water and air-dried. **CAUTION - EXPLOSIVE** when dry, store with 10% water.

3,5-Dinitrophenol *[586-11-8]* **M 184.1, m 126°.** Crystd from benzene or $CHCl_3$/pet ether. Should be stored with 10% water because it is **EXPLOSIVE** when dry.

2,4-Dinitrophenylacetic acid *[643-43-6]* **M 226.2, m 179°(dec).** Crystd from water.

2,4-Dinitrophenylhydrazine *[119-26-6]* **M 198.1, m 200°(dec).** Crystd from butan-1-ol, dioxane, EtOH or ethyl acetate.

2,2-Dinitropropane *[595-49-3]* **M 162.1, m 53.5°.** Crystd from EtOH or MeOH. Dried over $CaCl_2$ or under vacuum for 1h just above the melting point.

2,4-Dinitroresorcinol *[519-44-8]* **M 200.1, m 160°.** Crystd from aqueous EtOH.

3,5-Dinitrosalicylic acid *[609-99-4]* **M 228.1, m 173-174°.** Crystd from water.

2,6-Dinitrothymol *[303-21-9]* **M 240.2, m 53-54°.** Crystd from aq EtOH.

2,3-Dinitrotoluene *[602-01-7]* **M 182.1, m 63°.** Distd in steam and crystd from water or benzene/pet ether. Stored with 10% water. *Could be* **EXPLOSIVE** *when dry.*

2,4-Dinitrotoluene *[121-14-2]* **M 182.1, m 70.5-71.0°.** Crystd from acetone, isopropanol or MeOH. Dried under vacuum over H_2SO_4. Purified by zone melting. *Could be* **EXPLOSIVE** *when dry.*

2,5-Dinitrotoluene *[619-15-8]* **M 182.1, m 51.2°.** Crystd from benzene.

2,6-Dinitrotoluene *[606-20-2]* **M 182.1, m 64.3°.** Crystd from acetone.

3,4-Dinitrotoluene *[610-39-9]* **M 182.1, m 61°.** Distil in steam and cryst from benzene/pet ether. Store with 10% of water to avoid **EXPLOSION.**

2,5-Dinitro-*o*-toluic acid *[28169-46-2]* **M 226.2, m 206°.** Crystd from water.

2,4-Dinitro-*m*-xylene *[603-02-1]* **M 196.2, m 83-84°.** Crystd from EtOH.

Dinonyl phthalate (mainly (±)-3,5,5-trimethylhexyl phthalate isomer) *[28553-12-0] [14103-61-8]* **M 418.6, m 26-29°, b 170°/2mm, d 0.9640, n 1.4825.** Washed with aqueous Na_2CO_3, then shaken with water. Ether was added to break the emulsion, and the soln was washed twice with water, and dried ($CaCl_2$). After evaporating the ether, the residual liquid was distd three times under reduced pressure. It was stored in a vacuum desiccator over P_2O_5

Dioctadecyldimethylammonium bromide *[3700-67-2]* **M 570.5.** Crystd from acetone [Lukac *JACS* **106** 4387 *1984*].

Dioctyl phenylphosphonate see entry in Chapter 4.

Diosgenin *[512-04-9]* **M 294.5, m 204-207°, $[\alpha]_D^{25}$ -129° (in Me_2CO).** Crystd from acetone.

1,3-Dioxane *[505-22-6]* **M 88.1, b 104.5°/751mm, d 1.040, n 1.417.** Dried with sodium and fractionally distd.

1,3-Dioxalane *[646-06-0]* **M 74.1, b 75.0-75.2°, d 1.0600, n^{21} 1.3997.** Dried with solid NaOH, KOH or $CaSO_4$, and distd from sodium or sodium amalgam. Barker et al. [*JCS 802 1959*] heated 34ml of dioxalane under reflux with 3g of PbO_2 for 2h, then cooled and filtered. After adding xylene (40ml) and PbO_2 (2g) to the filtrate, the mixture was fractionally distd. Addition of xylene (20ml) and sodium wire to the main fraction (**b** 70-71°) led to vigorous reaction, following which the mixture was again fractionally distd. Xylene and sodium additions were made to the main fraction (**b** 73-74°) before it was finally distd.

1,4-Dioxane *[123-91-1]* **M 88.1, f.p. 11.8°, b 101.3°, d^{25} 1.0292, n^{15} 1.4236, n^{25} 1.42025.** Prepared commercially either by dehydration of ethylene glycol with H_2SO_4 and heating ethylene oxide or bis(ß-chloroethyl)ether with NaOH.
Usual impurities are acetaldehyde, ethylene acetal, acetic acid, water and peroxides. Peroxides can be removed (and the aldehyde content decreased) by percolation through a column of activated alumina (80g per 100-200ml solvent), by refluxing with $NaBH_4$ or anhydrous stannous chloride and distilling, or by acidification with conc HCl, shaking with ferrous sulphate and leaving in contact with it for 24h before filtering and purifying further.
Hess and Frahm [*B* **71** 2627 *1938*] refluxed 2L of dioxane with 27ml conc HCl amd 200ml water for 12h with slow passage of nitrogen to remove acetaldehyde. After cooling the soln KOH pellets were added slowly and with shaking until no more would dissolve and a second layer had separated. The dioxane was decanted, treated with fresh KOH pellets to remove any aq phase, then transferred to a clean flask where it was refluxed for 6-12h with sodium, then distd from it. Alternatively, Kraus and Vingee [*JACS* **56** 511 *1934*] heated on a steam bath with solid KOH until fresh addition of KOH gave no more resin (due to acetaldehyde). After filtering through paper, the dioxane was refluxed over sodium until the surface of the metal was not further discoloured during several hours. It was then distd from sodium.
The acetal (**b** 82.5°) is removed during fractional distn. Traces of benzene, if present, can be removed as the benzene/MeOH azeotrope by distn in the presence of MeOH. Distn from $LiAlH_4$ removes aldehydes, peroxides and water. Dioxane can be dried using Linde type 4X molecular sieves. Other purification procedures include

distn from excess C_2H_5MgBr, refluxing with PbO_2 to remove peroxides, fractional crystn by partial freezing and the addition of KI to dioxane acidified with aq HCl. Dioxane should be stored out of contact with air, preferably under N_2.
A detailed purification procedure is as follows: Dioxane was stood over ferrous sulphate for at least 2 days, under nitrogen. Then water (100ml) and conc HCl (14ml) / litre of dioxane were added (giving a pale yellow colour). After refluxing for 8-12h with vigorous N_2 bubbling, pellets of KOH were added to the warm soln to form two layers and to discharge the colour. The soln was cooled rapidly with more KOH pellets being added (magnetic stirring) until no more dissolved in the cooled soln. After 4-12h, if the lower phase was not black, the upper phase was decanted rapidly into a clean flask containing sodium, and refluxed over sodium (until freshly added sodium remained bright) for 1h. The middle fraction was collected (and checked for minimum absorbency below 250nm). The distillate was fractionally frozen three times by cooling in a refrigerator, with occasional shaking or stirring. This material was stored in a refrigerator. For use it was thawed, refluxed over sodium for 48h, and distilled into a container for use. All joints were clad with Teflon tape.
Coetzee and Chang [*PAC* **57** 633 *1985*] dried the solvent by passing it slowly through a column (20g/L) of 3A molecular sieve activated by heating at 250° for 24h. Impurities (including peroxides) were removed by passing the effluent slowly through a column packed with type NaX zeolite (pellets ground to 0.1mm size) activated by heating at 400° for 24h or chromatographic grade basic Al_2O_3 activated by heating at 250° for 24h. After removal of peroxides the effluent was refluxed several hours over sodium wire, excluding moisture, distilled under nitrogen or argon and stored in the dark.
One of the best tests of purity of dioxane is the formation of the purple disodium benzophenone complex during reflux and its persistence on cooling. (Benzophenone is better than fluorenone for this purpose, and for the storing of the solvent.) [Carter, McClelland and Warhurst *TFS* **56** 343 *1960*].

S-1,2-Dipalmitin,
***d,l*-βγ-Dipalmitoylphosphatidyl choline** see entries in Chapter 5.

2,5-Di-*tert*-pentylhydroquinone see **2,5-di-*tert*-amylhydroquinone**.

4,4'-Di-*n*-pentyloxyazoxybenzene *[64242-26-8]* **M 370.5.** Crystd from acetone, and dried by heating under vacuum.

Diphenic acid *[482-05-3]* **M 242.2, m 228-229°.** Crystd from water.

Diphenic anhydride *[6050-13-1]* **M 466.3, m 217°.** After removing free acid by extraction with cold aq Na_2CO_3, the residue has been crystd from acetic anhydride and dried at 100°. Acetic anhydride also converts the acid to the anhydride.

***N,N*-Diphenylacetamidine** *[621-09-0]* **M 210.3, m 131°.** Crystd from EtOH, then sublimed under vacuum at *ca* 96° onto a "finger" cooled in solid CO_2/MeOH, with continuous pumping to free it from occluded solvent.

Diphenylacetic acid *[117-34-0]* **M 212.3, m 147.4-148.4°.** Crystd from benzene or aq 50% EtOH.

Diphenylacetonitrile *[86-29-3]* **M 193.3, m 73-75°.** Crystd from EtOH or pet ether (b 90-100°).

Diphenylacetylene (tolan) *[501-65-5]* **M 178.2, m 62.5°, b 90-97°/0.3mm.** Crystd from EtOH.

Diphenylamine *[122-39-4]* **M 169.2, m 62.0-62.5°.** Crystd from pet ether, MeOH, or EtOH/water. Dried under vacuum.

Diphenylamine-2-carboxylic acid *[91-40-7]* **M 213.2, m 184°,**
Diphenylamine-2,2'-dicarboxylic acid *[579-92-0]* **M 257.2, m 298°(dec).** Crystd from EtOH.

9,10-Diphenylanthracene *[1499-10-1]* **M 330.4, m 248-249°.** Crystd from acetic acid or xylene [Baumstark et al. *JOC* **52** 3308 *1987*].

***N*-Diphenylanthranilic acid** see **diphenylamine-2-carboxylic acid.**

***N,N'*-Diphenylbenzidine** *[531-91-9]* **M 336.4, m 245-247°.** Crystd from toluene or ethyl acetate. Stored in the dark.

***trans-trans*-1,4-Diphenylbuta-1,3-diene** *[886-65-7]* **M 206.3, m 153-153.5°.** Its soln in pet ether (b 60-70°) was chromatographed on an alumina-Celite column (4:1) and the column was washed with the same solvent. The main zone was cut out, eluted with ethanol and transferred to pet ether, which was then dried and evaporated [Pinckard, Wille and Zechmesiter *JACS* **70** 1938 *1948*]. Recrystd from hexane.

***sym*-Diphenylcarbazide** *[140-22-7]* **M 242.3, m 172°.** A common impurity is phenylsemicarbazide which can be removed by chromatography [Willems et al. *Anal Chim Acta* **51** 544 *1970*]. Crystd from EtOH or glacial acetic acid.

1,5-Diphenylcarbazone *[538-62-5]* **M 240.3, m 124-127°.** Crystd from EtOH (*ca* 5ml/g), and dried at 50°. A commercial sample, nominally *sym*-diphenylcarbazone but of m 154-156°, was a mixture of diphenylcarbazide and diphenylcarbazone. The former was removed by dissolving 5g of the crude material in 75ml of warm EtOH, then adding 25g Na_2CO_3 dissolved in 400ml of distd water. The alkaline soln was cooled and extracted six times with 50ml portions of ethyl ether (discarded). Diphenylcarbazone was then ppted by acidifying the alkaline soln with 3M HNO_3 or glacial acetic acid. It was filtered on a Büchner funnel, air dried, and stored in the dark [Gerlach and Frazier *AC* **30** 1142 *1958*]. Other impurities were phenylsemicarbazide and diphenylcarbodiazone. Impurities can be detected by chromatography [Willems et al. *Anal Chim Acta* **51** 544 *1970*].

Diphenylcarbinol see **benzhydrol.**

Diphenyl carbonate *[102-09-0]* **M 214.2, m 80°.** Purified by sublimation, and by preparative gas chromatography with 20% Apiezon on Embacel, and crystn from EtOH.

Diphenyl diselenide *[1666-13-3]* **M 312.1, m 62-64°.** Recrystd twice from hexane [Kice and Purkiss *JOC* **52** 3448 *1987*].

Diphenyl disulphide *[882-33-7]* **M 218.3, m 60.5°.** Crystd from MeOH. [Alberti et al. *JACS* **108** 3024 *1986*]. Crystd repeatedly from hot ethyl ether, then vac dried at 30° over P_2O_5, fused under nitrogen and re-dried, the whole procedure being repeated, with a final drying under vac for 24h. Also recrystd from hexane/EtOH soln. [Burkey and Griller *JACS* **107** 246 *1985*].

***sym*-Diphenylethane** see **bibenzyl.**

1,1-Diphenylethanol *[599-67-7]* **M 198.3, m 80-81°.** Crystd from *n*-heptane. [Bromberg et al. *JACS* **107** 83 *1985*].

Diphenyl ether see **Phenyl ether.**

1,1-Diphenylethylene *[530-48-3]* **M 180.3, b 268-270°, d 1.024, n 1.6088.** Distd under reduced pressure from KOH. Dried with CaH_2 and redistd.

***N,N'*-Diphenylethylenediamine (Wanzlick's reagent)** *[150-61-8]* **M 212.3, m 67.5°.** Crystd from aqueous EtOH.

***N,N'*-Diphenylformamide** *[622-15-1]* **M 197.2, m 142° (137°).** Crystd from absolute EtOH, gives the hydrate with aqueous EtOH.

Diphenylglycollic acid see **benzilic acid.**

1,3-Diphenylguanidine *[102-06-7]* **M 211.3, m 148°.** Crystd from toluene, aqueous acetone or EtOH, and vacuum dried.

1,6-Diphenyl-1,3,5-hexatriene *[1720-32-7]* **M 232.3, m 200-203°.** Crystd from $CHCl_3$ or EtOH/$CHCl_3$ (1:1).

5,5-Diphenylhydantoin *[57-41-0]* **M 252.3, m 293-295°.** Crystd from EtOH.

1,1-Diphenylhydrazine *[530-50-7]* **M 184.2, m 126°.** Crystd from hot EtOH containing a little ammonium sulphide or H_2SO_3 (to prevent atmospheric oxidation), preferably under nitrogen. Dried in a vacuum desiccator.

Diphenyl hydrogen phosphate see entry in Chapter 4.

1,3-Diphenylisobenzofuran *[5471-63-6]* **M 270.3, m 129-130°.** Recrystd from EtOH or EtOH/$CHCl_3$ (1:1) under red light or from benzene in the dark.

Diphenylmethane *[101-81-5]* **M 168.2, m 25.4°.** Sublimed under vacuum, or distd at 72-75°/4mm. Crystd from EtOH. Purified by fractional crystn of the melt.

Diphenylmethanol see **benzhydrol.**

1,1-Diphenylmethylamine *[530-50-7]* **M 183.2, m 34°.** Crystd from water.

Diphenylmethyl chloride *[90-99-3]* **M 202.7, m 17.0°, b 167°/17mm, n 1.5960.** Dried with Na_2SO_4 and fractionally distd under reduced pressure.

Diphenylnitrosamine see ***N*-nitrosodiphenylamine.**

1,9-Diphenyl-1,3,6,8-nonatetraen-5-one see **dicinnamalacetone.**

***all-trans*-1,8-Diphenyl-1,3,5,8-octatetraene** *[3029-40-1]* **M 258.4, m 235-237°.** Crystd from EtOH.

2,5-Diphenyl-1,3,4-oxadiazole (PPD) *[725-12-2]* **M 222.3, m 70° (hydrate), 139-140° (anhydrous), b 231°/13mm, 248°/16mm.** Crystd from EtOH and sublimed *in vacuo*.

2,5-Diphenyloxazole (PPO) *[92-71-7]* **M 221.3, m 74°, b 360°/760mm.** Distd in steam and crystd from ligroin.

4,7-Diphenyl-1,10-phenantroline see **bathophenanthroline.**

***N,N'*-Diphenyl-*p*-phenylenediamine** *[39529-22-1]* **M 260.3, m 148-149°.** Crystd from chlorobenzene/pet ether or benzene. Has also been crystd from aniline, then extracted three times with absolute EtOH.

Diphenylphosphinic acid see entry in Chapter 4.

1,1-Diphenyl-2-picrylhydrazyl *[1707-75-1]* **M 394.3, m 178-179.5°.** Crystd from $CHCl_3$, or benzene/pet ether (1:1), then degassed at 100° and $<10^{-5}$mm Hg for *ca* 50h to decompose the 1:1 molar complex formed with benzene.

1,3-Diphenyl-1,3-propanedione see **dibenzoylmethane.**

1,3-Diphenyl-2-propanone see **dibenzyl ketone.**

2,2-Diphenylpropionic acid *[5558-66-7]* **M 226.3, m 173-174°,**
3,3-Diphenylpropionic acid *[606-83-7]* **M 226.3, m 155°.** Crystd from EtOH.

Diphenyl sulphide *[139-66-2]* **M 186.3, b 145°/8mm, d 1.114, n 1.633.** Washed with aqueous 5% NaOH, then water. Dried with $CaCl_2$, then with sodium. The sodium was filtered off and the diphenyl sulphide was distd under reduced pressure.

Diphenyl sulphone *[127-63-9]* **M 218.3, m 125°, b 378°(dec).** Crystd from ethyl ether. Purified by zone melting.

Diphenylthiocarbazone see **Dithizone.**

***sym*-Diphenylthiourea (thiocarbanilide)** *[102-08-9]* **M 228.3, m 154°.** Crystd from boiling EtOH by adding hot water and allowing to cool.

1,3-Diphenyltriazene see **diazoaminobenzene.**

1,1-Diphenylurea *[603-54-3]* **M 212.3, m 238-239°.** Crystd from MeOH.

***sym*-Diphenylurea** see **carbanilide.**

Diphosphopyridine nucleotide (NAD, DPN) see **β-nicotinamide adenine dinucleotide (diphosphopyridine nucleotide** entry in Chapter 5.

Dipicolinic acid (pyridine-2,6-dicarboxylic acid) *[499-83-2]* **M 167.1, m 255°(dec),** λ_{max} **270nm.** Crystd from water, and sublimed in a vacuum.

***N,N*-Di-*n*-propylaniline** *[2217-07-4]* **M 177.3, b 127°/10mm, 238-241°/760mm.** Refluxed for 3hr with acetic anhydride, then fractionally distd under reduced pressure.

Dipropylene glycol *[110-98-5]* **M 134.2, b 109-110°/8mm,d 1.022, n 1.441.** Fractionally distd below 15mm pressure, using packed column and taking precautions to avoid absorption of water.

Di-*n*-propyl ether see ***n*-propyl ether**

Di-*n*-propyl ketone *[123-19-3]* **M 114.2, b 143.5°, d 0.8143, n 1.40732.** Dried with $CaSO_4$, then distd from P_2O_5 under nitrogen.

Di-*n*-propyl sulphide *[111-47-7]* **M 118.2, b 141-142°, d 0.870, n 1.449.** Washed with aqueous 5% NaOH, then water. Dried with $CaCl_2$ and distd from sodium [Dunstan and Griffiths *JCS* 1344 *1962*].

Di-(4-pyridoyl)hydrazine *[4329-75-3]* **M 246.2, m 254-255°.** Crystd from water.

α,α'-Dipyridyl see **α,α'-bipyridyl.**

2,2'-Dipyridylamine *[1202-34-2]* **M 171.2, m 84° and remelts at 95° after solidifying, b 176-178°/13mm, 307-308°/760mm.** Crystd from benzene or toluene [Blakley and De Armond *JACS* **109** 4895 *1987*].

1,2-Di-(4-pyridyl)-ethane *[4916-57-8]* **M 184.2.** Crystd from cyclohexane/benzene (5:1).

***trans*-1,2-Di-(4-pyridyl)-ethylene** *[1135-32-6]* **M 182.2, m 153-154°.** Crystd from water (1.6g/100ml at 100°).

1,3-Di-(4-pyridyl)-propane *[17252-51-6]* **M 198.3, m 60.5-61.5°.** Crystd from *n*-hexane/benzene (5:1).

α,α'-Diquinolyl see **α,α'-biquinolyl.**

***S*-1,2-Distearin** *[1188-58-5]* **M 625.0, m 76-77°, $[\alpha]_D^{20}$ -2.8° (c 6.3, $CHCl_3$), $[\alpha]_{546}^{20}$ +1.4° (c 10, $CHCl_3$/MeOH, 9:1).** Crystd from chloroform/pet ether.

2,5-Distyrylpyrazine *[14990-02-4]* **M 284.3, m 219°.** Recrystd from xylene; chromatographed on basic silica gel (60-80 mesh) using methylene chloride as eluent, then vac sublimed on to a cold surface at 10^{-3} torr [Ebied *JCSFT 1* **78** 3213 *1982*]. Operations should be carried out in the dark.

1,3-Dithiane *[505-23-7]* **M 120.2, m 54°.** Crystd from 1.5 times its weight of MeOH at 0°, and sublimed at 40-50°/0.1mm.

2,2'-Dithiobis(benzothiazole) *[120-78-8]* **M 332.2, m 180°.** Crystd from benzene.

4,4'-Dithiodimorpholine *[103-34-3]* **M 236.2, m 124-125°.** Crystd from hot aq dimethylformamide.

1,4-Dithioerythritol (DTE, *erythro*-2,3-dihydroxy-1,4-dithiobutane) *[6892-68-8]* **M 154.3, m 82-84°.** Crystd from ether/hexane and stored in the dark at 0°.

Dithiooxamide (rubeanic acid) *[79-40-3]* **M 120.2, m >300°.** Crystd from EtOH and sublimed in a vacuum.

***RS*-1,4-Dithiothreitol (Cleland's reagent)** *[27565-41-9]* **M 154.3, m 42-43°.** Crystd from ether and sublimed at 37°/0.005mm. Should be stored at 0°.

Dithizone *[60-10-6]* **M 256.3, ratio of $\varepsilon_{620nm}/\varepsilon_{450nm}$ should be ≥1.65, ε_{620} 3.4 x 10^4 ($CHCl_3$).** The crude material is dissolved in CCl_4 to give a concentrated soln. This is filtered through a sintered glass funnel and shaken with 0.8M aq ammonia to extract dithizonate ion. The aqueous layer is washed with several portions of CCl_4 to remove undesirable materials. The aqueous layer is acidified with dil H_2SO_4 to precipitate pure dithizone. It is dried in a vacuum. When only small amounts of dithizone are required, purification by paper chromatography is convenient. [Cooper and Hibbits *JACS* **75** 5084 *1933*]. Instead of CCl_4, $CHCl_3$ can be used, and the final extract, after washing with water, can be evapd in air at 40-50° and dried in a desiccator.

Di-*p*-tolyl carbonate *[621-02-3]* **M 242.3, m 115°.** Purified by GLC with 20% Apiezon on Embacel followed by sublimation *in vacuo*.

***N,N'*-Di-*o*-tolylguanidine** *[97-39-2]* **M 239.3, m 179° (175-176°).** Crystd from aqueous EtOH.

Di-*p*-tolylphenylamine *[20440-95-3]* **M 273.4, m 108.5°.** Crystd from EtOH.

Di-*p*-tolyl sulphone *[599-66-6]* **M 278.3, m 158-159°, b 405°.** Crystd repeatedly from ethyl ether. Purified by zone melting.

Di-*m*-tolylurea see **3,3-dimethylcarbanilide.**

Djenkolic acid *[498-59-9]* **M 254.1, m 300-350°(dec).** Crystd from a large volume of water.

***cis*-4,7,10,13,16,19-Docosahexaenoic acid** *[6217-54-5]* **M 328.5, m -44/1°, -44.1°, n_D^{20} 1.5017.** Its solubility in $CHCl_3$ is 5%. It has been purified from fish oil by GLC using Ar as mobile phase and EGA as stationary phase with an ionisation detector [UV: Stoffel and Ahrens *J Lipid Research* **1** 139 *1959*], and *via* the ester by evaporative "molecular" distillation using a 'continuous molecular still' at 10^{-4} mm with the highest temperature being 110°, and a total contact time with the hot surface being 60sec [Farmer and van

den Heuvel *JCS* 427 *1938*]. The *methyl ester* has **b** 208-211°/2mm, d_4^{20} 0.9398, n_D^{20} 1.5035. With Br_2 it forms a *dodecabromide* **m** *ca* 240° dec. Also the acid was converted to the methyl ester and purified through a three stage molecular still [as described by Sutton *Chemistry and Industry (London)* 11383 *1953*] at 96° with the rate adjusted so that one third of the material was removed each cycle of three distillations. The distillate (numbered 4) (13g) was dissolved in EtOH (100ml containing 8g of KOH) at -70° and set aside for 4h at 30° with occasional shaking under a vac. Water (100ml) is added and the soln is extracted with pentane, washed with HCl, dried ($MgSO_4$), filtered and evapd to give a clear oil (11.5g) **m** -44.5° to -44.1°. In the catalytic hydrogenation of the oil six mols of H_2 were absorbed and *docosanoic acid (behenic acid)* was produced with **m** 79.0-79.3° undepressed with an authentic sample (see docosanoic acid below) [Whitcutt *BJ* **67** 60 *1957*].

Docosane *[629-97-0]* **M 310.6, m 47°, b 224°/15mm.** Crystd from EtOH or ether.

Docosanoic acid (behenic acid) *[112-85-6]* **M 340.6, m 81-82°.** Crystd from ligroin. [Francis and Piper *JACS* **61** 577 *1939*].

1-Docosanol *[661-19-8]* **M 182.3, m 70.8°.** Crystd from ether or chloroform/ether.

***n*-Dodecane** *[112-40-3]* **M 170.3, b 97.5-99.5°/5mm, 216°/760mm, d 0.748, n 1.42156.** Passed through a column of Linde type 13X molecular sieves. Stored in contact with, and distd from, sodium. Passed through a column of activated silica gel. Has been crystd from ethyl ether at -60°. Unsaturated dry material which remained after passage through silica gel has been removed by catalytic hydrogenation (Pt_2O) at 45lb/in^2, followed by fractional distn under reduced pressure [Zook and Goldey *JACS* **75** 3975 *1953*]. Also purified by partial crystn from the melt.

Dodecane-1,10-dioic acid *[693-23-2]* **M 230.3, m 129°, b 245°/10mm.** Crystd from water, 75% or 95% EtOH, or glacial acetic acid.

Dodecanoic see **lauric acid.**

1-Dodecanol *[112-53-8]* **M 186.3, m 24°, b 91°/1mm, 135°/10mm, 167°/40mm, 213°/200mm, 259°/atm, d^{24} 0.8309 (liquid).** Crystd from aqueous EtOH, and vacuum distd in a spinning-band column. [Ford and Marvel *Org Synth* **10** 62 *1930*].

1-Dodecanthiol *[112-55-0]* **M 202.4, b 111-112°/3mm, 153-155°/24mm, d 0.844, n 1.458.** Dried with CaO for several days, then distd from CaO.

Dodecyl alcohol see **1-dodecanol.**

Dodecylammonium butyrate *[17615-97-3]* **M 273.4, m 39-40°.** Recrystd from *n*-hexane.

Dodecylammonium propionate *[17448-65-6]* **M 259.4, m 55-56°.** Recrystd from hexanol/pet ether (b 60-80°).

Dodecyldimethylamine oxide *[1643-20-5]* **M 229.4.** Crystd from acetone or ethyl acetate. [Bunton et al. *JOC* **52** 3832 *1987*].

Dodecyl ether *[4542-57-8]* **M 354.6, m 33°.** Vacuum distd, then crystd from MeOH/benzene.

1-Dodecylpyridinium chloride *[104-71-5]* **M 301.9, m 68-70°.** Purified by repeated crystn from acetone (charcoal); twice recrystd from EtOH [Chu and Thomas *JACS* **108** 6270 *1986*].

Dodecyltrimethylammonium bromide *[1119-94-4]* **M 308.4.** Purified by repeated crystn from acetone. Washed with ethyl ether and dried in a vacuum oven at 60° [Dearden and Wooley *JPC* **91** 2404 *1987*].

Dodecyltrimethylammonium chloride *[112-00-5]* **M 263.9.** Dissolved in MeOH, treated with active charcoal, filtered and dried *in vacuo* [Waldenburg *JPC* **88** 1655 *1984*], or recrystd several times from 10% EtOH in acetone. Also repeatedly crystd from EtOH/ether or MeOH.

Dulcin see ***p*-phenethylurea.**

Dulcitol *[608-66-2]* **M 182.2, m 188-189°, b 276-280°/1.1mm.** Crystd from water by addition of EtOH.

Durene (1,2,4,5-tetramethylbenzene) *[95-93-2]* **M 134.2, m 79.5-80.5°.** Chromatographed on alumina, and recrystd from aqueous EtOH or benzene. Zone-refining removes duroaldehydes. Dried under vacuum. [Yamauchi et al. *JPC* **89** 4804 *1985*]. It has also been sublimed *in vacuo* [Johnston et al. *JACS* **109** 1291 *1987*].

Duroquinone (tetramethylbenzoquinone) *[527-17-3]* **M 164.2, m 110-111°.** Crystd from 95% EtOH. Dried under vacuum.

α-Ecdyson *[3604-87-3]* **M 464.7, m 239-242°, 242°, $[\alpha]_D^{20}$ +72° (c 1, EtOH).** Recrystd from tetrahydrofuran-pet ether, and from H_2O as a hydrate. It has been purified by chromatogaphy on Al_2O_3 and elution with EtOAc-MeOH. It has λmax at 242nm (ε 12.400). Its *acetate* has **m** 214-216° from EtOAc-pet ether, and the *2,4-dinitrophenylhydrazone* has **m** 170-175° (dec) from EtOAc. [Karlson and Hoffmeister *A* **662** 1 *1963*; Karlson *PAC* **14** 75 *1967*].

β-Ecdyson (β-echdysterone) *[5289-74-7]* **M 480.7, m 245-247°, $[\alpha]_D^{20}$ +66° (c 1, MeOH).** Crystd from water or tetrahydrofuran/pet ether.

Echinenone *[432-68-8]* **M 550.8, m 178-179°, $\varepsilon_{1cm}^{\%}$ 2160 (458nm) in pet ether.** Purified by chromatography on partially deactivated alumina or magnesia, or by using a thin layer of silica gel G with 4:1 cyclohexane/ethyl ether as the developing solvent. Stored in the dark at -20°.

Eicosane *[112-95-8]* **M 282.6, m 36-37°, b 205°/15mm, $d^{36.7}$ 0.7779, n^{40} 1.43453.** Crystd from EtOH.

Elaidic acid *[112-79-8]* **M 282.5, m 44.5°.** Crystd from acetic acid, then EtOH.

Ellagic acid ($2H_2O$) *[476-66-4]* **M 302.2, m >360°.** Crystd from pyridine.

Elymoclavine *[548-43-6]* **M 254.3.** Crystd from MeOH.

Embonic acid (Pamoic acid, 4,4'-methylene bis[3-hydroxy-2-naphthalenecarboxylic acid]) *[130-85-8]* **M 388.4, m >300°.** Forms crystals from dilute pyridine which decomposition above 280° without melting. It is almost insoluble in H_2O, EtOH, Et_2O, C_6H_6, CH_3CO_2H, sparingly soluble in $CHCl_3$ but soluble in nitrobenzene, pyridine and alkalis [Barber and Gaimster *J Appl Chem* **2** 565 *1952*].

Emetidine hydrochloride hydrate *[316-42-7]* **M 553.6 + aq, m 235-240°, 235-250°, 240-250°, 248-250° (depending on H_2O content), $[\alpha]_D^{20}$ -49.2° (free base, c 4, $CHCl_3$).** It crystallises from MeOH-Et_2O, MeOH or Et_2O-EtOAc. The *free base* has **m** 104-105°, and the *(-)-phenyl thiourea derivative* has **m** 220-221° [from EtOAc-pet ether, $[\alpha]_D^{25}$ - 29.3° ($CHCl_3$)]. IR: 3413 (OH) and 2611 (NH^+) cm^{-1}; UV λmax 230nm (ε 16 200) and 282nm (ε 6 890) [Brossi et al. *HCA* **42** 1515 *1959*; Barash et al. *JCS* 3530 *1959*].

Emodine (1,3,8-trihydroxy-6-methyl-9,10-anthracenedione, archin) *[518-82-1]* **M 270.2,**

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Dodecyltrimethylammonium chloride *[112-00-5]* **M 263.9.** Dissolved in MeOH, treated with active charcoal, filtered and dried *in vacuo* [Waldenburg *JPC* **88** 1655 *1984*], or recrystd several times from 10% EtOH in acetone. Also repeatedly crystd from EtOH/ether or MeOH.

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Echinenone *[432-68-8]* **M 550.8, m 178-179°, $\varepsilon^{\%}_{1cm}$ 2160 (458nm) in pet ether.** Purified by chromatography on partially deactivated alumina or magnesia, or by using a thin layer of silica gel G with 4:1 cyclohexane/ethyl ether as the developing solvent. Stored in the dark at -20°.

Eicosane *[112-95-8]* **M 282.6, m 36-37°, b 205°/15mm, $d^{36.7}$ 0.7779, n^{40} 1.43453.** Crystd from EtOH.

Elaidic acid *[112-79-8]* **M 282.5, m 44.5°.** Crystd from acetic acid, then EtOH.

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Emetidine hydrochloride hydrate *[316-42-7]* **M 553.6 + aq, m 235-240°, 235-250°, 240-250°, 248-250° (depending on H_2O content), $[\alpha]_D^{20}$ -49.2° (free base, c 4, $CHCl_3$).** It crystallises from MeOH-Et_2O, MeOH or Et_2O-EtOAc. The *free base* has **m** 104-105°, and the *(-)-phenyl thiourea derivative* has **m** 220-221° [from EtOAc-pet ether, $[\alpha]_D^{25}$ - 29.3° ($CHCl_3$)]. IR: 3413 (OH) and 2611 (NH^+) cm^{-1}; UV λmax 230nm (ε 16 200) and 282nm (ε 6 890) [Brossi et al. *HCA* **42** 1515 *1959*; Barash et al. *JCS* 3530 *1959*].

Emodine (1,3,8-trihydroxy-6-methyl-9,10-anthracenedione, archin) *[518-82-1]* **M 270.2,**

m 253-257°, 255-256°, 256-257°, 262°, 264°. Forms orange needles from EtOH, Et_2O, C_6H_6, toluene or pyridine. It sublimes above 200° at 12mm. [Tutin and Clewer *JCS* **99** 946 *1911*; IR: Bloom et al. *JCS* 178 *1959*; UV: Birkinshaw *BJ* **59** 495 *1955*; Raistrick *BJ* **34** 159 *1940*].

Enniatin A *[11113-62-5]* **M 681.9, m 122-122.5°.** Crystd from EtOH/water.

Eosin *[548-24-3]* **M 624.1, λ_{max} 514nm.** Freed from inorganic halides by repeated crystallisation from butan-1-ol.

1*R*,2*S*-(-)Ephedrine *[299-42-3]* **M 165.2, m 40°, b 225°, $[\alpha]_{546}^{20}$ -47° and $[\alpha]_{D}^{20}$ -40° (c 5, 2.2M HCl).** Crystd from aqueous 70% EtOH. Dehydrated by vacuum distn, the distillate being allowed to crystallise in a vacuum to prevent the uptake of CO_2 and water vapour. The anhydrous base was then recrystd from dry ether [Fleming and Saunders *JCS* 4150 *1955*].

(-)Ephedrine hydrochloride *[50-36-3]* **M 201.7, m 218°, $[\alpha]_{546}^{20}$ -48° (c 5, 2M HCl).** Crystd from water.

Epichlorohydrin *[106-89-8]* **M 92.5, b 115.5°, n 1.438, d 1.180.** Distd at atmospheric pressure, heated on a steam bath with one-quarter its weight of CaO, then decanted and fractionally distd.

***R*(-)Epinephrine (adrenalin)** *[51-43-4]* **M 183.2, m 215°(dec), $[\alpha]_{546}^{20}$ -61° (c 5, 0.5M HCl).** Dissolved in dilute aqueous acid, then ppted by addn of dilute aqueous ammonia or alkali carbonates. (Epinephrine readily oxidises in neutral alkaline soln. This can be diminished if a little sulphite is added).

1,2-Epoxybutane *[106-88-7]* **M 72.1, b 66.4-66.6°, d 0.837, n 1.3841.** Dried with $CaSO_4$, and fractionally distd through a long (126cm) glass helices-packed column. The first fraction contains a water azeotrope.

(+)-Equilenine *[517-09-9]* **M 266.3, m 258-259°, $[\alpha]_{D}^{16}$ +87° (c 7.1, H_2O).** Crystd from EtOH.

Ergocornine *[564-36-3]* **M 561.7, m 182-184°.** Crystd with solvent of crystn from MeOH.

Ergocristine *[511-08-0]* **M 573.7, m 165-170°.** Crystd with 2 moles of solvent of crystn, from benzene.

Ergocryptine *[511-09-1]* **M 575.7, m 212-214°.** Crystd with solvent of crystn, from acetone, benzene or methanol.

Ergosterol *[57-87-4]* **M 396.7, m 165-166°, $[\alpha]_{546}^{20}$ -171° (in $CHCl_3$).** Crystd from ethyl acetate, then from ethylene dichloride.

Ergotamine *[113-15-5]* **M 581.6, m 212-214°(dec).** Crystd from benzene, then dried by prolonged heating in high vacuum. Very *hygroscopic.*

Ergotamine tartrate *[379-79-3]* **M 657.1, m 203°(dec).** Crystd from MeOH.

Eriochrome Black T *[1787-61-7]* **M 416.4, $\varepsilon_{1cm}^{\%}$ 656 (620nm) at pH 10, using the dimethylammonium salt.** The sodium salt (200g) was converted to the free acid by stirring with 500ml of 1.5M HCl, and, after several minutes, the slurry was filtered on a sintered-glass funnel. The process was repeated and the material was air dried after washing with acid. It was extracted with benzene for 12h in a Soxhlet extractor, then the benzene was evaptd and the residue was air dried. A further desalting with 1.5M HCl (1L) was followed by crystn from dimethylformamide (in which it is very soluble) by forming a saturated soln at the boiling point, and allowing to cool slowly. The crystalline dimethylammonium salt so obtained was washed with benzene and treated repeatedly with dilute HCl to give the insoluble free acid which, after air drying, was dissolved in alcohol, filtered and evaporated. The final material was air dried, then dried in a vacuum

desiccator over $Mg(ClO_4)_2$ [Diehl and Lindstrom, *AC* **31** 414 *1959*].

Eriochrome Blue Black R *[2538-85-4]* **M 416.4.** Freed from metallic impurities by three pptns from aqueous soln by addn of HCl. The ppted dye was dried at 60° under vacuum.

Erucic acid *[112-86-7]* **M 338.6, m 33.8°, b 358°/400mm.** Crystd from MeOH.

***meso*-Erythritol** *[149-32-6]* **M 122.1, m 122°.** Crystd from distd water and dried at 60° in a vac oven.

Erythrityl tetranitrate *[7297-25-8]* **M 302.1, m 61°,**
β-Erythroidine *[466-81-9]* **M 273.3.** Crystd from EtOH.

D-Erythronic acid (3*R*-3,4-dihydroxyfuran-2-one) *[15667-21-7]* **M 118.1, m 98-100°, 103-104°, 104-105°, 105°, $[\alpha]_D^{20}$ -73.2° (c 0.5, H_2O), $[\alpha]_{546}^{20}$ -87.6° (c 4, H_2O).** Recrystd from EtOAc (20 parts) or isoPrOH (3 parts). [Baker and MacDonald *JACS* **82** 230 *1960*; Glattfeld and Forbrich *JACS* **56** 1209 *1934*; Weidenhagen and Wegner *B* **72** 2010 *1939*, Musich and Rapoport *JACS* **100** 4865 *1978*].

Erythrosin B *[568-63-8]* **M 879.9, λ_{max} 525nm.** Crystd from water.

Esculetin (cichorigenin, 6,7-dihydroxycoumarin) *[305-01-1]* **M 178.2, m 272-275° (dec), 274° (dec).** Forms prisms from AcOH and provides leaflets on sublimation in a vacuum. [Sethna and Shah *Chem Reviews*; Merz *Arch Pharmacie* **270** 486 *1932*]. *Esculin (the 6-glucoside)* has **m** 215° (dec), $[\alpha]_D^{20}$ -41° (c 5, pyridine).

Eserine (Physostigmine, Physostol, [(3aS-*cis*)-1,2,3,3a,8,8a-hexahydro-1,3a,8-trimethylpyrrolo[2,3-b]indol-5-ol methylcarbamate ester] *[57-47-6]* **M 275.4, m 102-104°, 105-106°, $[\alpha]_D^{17}$ -67° (c 1.3, $CHCl_3$), $[\alpha]_D^{25}$ -120° (C_6H_6).** Recrystallises form Et_2O or C_6H_6 and forms an unstable low melting form **m** 86-87° [Harley-Mason and Jackson *JCS* 3651 *1954*; Wijnberg and Speckamp *TET* **34** 2399 *1978*].

β-Estradiol see **β-oestradiol.**

β-Estradiol-3-benzoate see **β-oestradiol-3-benzoate.**

1,3,5-Estratrien-3-ol-17-one (Estrone, Folliculin) *[53-16-7]* **M 270.4, m 260-261°, polymorphic also m 254° and 256°, $[\alpha]_{546}^{20}$ +198° (c 1, dioxane).** Crystd from EtOH.

1,3,5-Estratrien-3ß,16a,17ß-triol (Estriol) *[50-27-1]* **M 288.4, m 283°, $[\alpha]_{546}^{20}$ +66° (c 1, dioxane).** Crystd from EtOH/ethyl acetate.

Estriol see **1,3,5-Estratrien-3ß,16a,17ß-triol.**

Estrone see **1,3,5-Estratrien-3-ol-17-one.**

Ethane *[74-84-0]* **M 30.1, f.p. -172°, b -88°, d_4^0 1.0493 (air = 1).** Ethylene can be removed by passing the gas through a sintered-glass disc into fuming H_2SO_4 then slowly through a column of charcoal satd with bromine. Bromine and HBr were removed by passage through firebrick coated with *N,N*-dimethyl-*p*-toluidine. The ethane was also passed over KOH pellets (to remove CO_2) and dried with $Mg(ClO_4)_2$. Further purification was by several distns of liquified ethane, using a condensing temperature of -195°. Yang and Gant [*JPC* **65** 1861 *1961*] treated ethane by standing it for 24h at room temperature in a steel bomb containing activated charcoal treated with bromine. They then immersed the bomb in a Dry-ice/acetone bath and transferred the ethane to an activated charcoal trap cooled in liquid nitrogen. (The charcoal had previously been degassed by pumping for 24h at 450°.) By allowing the trap to warm slowly, the ethane was distd, retaining only the middle third. Removal of methane was achieved using Linde type 13X molecular sieves (previously degassed by

pumping for 24h at 450°) in a trap which, after cooling in Dry-ice/acetone, was satd with ethane. After pumping for 10min, the ethane was recovered by warming the trap to room temperature. (The final gas contained less than 10^{-4} mole % of either ethylene or methane).

Ethanesulphonyl chloride *[594-44-5]* **M 128.6, b 55°/9mm, 62°/12mm, 74°/19mm, 76-79°/22mm, 95-98°/50mm, 177°/760mm, d_4^{20} 1.357, n_D^{20} 1.4539.** Purified by repeated distn to remove HCl formed from hydrolysis. **Fuming, corrosive liquid, handle in a good fumehood.** It is hydrolysed by aq N NaOH at room temperature and is best stored in aliquots in sealed ampules under N_2. [Davies and Dick *JCS* 484 *1932*; Klamann and Drahowzal *M* **83** 463 *1952*; Saunders et al. *BJ* **36** 372 *1942*].

Ethanethiol (ethyl mercaptan) *[540-63-6]* **M 62.1, b 32.9°/704mm, d^{52} 0.83147.** Dissolved in aqueous 20% NaOH, extracted with a small amount of benzene and then steam distd until clear. After cooling, the alkaline soln was acidified slightly with 15% H_2SO_4 and the thiol was distd off, dried with $CaSO_4$, $CaCl_2$ or 4A molecular sieves, and fractionally distd under nitrogen [Ellis and Reid *JACS* **54** 1674 *1932*].

Ethanol *[64-17-5]* **M 46.1, b 78.3°, d^{15} 0.79360, d^5 0.78506, n 1.36139.** Usual impurities of fermentation alcohol are fusel oils (mainly higher alcohols, especially pentanols), aldehydes, esters, ketones and water. With synthetic alcohol, likely impurities are water, aldehydes, aliphatic esters, acetone and ethyl ether. Traces of benzene are present in ethanol that has been dehydrated by azeotropic distillation with benzene. Anhydrous ethanol is very *hygroscopic*. Water (down to 0.05%) can be detected by formation of a voluminous ppte when aluminium ethoxide in benzene is added to a test portion, Rectified spirit (95% ethanol) is converted to *absolute* (99.5%) ethanol by refluxing with freshly ignited CaO (250g/L) for 6h, standing overnight and distilling with precautions to exclude moisture.

Numerous methods are available for further dehydration of *absolute* ethanol. Lund and Bjerrum [*B* **64** 210 *1931*] used reaction with magnesium ethoxide, prepared by placing 5g of clean dry magnesium turnings and 0,5g of iodine (or a few drops of CCl_4) in a 2L flask, followed by 50-75 ml of *absolute* ethanol, and warming the mixture until a vigorous reaction occurs. When this subsides, heating is continued until all the magnesium is converted to magnesium ethoxide. Up to 1L of ethanol is added and, after an hour's reflux, it is distd off. The water content should be below 0.05%. Walden, Ulich and Laun [*ZPC* **114** 275 *1925*] used amalgamated aluminium chips, prepared by degreasing aluminium chips, treating with alkali until hydrogen was vigorously evolved, washing with H_2O until the washings were weakly alkaline and then stirring with 1% $HgCl_2$ soln. After 2min, the chips were washed quickly with H_2O, then alcohol, then ether, and dried with filter paper. (The amalgam became warm.) These chips were added to the ethanol, which was then gently warmed for several hours until evolution of hydrogen ceased. The alcohol was distd and aspirated for some time with pure dry air. Smith [*JCS* 1288 *1927*] reacted 1L of *absolute* ethanol in a 2L flask with 7g of clean dry sodium, and added 25g of pure ethyl succinate 27g of pure ethyl phthalate was an alternative), and refluxed the mixture for 2h in a system protected from moisture, and then distd the ethanol. A modification used 40g of ethyl formate, instead, so that sodium formate separated out and, during reflux, the excess of ethyl formate decomposed to CO and ethanol.

Dehydrating agents suitable for use with ethanol include Linde type 4A molecular sieves, calcium metal, and CaH_2. The calcium hydride (2g) was crushed to a powder and dissolved in 100ml *absolute* ethanol by gently boiling. About 70ml of the ethanol were distd off to remove any ammonia before the remainder was poured into 1L of *ca* 99.9% ethanol in a still, where it was boiled under reflux for 20h, while a slow stream of pure, dry hydrogen (better use nitrogen or Ar) was passed through. It was then distd [Rüber *Z Elektrochem* **29** 334 *1923*]. If calcium was used for drying, about ten times the theoretical amount should be taken, and traces of ammonia would be removed by passing dry air into the vapour during reflux.

Ethanol can be freed from traces of basic materials by distn from a little 2,4,6-trinitrobenzoic acid or sulphanilic acid. Benzene can be removed by fractional distn after adding a little water (the benzene/water/ethanol azeotrope distils at 64.9°); the alcohol is then redried using one of the methods described above. Alternatively, careful fractional distn can separate benzene as the benzene/ethanol azeotrope (b 68.2°). Aldehydes can be removed from ethanol by digesting with 8-10g of dissolved KOH and 5-10g of aluminium or zinc per L, followed by distn. Another method is to heat under reflux with KOH (20g/L) and $AgNO_3$ (10g/L) or to add 2.5-3g of lead acetate in 5ml of water to 1L of ethanol, followed (slowly and without stirring) by 5g of KOH in 25ml of ethanol: after 1hr the flask is shaken thoroughly, then set aside overnight before filtering and distilling. The residual water can be removed by standing the distillate over activated aluminium amalgam for 1 week, then filtering and

distilling. Distn of ethanol from Raney nickel eliminates catalyst poisons.
Other purification procedures include pre-treatment with conc H_2SO_4 (3ml/L) to eliminate amines, and with $KMnO_4$ to oxidise aldehydes, followed by refluxing with KOH to resinify aldehydes, and distilling to remove traces of H_3PO_4 and other acidic impurities after passage through silica gel, and drying over $CaSO_4$. Water can be removed by azeotropic distn with dichloromethane (azeotrope boils at 38.1° and contains 1.8% water) or 2,2,4-trimethylpentane. Ethanol has a pKa^{25} of 15.5 in water.

Ethanolamine see **1-aminoethanol.**

Ethidium bromide *[1239-45-8]* **M 384.3, m 260-262°.** Crystd from MeOH [Lamos et al. *JACS* **108** 4278 *1986*]. **POSSIBLE CARCINOGEN.**

***S*-Ethionine** *[13073-35-3]* **M 163.2, m 282°(dec), $[\alpha]_D^{25}$ +23.7° (in 5M HCl).** Likely impurities are *N*-acetyl-(*R* and *S*)-ethionine, *S*-methionine, and *R*-ethionine. Crystd from water by adding 4 volumes of EtOH.

Ethoxycarbonyl isocyanate *[16182-04-0]* **M 131.5, b 51-55°/13mm, 56°/18mm, d_4^{20} 1.15.** Fractionally distilled. [*JHC* **5** 837 *1968*].

Ethoxycarbonyl isothiocyanate *[16182-04-0]* **M 131.5, b 43°/14mm, 51-55°/13mm, 56°/18mm, d_4^{20} 1.12.** Fractionally distd through a short column. It also distils at 83°/30mm with some decomposition liberating CO_2 and sulphuretted gases, best distil below 20mm vacuum. [*JCS* **93** 697 *1908;* 1340, *1948*; *JHC* **5** 837 *1968*].

3-Ethoxy-*N,N*-diethylaniline *[1846-92-2]* **M 193.3, b 141-142°/15mm.** Refluxed for 3h with acetic anhydride, then fractionally distilled under reduced pressure.

2-Ethoxyethanol *[110-80-5]* **M 90.1, b 134.8°, d 0.931, n 1.40751.** Dried with $CaSO_4$ or K_2CO_3, filtered and fractionally distd. Peroxides can be removed by refluxing with anhydrous $SnCl_2$ or by filtration under slight pressure through a column of activated alumina.

2-(2-Ethoxyethoxy)ethanol see **diethylene glycol monoethyl ether.**

2-Ethoxyethyl ether [*bis*-(2-ethoxyethyl) ether] *[112-36-7]* **M 162.2, b 76°/32mm, d 0.910, n 1.412. .** Refluxed with $LiAlH_4$ for several hours, distd under reduced pressure and stored with CaH_2 under nitrogen. Also passed through (alkaline) alumina.

2-Ethoxyethyl methacrylate *[2370-63-0]* **M 158.2, b 91-93°/35mm, d 0.965, n 1.429.** Purified as described under methyl methacrylate.

1-Ethoxynaphthalene *[5328-01-8]* **M 172.2, b 136-138°/14mm, 282°/760mm, d 1.061, n 1.604.** Fractionally distd (twice) under a vacuum, then dried with, and distd under a vacuum from, sodium.

2-Ethoxynaphthalene *[2224-00-2]* **M 172.2, m 35.6-36.0°, b 142-143°/12mm.** Crystd from pet ether. Dried under vacuum.

Ethyl acetamidate hydrochloride *[2208-07-3]* **M 123.6, m 110-115° (dec), 112-113° (dec).** Recrystd by dissolving in the minimum volume of super dry EtOH and addition of dry Et_2O or from dry Et_2O. Dry in vacuum and store in a vacuum desiccator with P_2O_5. The *free base* can be distd, **b** 89.7-90°/765mm [Glickman and Cope *JACS* **67** 1020 *1945*; McElvain and Schroeder *JACS* **71** 40 *1949*; McElvain and Tate *JACS* **73** 2233 *1951*; *Methods in Enzymology* **25** 585 *1972*].

Ethyl acetate *[141-78-6]* **M 88.1, b 77.1°, d 0.9003, n 1.37239, n^{25} 1.36979.** The commonest impurities are water, EtOH and acetic acid. These can be removed by washing with aqueous 5% Na_2CO_3, then with saturated aqueous $CaCl_2$ or NaCl, and drying with K_2CO_3, $CaSO_4$ or $MgSO_4$. More efficient drying is

achieved if the solvent is further dried with P_2O_5, CaH_2 or molecular sieves before distn. CaO has also been used. Alternatively, ethanol can be converted to ethyl acetate by refluxing with acetic anhydride (*ca* 1ml per 10ml of ester); the liquid is then fractionally distd, dried with K_2CO_3 and redistd.

Ethyl acetoacetate *[141-97-9]* **M 130.1, b 71°/12mm, 100°/80mm, d 1.026, n 1.419.** Shaken with small amounts of saturated aqueous $NaHCO_3$ (until no further effervescence), then with water. Dried with $MgSO_4$ or $CaCl_2$. Distd under reduced pressure.

Ethyl acrylate *[140-88-5]* **M 100.1, b 99.5°, d 0.922, n 1.406.** Washed repeatedly with aqueous NaOH until free from inhibitors such as hydroquinone, then washed with saturated aqueous $CaCl_2$ and distd under reduced pressure. Hydroquinone should be added if the ethyl acrylate is to be stored for extended periods,

Ethyl alcohol see **ethanol.**

Ethylamine *[75-04-7]* **M 45.1, b 16.6°/760mm, d 1.3663.** Condensed in an all-glass apparatus cooled by circulating ice-water, and stored with KOH pellets below 0°.

Ethylamine hydrochloride *[557-66-4]* **M 81.5, m 109-110°.** Crystd from absolute EtOH or $MeOH/CHCl_3$.

Ethyl *o*-aminobenzoate *[94-09-7]* **M 165.2, m 92°.** Crystd from EtOH/water and air dried.

***p*-Ethylaniline** *[589-16-2]* **M 121.2, 88°/8mm, d 0.975, n 1.554.** Dissolved in benzene, then acetylated. The acetyl derivative was recrystallised from benzene/pet ether, and hydrolysed by refluxing 50g with 500ml of water and 115ml of conc H_2SO_4 until the soln becomes clear. The amine sulphate was isolated, suspended in water and solid KOH was added to regenerate the free base, which was separated, dried and distd from zinc dust under a vacuum [Berliner and Berliner *JACS* **76** *6179 1954*].

Ethylbenzene *[100-41-6]* **M 106.2, b 136.2°, d 0.867, n 1.49594, n^{25} 1.49330.** Shaken with cold conc H_2SO_4 until a fresh portion of acid remained colourless, then washed with aqueous 10% NaOH or $NaHCO_3$, followed by distilled water until neutral. Dried with $MgSO_4$ or $CaSO_4$, then dried further with, and distd from, sodium, sodium hydride or CaH_2. Can also be dried by passing through silica gel. Sulphur-containing impurities have been removed by prolonged shaking with mercury. Also purified by fractional freezing.

2-Ethyl-1,2-benzisoxazolium tetrafluoroborate *[4611-62-5]* **M 235.0, m 107-109°, 109.5-110.2°.** Recrystd from MeCN-EtOAc to give magnificent crystals. It is not hygroscopic but on long exposure to moisture it etches glass. It is light-sensitive and should be stored in brown glass bottles. UV (H_2O), λmax 258nm (ε 13 100) and λmax 297nm (ε 2 900); IR (CH_2Cl_2): 1613 (C=N) and 1111-1000 (BF_4^+) [UV, IR, NMR: Kemp and Woodward *TET* **21** 3019 *1965*].

Ethyl benzoate *[93-89-0]* **M 150.2, b 98°/19mm, 212.4°/760mm, d 1.046, n^{15} 1.5074, n^{25} 1.5043.** Washed with aq 5% Na_2CO_3, then satd $CaCl_2$, dried with $CaSO_4$ and distd under reduced pressure.

Ethyl bis-(2,4-dinitrophenyl)acetate *[5833-18-1]* **M 358.3, m 150-153°.** Crystd from toluene as pale yellow crystals.

Ethyl bixin *[6895-43-8]* **M 436.6, m 138°.** Crystd from EtOH.

Ethyl bromide *[74-96-4]* **M 109.0, b 0°/165mm, 38°/745mm, d 1.460, n 1.4241.** The main impurities are usually EtOH and water, with both of which it forms azeotropes. Ethanol and unsaturated compounds can be removed by washing with conc H_2SO_4 until no further coloration is produced. The ethyl bromide is then washed with water, aq Na_2CO_3, and water again, then dried with $CaCl_2$, $MgSO_4$ or CaH_2, and distd. from P_2O_5. Olefinic impurities can also be removed by storing the ethyl bromide in daylight with elementary bromine, later removing the free bromine by extraction with dil aq Na_2SO_3, drying the ethyl

bromide with $CaCl_2$ and fractionally distilling. Alternatively, unsaturated compounds can be removed by bubbling oxygen containing *ca* 5% ozone through the liquid for an hour, then washing with aqueous Na_2SO_3 to hydrolyse ozonides and remove hydrolysis products, followed by drying and distn.

Ethyl bromoacetate *[105-36-2]* **M 167.0, b 158-158.5°/758mm, d 1.50, n 1.450,**
Ethyl α-bromopropionate *[535-11-5]* **M 181.0, b 69-70°/25mm, d 1.39, n 1.447.** Washed with saturated aqueous Na_2CO_3 (three times), 50% aq $CaCl_2$ (three times) and saturated aqueous NaCl (twice). Dried with $MgSO_4$, $CaCl_2$ or $CaCO_3$, and distd. **LACHRYMATORY.**

Ethyl bromopyruvate *[70-23-5]* **M 195.0, b 47°/0.5mm, 71-73°/5mm, 87°/9mm, 89-104°/14mm, d_4^{20} 1.561, n_D^{20} 1.464.** Most likely impurity is free carboxylic acid (bromopyruvic or bromoacetic acids). Dissolve in dry Et_2O or dry $CHCl_3$, stir with $CaCO_3$ until effecrvescence ceases, filter, (may wash with a little H_2O rapidly), dry ($MgSO_4$) and distil at least twice. The *2,4-dinitrophenylhydrazone* has **m** 144-145°. [Burros and Holland *JCS* 672 *1947*; Letsinger and Laco *JOC* **21** 764 *1956*; Kruse et al. *JACS* **76** 5796 *1954*].

2-Ethyl-1-butanol *[97-95-0]* **M 102.2, b 146.3°, n^{15} 1.4243, n^{25} 1.4205.** Dried with $CaSO_4$ for several weeks, filtered and fractionally distd.

2-Ethylbut-1-ene *[760-21-4]* **M 84.1, b 66.6°, d 0.833, n 1.423.** Washed with saturated aqueous NaOH, then water. Dried with $CaCl_2$, filtered and fractionally distd.

Ethyl *n*-butyrate *[105-54-4]* **M 116.2, b 49°/50mm, 119-120°/760mm, d 0.880, n 1.393.** Dried with anhydrous $CuSO_4$ and distd under dry nitrogen.

Ethyl carbamate (urethane) *[51-79-6]* **M 88.1, m 48.0-48.6°.** Crystd from benzene.

Ethyl carbazate *[4114-31-2]* **M 104.1, m 44-48°, 51-52°, b 95.5°/10m, 92-95°/12mm, 100-102°/11mm.** Fractionated using a Vigreux column until the distillate crystallises [Allen and Bell *Org Synth* Coll Vol III 404 *1955*].

***N*-Ethylcarbazole** *[86-28-2]* **M 195.3, m 69-70°.** Recrystd from EtOH, EtOH/water or isopropanol and dried below 55°.

Ethyl carbonate *[105-58-8]* **M 118.1, b 124-125°, d 0.975, n 1.385.** Washed with aqueous 10% Na_2CO_3, then aqueous saturated $CaCl_2$. Dried with $MgSO_4$ and distd.

Ethyl chloride *[75-00-3]* **M 64.5, b 12.4°, d 0.8978, n 1.3676.** Passed through absorption towers containing, successively, conc H_2SO_4, NaOH pellets, P_2O_5 on glass wool, or soda-lime, $CaCl_2$, P_2O_5. Condensed into a flask containing CaH_2 and fractionally distd. Has also been purified by illumination in the presence of bromine at 0° using a 1000W lamp, followed by washing, drying and distn.

Ethyl chloroacetate *[105-39-5]* **M 122.6, b 143-143.2°, d 1.150, n^{25} 1.4192.** Shaken with satutated aqueous Na_2CO_3 (three times), aqueous 50% $CaCl_2$ (three times) and saturated aqueous NaCl (twice). Dried with Na_2SO_4 or $MgSO_4$ and distd. **LACHRYMATORY.**

Ethyl chloroformate *[541-41-3]* **M 108.5, m -81°, b 94-95°, d 1.135, n 1.3974.** Washed several times with water, redistd using an efficient fractionating column at atmospheric pressure and a $CaCl_2$ guard tube to keep free from moisture [Hamilton and Sly *JACS* **47** 435 *1925*; Saunders, Slocombe and Hardy, *JACS* **73** 3796 *1951*]. **LACHRYMATORY AND TOXIC.**

Ethyl chrysanthemate (ethyl ±2,2-dimethyl-3{c and t}-[2-methylpropenyl]-cyclopropane carboxylate) *[97-41-6]* **M 196.3, b 98-102°/11mm, 117-121°/20mm.** Purified by vacuum distn. The free *trans-acid* has **m** 54° (from, EtOAc) and the free *cis-acid* has **m** 113-116° (from EtOAc). The *4-nitrophenyl ester* has **m** 44-45° (from pet ether) [Campbell and Harper *JCS* 283 *1945*; IR: Allen et al. *JOC*

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22 1291 *1957*].

Ethyl cinnamate *[103-36-6]* **M 176.2, f.p. 6.7°, b 127°/6mm, 272.7°/768mm, d 1.040, n 1.55983.** Washed with aqueous 10% Na_2CO_3, then water, dried ($MgSO_4$), and distd. The purified ester was saponified with aqueous KOH, and, after acidifying the soln, cinnamic acid was isolated, washed and dried. The ester was reformed by refluxing for 15h the cinnamic acid (25g) with abs EtOH (23g), conc H_2SO_4 (4g) and dry benzene (100ml), after which it was isolated, washed, dried and distd under reduced pressure [Jeffery and Vogel *JCS* 658 *1958*].

Ethyl *trans*-crotonate *[623-70-1]* **M 114.2, b 137°, d 0.917, n 1.425.** Washed with aqueous 5% Na_2CO_3, washed with saturated aqueous $CaCl_2$, dried with $CaCl_2$ and distd.

Ethyl cyanoacetate *[105-56-6]* **M 113.1, b 206.0°, d 1.061, n 1.41751.** Shaken several times with aqueous 10% Na_2CO_3, washed well with water, dried with Na_2SO_4 and fractionally distd.

Ethyl cyanoformate *[623-49-4]* **M 99.1, b 113-114°/740mm, 116.5-116.8°/765.5mm, d_4^{20} 1.0112, n_D^{20} 1.3818.** Dissolve in Et_2O, dry over Na_2SO_4, filter, evaporate and distil [Malachowsky et al. *B* **70** 1016 *1937*; Adickes et al. *J prakt Chem* [2] **133** 313 *1932*; Grundmann et al. *A* **577** 77 *1952*].

Ethylcyclohexane *[1678-91-7]* **M 112.2, b 131.8°, d 0.789, n 1.43304, n^{25} 1.43073.** Purified by azeotropic distn with 2-ethoxyethanol, then the alcohol was washed out with water and, after drying, the ethylcyclohexane was redistd.

Ethyl cyclohexanecarboxylate *[3289-28-9]* **M 156.2, b 76-77°/10mm, 92-93°/34mm, d 0.960, n 1.420.** Washed with M sodium hydroxide solution, then water, dried with Na_2SO_4 and distd.

Ethyl diazoacetate *[623-73-4]* **M 114.1, m -22°, b 42°/5mm, 45°/12mm, 85-86°/88mm, 140-141°/720mm, 140-143°/atm, $d_4^{17.6}$ 1.0852, $n_D^{17.6}$ 1.4588.** A very volatile yellow oil with a strong pungent odour. **EXPLOSIVE [distillation even under reduced pressure is dangerous and may result in an explosion — TAKE ALL THE NECESSARY PRECAUTIONS IF DISTILLATION IS TO BE CARRIED OUT].** It explodes in contact with conc H_2SO_4 - trace acid causes rapid decomp. It is slightly sol in H_2O, but is miscible with EtOH, C_6H_6, pet ether and Et_2O. To purify dissolve in Et_2O [using CH_2Cl_2 instead of Et_2O protects the ester from acid], wash with 10% aq Na_2CO_3, dry ($MgSO_4$), filter and repeat as many times as possible until the Et_2O layer loses its yellow colour, remove the solvent below 20° (vac). Note that prolonged heating may lead to rapid decomp and low yields. It can also be purified by steam distn under reduced pressure but with considerable loss in yield. Place the residual oil in a brown bottle and keep below 10°, and use as soon as possible without distilling. [Womack and Nelson *Org Synth* Coll Vol III 392 *1955*; UV: Miller and White *JACS* **79** 5974 *1957*; Fieser **1** 367 *1967*].

Ethyl dibromoacetate *[105-36-2]* **M 245.9, b 81-82°/14.5mm, n^{22} 1.4973.** Washed briefly with conc aqueous $NaHCO_3$, then with aqueous $CaCl_2$. Dried with $CaSO_4$ and distd under reduced pressure.

Ethyl α,β-dibromo-β-phenylpropionate *[5464-70-0] [erythro: 30983-70-1]* **M 336.0, m 75°.** Crystd from pet ether (b 60-80°).

Ethyl dichloroacetate *[535-15-9]* **M 157.0, b 131.0-131.5°/401mm, d 1.28, n 1.438.** Shaken with aqueous 3% $NaHCO_3$ to remove free acid, washed with distd water, dried for 3 days with $CaSO_4$ and distd under reduced pressure.

Ethyl 3,3-diethoxypropionate *[10601-80-6]* **M 190.2, b 58.5°/1.5mm, 65°/2mm, 95-96°/12mm, d_4^{20} 0.78, n_D^{25} 1.4101.** Dissolve in dry Et_2O, and dry with solid $NaHCO_3$, filter and distil and carefully fractionate [Dyer and Johnson *JACS* **56** 223 *1934*].

Ethyl 1,3-dithiane-2-carboxylate *[20462-00-4]* **M 192.3, b 75-77°/0.2mm, 96°/0.4mm, d_4^{20} 1.220, n_D^{25} 1.5379.** Dissolve in $CHCl_3$, wash with aqueous K_2CO_3, 2 x with H_2O, dry over $MgSO_4$, filter,

evaporate and distil. [Eliel and Hartman *JOC* **37** 505 *1972*; Seebach *S* **1** 17 *1969*].

Ethyl 1,3-dithiolane-2-carboxylate *[20461-99-8]* **M 178.3, b 85°/0.1mm, d_4^{20} 1.250, n_D^{20} 1.538.** Dissolve in $CHCl_3$, wash with aqueous K_2CO_3, 2 x with H_2O, dry over $MgSO_4$, filter, evaporate and distil [Hermann et al *TET LETT* 2599 *1973*; Corey and Erickson *JOC* **36** 3553 *1971*].

Ethylene *[74-85-1]* **M 28.0, m -169.4°, b -102°/700mm.** Purified by passage through a series of towers containing molecular sieves or anhydrous $CaSO_4$ or a cuprous ammonia soln, then conc H_2SO_4, followed by KOH pellets. Alternatively, ethylene has been condensed in liquid nitrogen, with melting, freezing and pumping to remove air before passage through an activated charcoal trap, followed by a further condensation in liquid air. A sputtered sodium trap has also been used, to remove oxygen.

Ethylene bis(diphenylphosphine) (DIPHOS) *[1663-45-2]* **M 398.4, m 139-140°.** Crystd from EtOH [Backvell et al. *JOC* **52** 5430 *1987*].

Ethylenebis[(*o*-hydroxyphenyl)glycine] *[1170-02-1]* **M 360.4, m 249°(dec).** Purified by extensive Soxhlet extraction with acetone. [Bonadies and Carrano *JACS* **108** 4088 *1986*].

[Ethylene bis(oxyethylenenitrilo)]tetraacetic acid see **ethylene glycol bis(ß-aminoethylether)-tetraacetic acid.**

Ethylene carbonate (1,3-dioxalan-2-one) *[96-49-1]* **M 88.1, m 37°, d 1.32, n^{40} 1.4199.** Dried over P_2O_5 then fractionally distd at 10mm pressure. Crystd from dry ethyl ether.

Ethylene chlorohydrin see **2-chloroethanol.**

Ethylenediamine *[107-15-3]* **M 60.1, f.p. 11.0°, b 117.0°, d 0.897, n 1.45677, n^{30} 1.4513.** Forms a constant-boiling (b 118.5°) mixture with water (15%) [*hygroscopic* and miscible with water]. Recommended purification procedure [Asthana and Mukherjee in Coetzee, 1982 cf p 53]: to 1L of ethylenediamine was added 70g of type 5A Linde molecular sieves and shaken for 12h. The liquid was decanted and shaken for a further 12h with a mixture of CaO (50g) and KOH (15g). The supernatant was fractionally distd (at 20:1 reflux ratio) in contact with freshly activated molecular sieves. The fraction distilling at 117.2° /760mm was collected. Finally it was fractionally distilled from sodium metal. All distns and storage of ethylenediamine should be carried out under nitrogen to prevent reaction with CO_2 and water. Material containing 30% water was dried with solid NaOH (600g/L), heated on a water bath for 10h. Above 60°, separation into two phases took place. The hot ethylenediamine layer was decanted off, refluxed with 40g of sodium for 2h and distd [Putnam and Kobe *Trans Electrochem Soc* **74** 609 *1938*]. Ethylenediamine is usually distd under nitrogen. Type 5A Linde molecular sieves (70g/L), then a mixture of 50g of CaO and 15g of KOH/L, with further dehydration of the supernatant with molecular sieves has also been used for drying this diamine, followed by distn from molecular sieves and, finally, from sodium metal. A spectroscopically improved material was obtained by shaking with freshly baked alumina (20g/L) before distn.

***N,N'*-Ethylenediaminediacetic acid** *[5657-17-0]* **M 176.2, m 222-224°(dec),**
Ethylenediamine dihydrochloride *[333-18-6]* **M 133.0.** Crystd from water.

Ethylenediaminetetraacetic acid (EDTA) *[60-00-4]* **M 292.3, m 253°(dec).** Dissolved in aqueous KOH or ammonium hydroxide, and ppted with dil HCl or HNO_3, twice. Boiled twice with distd water to remove mineral acid, then recrystd from water or dimethylformamide. Dried at 110°. Also recrystd from boiling 1N HCl, wash crystals with distd H_2O and dried *in vacuo*. [Ma and Ray *Biochemistry* **19** 751 *1980*].

Ethylene dibromide see **1,2-dibromoethane.**

Ethylene dichloride see **1,2-dichloroethane.**

Ethylene dimethacrylate *[97-90-5]* **M 198.2, b 98-100°/5mm, d 1.053, n 1.456.** Distd through

a short Vigreux column at about 1mm pressure, in the presence of 3% (w/w) of phenyl-ß-naphthylamine.

Ethylene dimyristate *[627-84-9]* **M 482.8, m 61.7°.** Crystd from benzene-MeOH or ethyl ether-MeOH, and dried in a vacuum desiccator.

(Ethylenedinitrilo)tetraacetic acid see **ethylenediaminetetraacetic acid.**

Ethylene dipalmitate *[624-03-3]* **M 538.9, m 69.1°,**
Ethylene distearate *[627-83-8]* **M 595.0, m 75.3°.** Crystd from benzene-MeOH or ethyl ether-MeOH and dried in a vacuum desiccator.

Ethylene glycol *[107-21-1]* **M 62.1, b 68°/4mm, 197.9°/760mm, d 1.0986, n^{15} 1.43312, n^{25} 1.43056.** Very *hygroscopic*, and also likely to contain higher diols. Dried with CaO, $CaSO_4$, $MgSO_4$ or NaOH and distd under vacuum. Further dried by reaction with sodium under nitrogen, refluxed for several hours and distd. The distillate was then passed through a column of Linde type 4A molecular sieves and finally distd under nitrogen, from more molecular sieves. Fractionally distd.

Ethylene glycol bis(ß-aminoethylether)-*N,N'*-tetraacetic acid (EGTA) *[67-42-5]* **M 380.4, m >245°(dec).** Dissolved in aq NaOH, pptd by addn of aq HCl, washed with water and dried at 100° *in vacuo*. ueous 5% Na_2CO_3, dried with $MgSO_4$ and stored with chromatographic alumina to prevent peroxide formation.

Ethylene glycol diethyl ether *[629-14-1]* **M 118.2, b 121.5°, d 0.842, n 1.392.** After refluxing for 12h, a mixture of the ether (2L), conc HCl (27ml) and water (200ml), with slow passage of nitrogen, the soln was cooled, and KOH pellets were added slowly and with shaking until no more dissolved. The organic layer was decanted, treated with some KOH pellets and again decanted. It was refluxed with, and distd from sodium immediately before use. Alternatively, after removal of peroxides by treatment with activated alumina, the ether has been refluxed in the presence of the blue ketyl formed by sodium-potassium alloy with benzophenone, then distd.

Ethylene glycol dimethyl ether (monoglyme) *[110-71-4]* **M 90.1, b 85°, d 0.866, n 1.379.** Purified by distn from $LiAlH_4$ or sodium.

Ethylene glycol monobutyl ether see **2-butoxyethanol.**

Ethylene glycol monoethyl ether see **2-ethoxyethanol.**

Ethylene glycol monomethyl ether see **2-methoxyethanol.**

Ethylene oxide *[75-21-8]* **M 44.0, b 13.5°/746mm, d^{10} 0.882, n^{7} 1.3597.** Dried with $CaSO_4$, then distd from crushed NaOH. Has also been purified by its passage, as a gas, through towers containing solid NaOH.

Ethylene thiourea *[96-45-7]* **M 102.2, m 203-204°.** Crystd from EtOH or amyl alcohol.

Ethylene urea *[120-93-4]* **M 86.1, m 131°.** Crystd from MeOH (charcoal).

Ethylenimine (aziridine) *[151-56-4]* **M 43.1, b 55.5°/760mm, d 0.8321.** Dried with BaO, and distd from sodium under nitrogen. **TOXIC.**

Ethyl ether *[60-29-7]* **M 74.1, b 34.6°/760mm, d 0.714, n^{15} 1.3555, n 1.35272.** Usual impurities are water, EtOH, diethyl peroxide (which is explosive when concentrated), and aldehydes. Peroxides [detected by liberation of iodine from weakly acid (HCl) solutions of KI, or by the blue colour in the ether layer when 1mg of $Na_2Cr_2O_7$ and 1 drop of dil H_2SO_4 in 1ml of water is shaken with 10ml of ether] can be removed in several different ways. The simplest method is to pass dry ether through a column of activated alumina (80g Al_2O_3/700ml of ether). More commonly, 1L of ether is shaken repeatedly with 5-10ml of a soln comprising

6.0g of ferrous sulphate and 6ml of conc H_2SO_4 in 110ml of water. Aqueous 10% Na_2SO_3 or stannous chloride can also be used. The ether is then washed with water, dried for 24h with $CaCl_2$, filtered and dried further by adding sodium wire until it remains bright. The ether is stored in a dark cool place, until distd from sodium before use. Peroxides can also be removed by wetting the ether with a little water, then adding excess $LiAlH_4$ or CaH_2 and leaving to stand for several hours. (This also dried the ether.)
Werner [*Analyst* **58** 335 *1933*] removed peroxides and aldehydes by adding 8g $AgNO_3$ in 60ml of water to 1L of ether, then 100ml of 4% NaOH and shaking for 6min. Fierz-David [*Chimia* **1** 246 *1947*] shook 1L of ether with 10g of a zinc-copper couple. (This reagent was prepared by suspending zinc dust in 50ml of hot water, adding 5ml of 2M HCl and decanting after 20sec, washing twice with water, covering with 50ml of water and 5ml of 5% cuprous sulphate with swirling. The liquid was decanted and discarded, and the residue was washed three times with 20ml of ethanol and twice with 20ml of ethyl ether).
Aldehydes can be removed from ethyl ether by distn from hydrazine hydrogen sulphate, phenyl hydrazine or thiosemicarbazide. Peroxides and oxidisable impurities have also been removed by shaking with strongly alkaline satd $KMnO_4$ (with which the ether was left to stand in contact for 24h), followed by washing with water, conc H_2SO_4, water again, then drying ($CaCl_2$) and distn from sodium, or sodium containing benzophenone to form the ketyl. Other purification procedures include distn from sodium triphenylmethide or butyl magnesium bromide, and drying with solid NaOH or P_2O_5.

2-Ethylethylenimine *[25449-67-9]* **M 71.1, b 88.5-89°.** Freshly distd from sodium before use. **TOXIC.**

Ethyl formate *[109-94-4]* **M 74.1, b 54.2°, d 0.921, d^{30} 0.909, n 1.35994, n^{25} 1.3565.** Free acid or alcohol is removed by standing with anhydrous K_2CO_3, with occasional shaking, then decanting and distilling from P_2O_5. Alternatively, the ester can be stood wih CaH_2 for several days, then distd from fresh CaH_2. Cannot be dried with $CaCl_2$ because it reacts rapidly with the ester to form a crystalline compound.

Ethyl gallate *[831-61-8]* **M 198.2, m 150-151°, 163-165°.** Recryst from 1,2-dichloroethane, UV: λmax (neutral species) 275nm (ε 10 000); (anion) 235nm (ε 10 300), 279nm (ε 11 400) and 324nm (ε 8 500) [Campbell and Coppinger *JACS* **73** 2708 *1951*].

2-Ethyl-1-hexanol *[104-76-7]* **M 130.2, b 184.3°, d 0.833, n 1.431.** Dried with sodium, then fractionally distd.

2-Ethylhexyl vinyl ether *[37769-62-3] [103-44-6]* **M 156.3, b 177-178°/atm.** Usually contains amines as polymerization inhibitors. These are removed by fractional distn.

Ethyl hydrocupreine hydrochloride (Optochin) *[3413-58-9]* **M 376.9, m 249-251°.** Recryst from H_2O, pKa^{25} 5.5 and 9.95 [UV: Heidt and Forbes *JACS* **55** 2701 *1933*].

Ethylidene dichloride see **1,1-dichloroethane.**

Ethyl iodide *[75-03-6]* **M 156.0, b 72.4°, d 1.933, n^{15} 1.5682, n^{25} 1.5104.** Drying with P_2O_5 is unsatisfactory, and with $CaCl_2$ is incomplete. It is probably best to dry with sodium wire and distil [Hammond et al. *JACS* **82** 704 *1960*]. Exposure of ethyl iodide to light leads to rapid decomposition, with the liberation of iodine. Free iodine can be removed by shaking with several portions of dil aq $Na_2S_2O_3$ (until the colour is discharged), followed by washing with water, drying (with $CaCl_2$, then sodium), and distn. The distd ethyl iodide is stored, over mercury, in a dark bottle away from direct sunlight. Other purification procedures include passage through a 60cm column of silica gel, followed by distn; and treatment with elemental bromine, extraction of free halogen with $Na_2S_2O_3$ soln, followed by washing with water, drying and distn. Free iodine and HI have also been removed by direct distn through a LeBel-Henninger column containing copper turnings. Purification by shaking with alkaline solns, and storage over silver, are reported to be unsatisfactory.

Ethyl isobutyrate *[623-48-3]* **M 116.2, b 110°, d 0.867, n 1.388.** Washed with aqueous 5% Na_2CO_3, then with saturated aqueous $CaCl_2$. Dried with $CaSO_4$ and distd.

Ethyl isocyanate *[109-90-0]* **M 71.1, b 559.8°/759mm, 59-61°/atm, 60-63°/atm, d_4^{20} 0.9031, n_D^{20} 1.3808.** Fractionate through an efficient column preferably in an inert atmosphere and store in aliquots in sealed tubes [Bieber *JACS* **74** 4700 *1952*; Slocombe et al. *JACS* **72** 1888 *1950*].

3-Ethylisothionicotinamide *[10605-12-6]* **M 166.2, m 164-166°(dec).** Crystd from EtOH.

Ethyl isovalerate *[108-64-5]* **M 130.2, b 134.7°, d 0.8664, n 1.39621, n^{25} 1.3975.** Washed with aqueous 5% Na_2CO_3, then saturated aqueous $CaCl_2$. Dried with $CaSO_4$ and distd.

Ethyl levulinate (4-oxopentanoic acid ethyl ester) *[539-88-8]* **M 144.2, m 37.2°, b 106-108°/2mm, 138.8°/8mm, 203-205°/atm, d_4^{20} 1.012, n_D^{20} 1.423.** Stir ester with Na_2CO_3 and charcoal, filter and distil. It is freely soluble in H_2O and EtOH [IR, NMR: Sterk *M* **99** 1770 *1968*; Thomas and Schuette *JACS* **53** 2328 *1931*; Cox and Dodds *JACS* **55** 3392 *1933*].

Ethyl malonate *[105-53-3]* **M 160.2, b 92°/22mm, 198-199°/760mm, d 1.056, d^{25} 1.0507, n 1.413.** If too impure (IR, NMR) the ester (250g) has been heated on a steam bath for 36h with absolute EtOH (125ml) and conc H_2SO_4 (75ml), then fractionally distd under reduced pressure. Otherwise fractionally distil under reduced pressure and collect the steady boiling middle fraction.

Ethyl malonate monoamide *[7597-56-0]* **M 131.1, m 47-50°, 49.5-50°, 50°, b 130-135°/2mm.** Crystallise from Et_2O or by slow evaporation of an aqueous soln as colourless crystals [Snyder and Elston *JACS* **76** 3039 *1954*; McAlvain and Schroeder *JACS* **71** 45 *1949*; Rising et al. *JBC* **89** 20 *1930*].

Ethyl mercaptan see **ethanethiol.**

Ethyl methacrylate *[97-63-2]* **M 114.2, b 59°/100mm, d 0.915, n 1.515.** Washed successively with 5% aqueous $NaNO_2$, 5% $NaHSO_3$, 5% NaOH, then water. Dried with $MgSO_4$, added 0.2% (w/w) of phenyl-ß-naphthylamine, and distd through a short Vigreux column [Schultz *JACS* **80** 1854 *1958*].

Ethyl methyl ether *[540-67-0]* **M 60.1, b 10.8°, d^0 0.725.** Dried with $CaSO_4$, passed through an alumina column (to remove peroxides), then fractionally distd.

Ethyl methyl ketone (methyl ethyl ketone, MEK) see **2-butanone.**

3-Ethyl-2-methyl-2-pentene *[19780-67-7]* **M 112.2, b 114.5°/760mm.** Purified by preparative GLC on a column of 20% squalene on Chromosorb P at 70°.

3-Ethyl-4-methylpyridine *[529-21-5]* **M 121.2, b 76°/12mm, 194.5°/750mm, d 0.947, n 1.510.** Dried with solid NaOH, and fractionally distd.

5-Ethyl-2-methylpyridine *[104-90-5]* **M 121.2, b 178.5°/765mm, d 0.919, n 1.497.** Purified by conversion to the picrate, crystn, and regeneration of the free base, then distn.

***N*-Ethylmorpholine** *[100-74-3]* **M 115.2, b 138-139°/763mm, d 0.912, n 1.445.** Distd twice, then converted by HCl gas into the hydrochloride (extremely deliquescent) which was crystd from anhydrous EtOH-acetone (1:2) [Herries, Mathias and Rabin *BJ* **85** 127 *1962*].

Ethyl nitroacetate *[626-35-7]* **M 133.1, n 42-43°/0.2mm, 65°/0.6-2mm, 71-72°/3mm, 93-96°/9mm, 194-195°/atm, d_4^{20} 1.1953, n_D^{20} 1.4260.** Purified by repeated distn. IR 1748 (CO_2), 1570 and 1337 (NO_2), and 800cm^{-1} [Hazeldine *JCS* 2525 *1953*], pKa $^{25}_{H_2O}$ 5.82. The *hydrazine salt* crystallises from 95% EtOH or MeOH as yellow crystals **m** 104-105° [Ungnade and Kissinger *JOC* **22** 1661 *1957*, Emmons and Freeman *JACS* **77** 4391 *1955*].

Ethyl *p*-nitrobenzoate *[99-77-4]* **M 195.2, m 56°.** Dissolved in ethyl ether and washed with aqueous alkali, then the ether was evaporated and the solid recrystd from EtOH.

Ethyl Orange *[13545-67-0]* **M 372.4.** Recrystd twice from water.

Ethyl orthoformate *[122-51-0]* **M 148.2, b 144°/760mm, d 0.892, n 1.391.** Shaken with aqueous 2% NaOH, dried with solid KOH andd distd from sodium through a 20cm Vigreux column.

o-**Ethylphenol** *[90-00-6]* **M 122.2, f.p. 45.1°, b 210-212°, d 1.020, n 1.537,**
p-**Ethylphenol** *[123-07-9]* **M 122.2, m 47-48°, b 218.0°/762mm, n^{25} 1.5239.** Non-acidic impurities were removed by passing steam through a boiling soln containing 1 mole of the phenol and 1.75 moles of NaOH (as aq 10% soln). The residue was cooled and acidified with 30% (v/v) H_2SO_4, and the free phenol was extracted into ethyl ether. The extract was washed with water, dried with $CaSO_4$ and the ether was evapd. The phenol was distd at 100mm pressure through a Stedman gauze-packed column. It was further purified by fractional crystn by partial freezing, and by zone refining, under nitrogen [Biddiscombe et al. *JCS* 5764 *1963*]. Alternative purification is *via* the benzoate, as for phenol.

Ethyl phenylacetate *[101-97-3]* **M 164.2, b 99-99.3°/14mm, d 1.030, n 1.499.** Shaken with saturated aqueous Na_2CO_3 (three times), aqueous 50% $CaCl_2$ (twice) and saturated aqueous NaCl (twice). Dried with $CaCl_2$ and distd under reduced pressure.

2-Ethyl-2-phenylglutarimide see **3-ethyl-3-phenyl-2,6-piperidinedione.**

3-Ethyl-5-phenylhydantoin *[86-35-1]* **M 204.2, m 94°.** Crystd from water.

N-**Ethyl-5-phenylisoxazolinium-3'-sulphonate** *[4156-16-5]* **M 253.3, m 220°(dec).** [Lamas et al. *JACS* **108** 5543 *1986*],
3-Ethyl-3-phenyl-2,6-piperidinedione *[77-21-4]* **M 217.3, m 84°.** Crystd from ethyl ether or ethyl acetate/pet ether.

Ethyl propionate *[105-37-3]* **M 102.1, b 99.1°, d 0.891, n^{15} 1.38643, n 1.38394.** Treated with anhydrous $CuSO_4$ and distd under nitrogen.

2-Ethylpyridine *[100-71-0]* **M 107.2, b 148.6°, d 0.942,**
4-Ethylpyridine *[536-75-4]* **M 107.2, b 168.2-168.3°, d 0.942.** Dried with BaO, and fractionally distd. Purified by conversion to the picrate, recrystn and regeneration of the free base followed by distn.

4-Ethylpyridine-1-oxide *[14906-55-9]* **M 123.1, m 109-110°.** Crystd from acetone/ether.

Ethyl pyruvate *[617-35-6]* **M 116.1, m -50°, b 44-45°/10mm, 56°/20mm, 69-71°/42mm, 63°/23mm, 155.5°/760mm, d_4^{20} 1.047, n_D^{20} 1.4052.** Shake the ester with 10ml portions of satd aq $CaCl_2$ soln (removes ethyl acetate) and the organic layer is removed by centrifugation, decantation and filtration, and is distilled under reduced pressure. Purification of small quantities is carried out *via* the bisulphite adduct: the ester (2.2ml) is shaken with saturated $NaHSO_3$ (3.6ml), chill in a freezing mixture when crystals separate rapidly (particularly if seeded). After 5min EtOH (10ml) is added and the crystals are filtered off, washed with EtOH and Et_2O and dried. Yield *ca* 3g of *bisulphite adduct.* Then treat the adduct (16g) with saturated aqueous $MgSO_4$ (32ml) and 40% formaldehyde (5ml) and shake, whereby the ester separates as an oil which is extracted with Et_2O, the extract is dried ($MgSO_4$), filtered, evapd and the residue is distd (**b** 56°/20mm), and then redistd (**b** 147.5°/750mm) to give 5.5g of pure ester. [Cornforth *Org Synth* Col Vol IV 467 *1963*].

1-Ethylquinolinium iodide see **quinolinium ethiodide.**

Ethyl Red *[76058-33-8]* **M 197.4, m 150-152°.** Crystd from EtOH/ethyl ether.

Ethyl stearate *[111-61-5]* **M 312.5, m 33°, b 213-215°/15mm.** The solid portion was separated from the partially solid starting material, then crystd twice from EtOH, dried by azeotropic distn with benzene, and fractionally distd in a spinning-band column at low pressure [Welsh *TFS* **55** 52 *1959*].

Ethyl sulphide *[352-93-2]* **M 90.2, b 92.1°, d 0.835, n^{15} 1.44550.** Fractionally distd from sodium metal.

Ethyl thioglycolate *[623-51-8]* **M 120.2, b 50-51°/10mm, 55°/17mm, 62.5-64°/22mm, 67-68°/24mm, 155-158°/atm, d_4^{20} 1.096, n_D^{20} 1.457.** Dissolve in Et_2O, wash with H_2O, dry over Na_2SO_4, filter, evaporate and distil the residue under reduced pressure [Bredereck et al. *B* **90** 1837 *1957*). The *Ni complex [Ni(SCH$_2$CO$_2$Et)$_2$]* recrystallised twice from EtOH gives crystals which became black when dried in a vacuum over H_2SO_4, **m** 104-105° [Dranet and Cefola *JACS* **76** 1975 *1954*].

***N*-Ethyl thiourea** *[625-53-6]* **M 104.2, m 110°.** Crystd from EtOH, MeOH or ether.

Ethyl trichloroacetate *[515-84-4]* **M 191.4, b 100-100.5°/30mm, d 1.383.** Shaken with saturated aqueous Na_2CO_3 (three times), aqueous 50% $CaCl_2$ (three times), saturated aqueous NaCl (twice), then distd with $CaCl_2$ and distd under reduced pressure.

Ethyl trifluoroacetate *[383-63-1]* **M 142.1, b 61.3°/750, 60-62°/atm, 62-64°/755mm, d_4^{20} 1.191, n_D^{20} 1.30738.** Fractionate through a long Vigreux column. IR has ν at 1800 (CO_2) and 1000 (OCO) cm^{-1} [Fuson et al. *JCP* **20** 1627 *1952*; Bergman *JOC* **23** 476 *1958*].

Ethyl trifluoromethanesulphonate *[425-75-2]* **M 178.1, b 115°/atm, 118-120°/atm, d_4^{20} 1.378, n_D^{20} 1.336.** The ester reacts slowly with H_2O and aqueous alkali. If its IR has no OH bands (~3000 cm^{-1}) then purify by redistillation. If OH bands are present then dilute with dry Et_2O and shake (carefully) with aqueous $NaHCO_3$ until effervescence ceases, then wash with H_2O and dry ($MgSO_4$), filter, evaporate and distil the residue under slight vacuum then at atmospheric pressure in a N_2 atmosphere. **IT IS A POWERFUL ALKYLATING AGENT, AND THE FUMES ARE VERY TOXIC - CARRY ALL OPERATIONS IN AN EFFICIENT FUMECUPBOARD.** [Gramstad and Hazeldine *JCS* 173 *1956*; Howells and McCown *Chem Reviews* **77** 69*1977*].

S-Ethyl trifluorothioacetate *[383-64-2]* **M 158.1, b 88-90°/atm, 90.5°/760mm, d_4^{20} 1.255, n_D^{20} 1.372.** If IR is free of OH bands then fractionate, but if OH bands are present then dilute with dry Et_2O, wash with 5% KOH and H_2O, dry over $MgSO_4$ and fractionate through an efficient column [Hauptschein et al. *JACS* **74** 4005 *1952*]. *Powerful obnoxious odour.*

Ethyl vinyl ether *[109-92-2]* **M 72.1, b 35.5°, d 0.755.** Contains polymerization inhibitors (usually amines, e.g. triethanolamine) which can be removed by fractional distn. Redistd from sodium. **LACHRYMATORY.**

Ethynylbenzene see **phenylacetylene.**

1-Ethynyl-1-cyclohexanol *[78-27-3]* **M 124.2, m 30-33°, 32-33°, b 74°/12mm, 76-78°/17mm, 171-172°/694mm, 180°/atm, d_4^{25} 0.9734, n_D^{25} 1.4801.** Dissolve in Et_2O, wash with H_2O, dilute $NaHCO_3$, H_2O again, dry (Na_2SO_4), filter, evaporate and distil the residue. IR (CCl_4): 3448 (OH), 2941 (CH), 1449-1123 and 956 cm^{-1}; NMR (CCl_4) δ: 3.2 (OH), 2.5 (≡CH), 1.70 (m 10CH_2) [Hasbrouck and Kiessling *JOC* **38** 2103 *1972*].

Etiocholane (5ß-androsterone) *[438-23-3]* **M 260.5, m 78-80°.** Crystd from acetone.

Etiocholanic acid *[438-08-4]* **M 304.5, m 228-29°.** Crystd from glacial acetic acid and sublimes at 160°/0.002mm. The *methyl ester* has **m** 99-101°. [Weiland et al. *Z Physiol Chem* **161** 80 *1926*].

Etioporphyrin I *[448-71-5]* **M 478.7, m 360-363°.** Crystd from pyridine or $CHCl_3$-pet ether.

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Europium shift reagents see **lanthanide shift reagents.**

Farnesyl pyrophosphate *[13058-04-3], [E,E: 372-97-4]* **M 382.3.** Purified by chromatography on Whatman No3 MM paper in a system of isopropanol-isobutanol-ammonia-water (40:20:1:30) (v/v). Stored as the Li or NH_4 salt at 0°.

(+)-α-Fenchol (1*R*-1,3,3-trimethyl-norbornan-2-ol) *[1632-73-1]* **M 154.3, m 40-43°, 47-47.5°, b 201-202°, $[\alpha]_D^{20}$ +12.5° (c 10, EtOH).** It is prepared by reduction of (-)-fenchone and is purified by recrystallisation from C_6H_6-pet ether, or distn, or both. The *2-carboxybenzoyl (monophthalate)* derivative has **m** 146.5-147.5° $[\alpha]_D^{20}$ -20.4° (EtOH), and the *2-phenylurethane* has **m** 81°. [Beckmann and Metzger *B* **89** 2738 *1956*].

(+)- Fenchone (1*S*-1,3,3-trinmethyl-norbornan-2-one) *[4695-62-9]* **M 152.2, m 5-7°, 6.1°, b 63-65°/13mm, 66°/15mm, 122°/10mm, d_4^{20} 0.9434, n_D^{20} 1.4636, $[\alpha]_D^{20}$ +66.9° (neat, or in c 1.5, EtOH), $[\alpha]_{546}^{20}$ +60.4° (neat).** The oily liquid is purified by distn in a vacuum, and is very soluble in EtOH and Et_2O. [Boyle et al. *JCSCC* 395 *195,* Hückel *A* **549** 186 *1941*; (±)-isomer: Braun and Jacob *B* 66 1461 *1933*]. It forms two *oximes*; *Seqcis-oxime*: **m** 167° (cryst from pet ether) $[\alpha]_D^{20}$ +46.5° (c 2, EtOH), *O-benzoyloxime* **m** 81° $[\alpha]_D^{20}$ +49° (EtOH) and *oxime-HCl* **m** 136° (dec). The *Seqtrans-oxime* has **m** 123° (cryst from pet ether) $[\alpha]_D^{18}$+148° (c 2, EtOH) and the *O-benzoyloxime* has **m** 125° $[\alpha]_D^{20}$ +128.5° (c 2, EtOH) [Hückel *A* **549** 186 *1941*; Hückel and Sachs *A* **498** 166 *1932*].

(-)- Fenchone (1*R*-1,3,3-trinmethyl-norbornan-2-one) *[7787-20-4]* **M 152.2, m 5.2°, b 67.2°/10mm, 191-195°/atm, d_4^{20} 0.9484, n_D^{20} 1.4630, $[\alpha]_D^{20}$ -66.8° (neat).** Purification as for the (+)-enantiomer above and should have the same physical properties except for the optical rotations. UV: λmax 285nm (ε 12.29). [Braun and Jacob *B* **66** 1461 *1933*; UV: Ohloff et al. *B* **90** 106 *1957*.

Ferulic acid see **4-hydroxy-3-methoxycinnamic acid.**

Flavin adenine dinucleotide (diNa, $2H_2O$ salt), see Chapter 5.

Flavin mononucleotide (Na, $2H_2O$ salt), see Chapter 5.

Flavone *[525-82-6]* **M 222.3, m 99-100°.** Crystd from pet ether.

Fluoranthene *[206-44-0]* **M 202.3, m 110-111°.** Purified by chromatography of CCl_4 solns on alumina, with benzene as eluent. Crystd from EtOH, MeOH or benzene. Purified by zone melting. [Gorman et al. *JACS* **107** 4404 *1985*].

2-Fluorenamine *[153-78-6]* **M 181.2, m 131-132°.** Crystd from EtOH.

9-Fluorenamine *[525-03-1]* **M 181.2, m 64-65°.** Crystd from hexane.

Fluorene *[86-73-7]* **M 166.2, m 114.7-115.1°, b 160°/15mm.** Purified by chromatography of CCl_4 or pet ether (b 40-60°) soln on alumina, with benzene as eluent. Crystd from 95% EtOH, 90% acetic acid and again from EtOH. Crystn using glacial acetic acid retained an impurity which was removed by partial mercuration and pptn with LiBr [Brown, Dubeck and Goldman *JACS* **84** 1229 *1962*]. Has also been crystd from hexane, or benzene/EtOH, distd under vacuum and purified by zone refining. [Gorman et al. *JACS* **107** 4404 *1985*].

9-Fluorenone *[486-25-9]* **M 180.2, m 82.5-83.0°, 85-86°, b 341°/760mm.** Crystd from absolute EtOH, MeOH or benzene/pentane. [Ikezawa *JACS* **108** 1589 *1986*]. Also twice recrystd from toluene and sublimed under reduced pressure [Saltiel *JACS* **108** 2674 *1986*]. Can be distd under high vacuum.

***N*-2-Fluorenylacetamide** *[53-96-3]* **M 223.3, m 194-195°.** Crystd from EtOH/water. **CARCINOGEN.**

9-Fluorenylmethyl chloroformate (FMOC-Cl) *[28920-42-6]* **M 258.7, m 61-63°, 61.4-63°.** The IR should contain no OH bands (at ~3000 cm^{-1}) due to the hydrolysis product 9-fluorenylmethanol. Purify by recrystn from dry Et_2O. IR ($CHCl_3$) has band at 1770 cm^{-1} (C=O) and the NMR ($CDCl_3$) has δ at 4-4.6 (m 2H, $CHCH_2$) and 7.1-7.8 (m, 8 aromatic *H*). The *azide* (*FMOC-N_3*) has **m** 89-90° (from hexane) and IR ($CHCl_3$) at 2135 (N_3) and 1730 (C=O) cm^{-1}; and the *carbazate* (*FMOC-$NHNH_2$*) has **m** 171° dec (from nitromethane), IR (KBr) 3310, 3202 (NH) and 1686 (CONH) cm^{-1}. [Caprino and Han *JOC* **37**, 3404 *1972* and *JACS* **92** 5748 *1970*; Koole et al. *JOC* **59** 1657 *1989*; Fürst et al. *JC* **499** 537 *1990*].

9-Fluorenylmethyl succinimidyl carbonate *[82911-69-1]* **M 337.3, m 147-151° (dec), 151° (dec).** Recrystd from $CHCl_3$-Et_2O, or from pet ether (b 40-60°). [Pauet *Canad J Chem* **60** 976 *1982*; Lapatsaris et al. *S* 671 *1983*].

Fluorescein *[2321-07-5]* **M 320.0, ε_{495nm} 7.84 x 10^4 (in 10^{-3}M NaOH).** Dissolved in dilute aqueous NaOH, filtered and ppted by adding dilute (1:1) HCl. The process was repeated twice more and the fluorescein was dried at 100°. Alternatively, it has been crystd from acetone by allowing the soln to evaporate at 37° in an open beaker. Also recrystd from EtOH and dried in a vacuum oven.

Fluoresceinamine (5- and 6-aminofluorescein) *[27599-63-9]* **M 347.3, m 314-316° (dec, 5-isomer) and m >200° (dec, 6-somer).** Dissolve in EtOH, treat with charcoal, filter, evaporate and dry residue in vacuum at 100° overnight. Also recrystallise from 6% HCl, then dissolve in 0.5% aqueous NaOH and ppte by acidifying with acetic acid. The separate amines are made from the respective nitro compounds which are best separated *via* their acetate salts. They have similar R_F of 0.26 on Silica Gel Merck F_{254} in 5 ml MeOH + 150 ml Et_2O satd with H_2O. IR (Me_2SO) has a band at 1690 cm^{-1} (CO_2^-) and sometimes a weak band at 1750 cm^{-1} due to lactone. UV (EtOH) of 6-isomer λmax 222 (ε 60 000) and 5-isomer λmax 222 (ε 60 000) and 285 (ε 20.600). [IR: McKinney and Churchill *JCS-C* 654 *1970*; McKinney et al. *JOC* **27** 3986*1962*; UV: Verbiscar *JOC* **29** 490 *1964*].

Fluorescein isothiocyanate Isomer I (5-isocyanato isomer) *[3326-32-7] [27072-45-3 **mixture of 5- and 6-isomers**]* **M 389.4, m >160° (slow dec).** It is made from the pure 5-amino isomer. Purified by dissolving in boiling Me_2CO, filtering and adding pet ether (b 60-70°) until it becomes turbid. If an oil separates then decant and add more pet ether to the supernatant and cool. Orange-yellow crystals separate, collect and dry *in vacuo*. Should give one spot on TLC(silica gel) in EtOAc, pyridine, AcOH (50:1:1) and in Me_2NCHO, $CHCl_3$, 28% N_4OH (10:5:4). IR (Me_2SO): 2110 (NCS) and 1760 (C=O). The NMR spectra in Me_2CO-d_6 of the 5- and 6-isomers are distinctly different for the protons in the benzene ring; the UV in phosphate buffer pH 8.0 shows a max at ~490nm. [Sinsheimer et al. *AB* **57** 227 *1974*; McKinney et al. *AB* **7** 74 *1964*].

Fluoroacetamide *[640-19-7]* **M 77.1, m 108°.** Crystd from chloroform.

1-Fluoroadamantane see **1-adamantyl fluoride.**

Fluorobenzene *[462-06-6]* **M 96.1, b 84.8°, d 1.025, n 1.46573, n^{30} 1.4610.** Dried for several days with P_2O_5, then fractionally distd.

***o*-Fluorobenzoic acid** *[445-29-4]* **M 140.1, m 127°.** Crystd from 50% aqueous EtOH, then zone melted or vacuum sublimed at 130-140°.

m-**Fluorobenzoic acid** *[445-38-9]* **M 140.1, m 124°.** Crystd from 50% aqueous EtOH, then vacuum sublimed at 130-140°.

p-**Fluorobenzoic acid** *[456-22-4]* **M 140.1, m 182°.** Crystd from 50% aqueous EtOH, then zone melted or vacuum sublimed at 130-140°.

3-Fluoro-4-hydroxyphenylacetic acid *[458-09-3]* **M 170.1, m 33°.** Crystd from water.

1-Fluoro-4-nitrobenzene *[350-46-9]* **M 141.1, m 27° (stable form), 21.5° (unstable form), b 205.3°/735mm, 95-97.5°/22mm, 86.6°/14mm.** Crystd from EtOH.

1-Fluoro-4-nitronaphthalene *[341-92-4]* **M 191.2, m 80°.** Recrystd from EtOH as yellow needles [Bunce et al. *JOC* **52** 4214 *1987*].

o-**Fluorophenol** *[367-12-4]* **M 112.1, m 16°, b 53°/14mm, d 1.257, n 1.514.** Passed at least twice through a gas chromatographic column for small quantities, or fractionally distd under reduced pressure.

p-**Fluorophenoxyacetic acid** *[405-79-8]* **M 170.1, m 106°.** Crystd from EtOH.

4-Fluorophenyl isocyanate *[1195-45-5]* **M 137.1, b 55°/8mm, n_D^{20} 1.514.** Purify by repeated fractionation through an efficient column. If IR indicated that there is too much urea (in the presence of moisture the symmetrical urea is formed) then dissolve in dry EtOH-free $CHCl_3$, filter, evaporate and distil. **It is a pungent LACHRYMATORY liquid.** [see Hardy *JCS* 2011 *1934*; and Hickinbottom *Reactions of Organic Compounds* Longmans p493 *1957*].

p-**Fluorophenylacetic acid** *[405-50-5]* **M 154.1, m 86°.** Crystd from heptane.

4-Fluorophenyl isothiocyanate *[1544-68-9]* **M 153.2, m 24-26°**, 26-27°, **b 66°/2mm, 215°/atm, 228°/760mm, n_D^{20} 1.6116.** Likely impurity is the symmetrical thiourea. Dissolve the isothiocyanate in dry $CHCl_3$, filter and distil the residue in a vacuum. It can also be steam distd, the oily layer separated, dried over $CaCl_2$ and distilled *in vacuo*. *Bis-(4-fluorophenyl)thiourea* has **m** 145° (from aq EtOH). [Browne and Dyson *JCS* 3285 *1931*; Buu Hoi et al. *JCS* 1573 *1955*; Olander *Org Synth* Coll Vol I 448 *1941*].

p-**Fluorophenyl**-*o*-**nitrophenyl ether** *[448-37-3]* **M 247.2, m 62°.** Crystd from EtOH.

o-**Fluorotoluene** *[95-52-3]* **M 110.1, b 114.4°, d 1.005, n 1.475,**
m-**Fluorotoluene** *[352-70-5]* **M 110.1, b 116.5°, d 1.00, n^{27} 1.46524,**
p-**Fluorotoluene** *[352-32-9]* **M 116.0°, d 1.00, n 1.46884.** Dried with P_2O_5 or $CaSO_4$ and fractionally distd through a silvered vacuum-jacketed glass column with 1/8th-in glass helices. A high reflux ratio is necessary because of the closeness of the boiling points of the three isomers [Potter and Saylor *JACS* **37** 90 *1951*].

Folic acid see entry in Chapter 5.

Formaldehyde *[50-00-0]* **M 30.0, m 92°, b -79.6°/20mm, d^{20} 0.815.** Commonly contains added MeOH. Addition of KOH soln (1 mole KOH: 100 moles HCHO) to 40% formaldehyde soln, or evaporation to dryness, gives paraformaldehyde polymer which, after washing with water, is dried in a vacuum desiccator over P_2O_5 or H_2SO_4. Formaldehyde is regenerated by heating the paraformaldehyde to 120° under vacuum, or by decomposing it with barium peroxide. The monomer, a gas, is passed through a glass-wool filter cooled to -48° in $CaCl_2$/ice mixture to remove particles of polymer, then dried by passage over P_2O_5 and either condensed in a bulb immersed in liquid nitrogen or absorbed in ice-cold conductivity water.

Formaldehyde dimethyl acetal (dimethoxy methane, methylal, formal) *[109-87-5]* **M 76.1, m -108°, b 41-42°/736mm, 41-43°/atm, 42-46°/atm, d_4^{20} 0.8608, n_D^{20} 1.35335.** It is a volatile flammable liquid which is soluble in three parts of H_2O. It is readily hydrolysed by acids. Purify by drying

over fused $CaCl_2$, filter and fractionally distil through Clarke and Rahrs column. [Buchler et al. *Org Synth* Coll Vol III 469 *1955*; In Eng Chem **18** 1092 *1926*; Rambaud and Besserre *Bull Soc Chim France* 45 *1955*; IR: *Canad J Chem* **36** 285 *1958*].

Formaldehyde dimethyl mercaptal (bis-[methylthio]methane) *[1618-26-4]* **M 108.2, b 44-47°/13mm, 45.5°/18mm, 148-149°/atm, d_4^{20} 1.0594, n_D^{20} 1.5322. Work in an efficient Fumecupboard as the substance may contain traces (or more) of methylmercaptan which has a very bad odour.** Dissolve in Et_2O, shake with aqueous alkalis then dry over anhydrous K_2CO_3, filter and distil over K_2CO_3 under a stream of N_2. If the odour is very strong then allow all gas efluents to bubble through 5% aqueous NaOH soln which is then treated with dilute $KMnO_4$ in order to oxidise MeSH to odourless products. UV: λmax 238 nm (log ε 2,73) [Fehnel and Carmack *JACS* **71** 85 *1948*; Fehér and Vogelbruch *B* 91 996 *1958*; Bøohme and Marz *B* **74** 1672 *1941*]. Oxidation with aq $KMnO_4$ yields *bis-(methylsulphonyl)methane* which has **m** 142-143° [Fiecchi et al. *TET LETT* 1681 *1967*].

Formamide *[75-12-7]* **M 45.0, f.p. 2.6°, b 103°/9mm, 210.5°/760mm(dec), d 1.13, n 1.44754, n^{25} 1.44682.** Formamide is easily hydrolysed by acids and bases. It also reacts with peroxides, acid halides, acid anhydrides, esters and (on heating) alcohols; while strong dehydrating agents convert it to a nitrile. It is very *hygroscopic*. Commercial material often contains acids and ammonium formate. Vorhoek [*JACS* **58** 2577 *1956*] added some bromothymol blue to formamide and then neutralised it with NaOH before heating to 80-90° under reduced pressure to distil off ammonia and water. The amide was again neutralised and the process was repeated until the liquid remained neutral on heating. Sodium formate was added, and the formamide was reduced under reduced pressure at 80-90°. The distillate was again neutralised and redistd. It was then fractionally crystd in the absence of CO_2 and water by partial freezing.
Formamide (specific conductance 2 x 10^{-7} ohm^{-1} cm^{-1}) of low water content was dried by passage through a column of 3A molecular sieves, then deionized by treatment with a mixed-bed ion-exchange resin loaded with H^+ and $HCONH^-$ ions (using sodium formamide in formamide)[Notley and Spiro *JCS(B)* 362 *1966*].

Formamidine sulphinic acid *[1758-73-2]* **M 108.1, m 124-126°(dec).** Dissolved in five parts of aq 1:1% $NaHSO_3$ at 60-63° (charcoal), then crystd slowly, with agitation, at 10°. Filtered. Dried immediately at 60° [Koniecki and Linch *AC* **30** 1134 *1958*].

Formanilide *[103-70-8]* **M 121.1, m 50°, b 166°/14mm, 216°/120mm, d 1.14.** Crystd from ligroin/xylene.

Formic acid *[64-18-6]* **M 46.0 (anhydr), f.p. 8.3°, b 25°/40mm, 100.7°/760mm, n 1.37140, n^{25} 1.36938, d 1.22.** Anhydrous formic acid can be obtained by direct fractional distillation under reduced pressure, the receiver being cooled in ice-water. The use of P_2O_5 or $CaCl_2$ as dehydrating agents is unsatisfactory. Reagent grade 88% formic acid can be satisfactorily dried by refluxing with phthalic anhydride for 6h and then distilling. Alternatively, if it is left in contact with freshly prepared anhydrous $CuSO_4$ for several days about one half of the water is removed from 88% formic acid: distn removes the remainder. Boric anhydride (prepared by melting boric acid in an oven at a high temperature, cooling in a desiccator, and powdering) is a suitable dehydrating agent for 98% formic acid; after prolonged stirring with the anhydride the formic acid is distd under vacuum. Formic acid can be further purified by fractional crystn using partial freezing.

Forskolin (5-[acetyloxy]-3-ethenyldodecahydro-6,10,10b-trihydroxy-3,4a,7,7,10a-pentamethyl-[3*R*-{3α-4aβ, 5β, 6β, 6aα,10α, 10aβ, 10bα}-1*H*-naphtho[2,1-b]pyran-1-one) *[66575-29-9]* **M 410.5, m 229-232°, 228-233°.** Recrystd from C_6H_6-pet ether. [*Chem Abstr* **89** 1978 244150].

D(-)-Fructose *[57-48-7]* **M 180.2, m 103-106°, $[\alpha]_{546}^{20}$ -190° (after 1h, c 10, H_2O).** Dissolved in an equal weight of water (charcoal, previously washed with water to remove any soluble material), filtered and evaporated under reduced pressure at 45-50° to give a syrup containing 90% of fructose. After cooling to 40°, the syrup was seeded and kept at this temperature for 20-30h with occasional stirring. The crystals were removed by centrifugation, washed with a small quantity of water and dried to constant weight under a vacuum

over conc H_2SO_4. For higher purity, this material was recrystd from 50% aqueous ethanol [Tsuzuki, Yamazaki and Kagami *JACS* **72** 1071 *1950*].

Fructose-1,6-diphosphate (trisodium salt) *[38099-82-0]* **M 406.1.** For purification *via* the acid strychnine salt, see Neuberg, Lustig and Rothenberg [*Arch Biochem* **3** 33 *1943*]. The calcium salt can be partially purified by soln in ice-cold M HCl (1g per 10ml) and repptn by dropwise addition of 2M NaOH: the ppte and supernatant are heated on a boiling water bath for a short time, then filtered and the ppte is washed with hot water. The magnesium salt can be pptd from cold aqueous soln by adding four volumes of EtOH.

Fructose-6-phosphate *[643-13-0]* **M 260.1.** Crystd as the barium salt from water by adding four volumes of EtOH. The barium can be removed by passage through the H^+ form of a cation exchange resin and the free acid collected by freeze-drying.

D(+)-Fucose *[3615-37-0]* **M 164.2, m 144°, $[\alpha]_{546}^{20}$ +89° (after 24h, c 10 in H_2O).** Crystd from EtOH.

Fullerene C_{60} (Buckminsterfullerene C_{60}, Footballene, Buckyball 60) *[99685-96-8]* **M 720.66 and Fullerene C_{70}** *[115383-22-7]* **M 840.77.** Purified from the soluble toluene extract (400mg) of the soot (Fullerite) formed from resistive heating of graphite by adsorption on neutral alumina (100g; Brockmann I; 60 x 8cm). Elution with toluene-hexane (5:95 v/v) gives *ca* 250mg of quite pure C_{60}. It has characteristic spectral properties (see below). Further elution with toluene-hexane (20:80 v/v; i.e. increased polarity of solvent) provides 50mg of "pure" C_{70} [*JACS* **113** 1050 *1991*].
Chromatography on alumina can be improved by using conditions which favour adsorption rather than crystn. Thus the residue from toluene extraction (1g) in CS_2 (*ca* 300ml) is adsorbed on alumina (375g, standard grade, neutral *ca* 150 mesh, Brockmann I) and loaded as a slurry in toluene-hexanes (5:95 v/v) to a 50 x 8cm column of alumina (1.5Kg) in the same solvent. To avoid crystn of the fullerenes, 10% of toluene in hexanes is added quickly followed by 5% of toluene in hexanes after the fullerenes had left the loading fraction (2-3h). With a flow rate of 15ml/min the purple C_{60} fraction is eluted during a 3-4h period. Evapn of the eluates gives 550-630mg of product which, after recrystn from CS_2-cyclohexane yields 520-600mg of C_{60} which contains adsorbed solvent. On drying at 275°/10^{-3}mm for 48h a 2% weight loss is observed although the C_{60} still contains traces of solvent. Further elution of the column with 20% of toluene in hexanes provides 130mg of C_{70} containing 10-14% of C_{60} (by ^{13}C NMR). This was rechromatographed as above using a half scale column and adsorbing the 130mg in CS_2 (20ml) on alumina (24g) and gave 105mg of recrystd C_{70} (containing 2% of C_{60}). The purity of C_{60} can be improved further by washing the crystalline product with Et_2O and Me_2CO followed by recrystn from C_6H_6 and vacuum drying at high temperatures. [*JCSCC* 956 *1922*].
Carbon soot from resistive heating of a carbon rod in a partial helium atmosphere (0.3bar) under specified conditions is extracted with boiling C_6H_6 or toluene, filtered and the red-brown soln evapd to give crystalline material in 14% yield which is mainly a mixture of fullerenes C_{60} and C_{70}. Chromatographic filtration of the 'crude' mixture with C_6H_6 allows no separation of components, but some separation was observed on silica gel TLC with *n*-hexane or *n*-pentane, but not cyclohexane. Analytical HPLC with hexanes (5µm Econosphere silica) gave satisfactory separation of C_{60} and C_{70} (retention times of 6.64 and 6.93min respectively) at a flow rate of 0.5ml/min and using a detector at 256nm. HPLC indicated the presence of minor (<1.5% of total mass) unidentified C_n with species (retention times of 5.86 and 8.31min. Column chromatography on flash silica gel with hexanes gives a few fractions of C_{60} with ≥95% purity but later fractions contain mixtures of C_{60} and C_{70}. These can be obtained in 99.85 and >99% purity respectively by column chromatography on neutral alumina. [*JPC* **94** 8630 *1990*].
Separation of C_{60} and C_{70} can be achieved by HPLC on a dinitroanilinopropyl (DNAP) silica (5µm pore size, 300Å pore diameter) column with a gradient from *n*-hexane to 50% CH_2Cl_2 using a diode array detector at wavelengths 330nm (for C_{60}) and 384nm (for C_{70}). [*JACS* **113**, 2940, *1991*].
Soxhlet extraction of the "soot" is a good preliminary procedure, or if material of only *ca* 98% purity is required. Soxhlet extraction with toluene is run (20min per cycle) until colourless solvent filled the upper part of the Soxhlet equipment (10h). One third of the toluene remained in the pot. After cooling, the solution was filtered through a glass frit. This solid (purple in toluene) was *ca* 98% C_{60}. This powder was again extracted in a Soxhlet using identical conditions as before and the C_{60} was recrystd from toluene to give 99.5% pure C_{60}. C_{70} has greater affinity than C_{h60} for toluene. [*JCSCC* 1402 *1992*].

Purification of C_{60} from a C_{60}/C_{70} mixture was achieved by dissolving in an aqueous soln of γ (but not β) cyclodextrin (0.02M) upon refluxing. The rate of dissolution (as can be followed by UV spectra) is quite slow and constant up to 10^{-5}M of C_{60}. The highest concn of C_{60} in H_2O obtained was 8 x 10^{-5}M and a 2 γ–cyclodextrin:1 C_{60} clathrate is obtained. C_{60} is extracted from this aqueous soln by toluene and C_{60} of >99 purity is obtained by evaporation. With excess of γ–cyclodextrin more C_{60} dissolves and the complex precipitates. The ppte is insol in cold H_2O but sol in boiling H_2O to give a yellow soln. [*JCSCC* 604 *1922*].

C_{60} and C_{70} can also be readily purified by inclusion complexes with *p*-ter-butylcalix[6] and [8]arenes. Fresh carbon-arc soot (7.5g) is stirred with toluene (250ml) for 1h and filtered. To the filtrate is added *p*-ter-butylcalix[8]arene, refluxed for 10min and filtered. The filtrate is seeded and set aside overnight at 20°. The C_{60} complex separated as yellow-brown plates and recrystd twice from toluene (1g from 80ml), 90% yield. Addition of $CHCl_3$ (5ml) to the complex (0.85g) gave C_{60} (0,28g, 92% from recryst complex).

p-ter-Butylcalix[6]arene-$(C_{60})_2$ complex is prepared by adding to a refluxing soln of C_{60} (5mg) in toluene (5ml), *p*-ter-butylcalix[6]arene (4.4mg). The hot soln was filtered rapidly and cooled overnight to give prisms (5.5mg, 77% yield).. Pure C_{60} is obtained by decomposing the complex with $CHCl_3$ as above.

The *p*-ter-butylcalix[6]arene-$(C_{70})_2$ complex is obtained by adding *p*-ter-butylcalix[6]arene (5.8mg) to a refluxing soln of C_{70} (5mg) in toluene (2ml), filtering hot and slowly cooling. to give red-brown needles (2.5mg, 31% yield) of the complex. Pure C_{70} is then obtained by decomposing the complex with $CHCl_3$.

Decomposition of these complexes can also be achieved by boiling a toluene soln over KOH pellets for *ca* 10min. The calixarenes form Na salts which do not complex with the fullerenes. These appear to be the most satisfactory means at present for preparing large quantities of relatively pure fullerene C_{60} and C_{70} and is considerably cheaper than previous methods. [*Nature* **368** 229 *1994*].

Repeated chromatography on neutral alumina yields minor quantities of solid samples of C_{76}, C_{84}, C_{90} and C_{94} believed to be higher fullerenes. A stable oxide $C_{70}O$ has been identified. Chromatographic procedures for the separation of these compounds are reported. [*Science* **252** 548 *1991*].

Physical properties of Fullerene C_{60}: It does not melt below 360°, and starts to sublime at 300° *in vacuo*. It is a mustard coloured solid that appears brown or black with increasing film thickness. It is soluble in common organic solvents, particularly aromatic hydrocarbons which give a beautiful magenta colour. Toluene solutions are purple in colour. Sol in C_6H_6 (5mg/ml), but dissolves slowly. Crysts of C_{60} are both needles and plates.

UV-Vis in hexanes: λmax nm(log ε) 211(5.17), 227sh(4.91), 256(5.24), 328(4.71), 357sh(4.08), 368sh(3.91), 376sh(3.75), 390(3.52), 395sh(3.30), 403(3.48), 407(3.78), 492sh(2.72)< 540(2.85), 568(2.78), 590(2.86), 598(2.87) and 620(2.60).

IR (KBr): ν 1429m, 1182m, 724m, 576m and 527s cm^{-1}. ^{13}C NMR: one signal at 142,68ppm.

Physical properties of Fullerene C_{70}: It does not melt below 360°, and starts to sublime at 350° *in vacuo*. A reddish-brown solid, greenish black in thicker films. Solns are port-wine red in colour. Mixtures of C_{60} and C_{70} are red due to C_{70} being more intensely coloured. It is less soluble than C_{60} in C_6H_6 but also dissolves slowly. C_{70} gives orange coloured soln in toluene. Drying at 200-250° is not sufficient to remove All solvent. Samples need to be sublimed to be free from solvent.

UV-Vis in hexanes: λmax nm(log ε) 214(5.05), 235(5.06), 249sh(4.95), 268sh(4.78), 313(4.23), 330(4.38), 359(4.29), 377(4.45), 468(4.16), 542(3.78), 590sh(3.47), 599sh(3.38), 609(3.32), 623sh(3.09), 635sh(3.13) and 646sh(2.80).

IR (KBr): ν 1430m, 1428m, 1420m, 1413m, 1133mw, 1087w, 795s, 674ms, 642ms, 5778s, 566m, 535ms and 458m cm^{-1}.

^{13}C NMR [run in the presence of Cr(pentan-2,4-dione)$_3$ which induces a *ca* 0.12pp in the spectrum]: Five signals at 150.07, 147.52, 146.82, 144.77 and 130.28ppm, unaffected by proton decoupling.

Fumagillin *[101993-69-5]* **M 458.5, m 194-195°, $[\alpha]_D^{20}$ -26.2° (in 95% EtOH).** Forty grams of a commercial sample containing 42% fumagillin, 45% sucrose, 10% antifoam agent and 3% of other impurities were digested with 150ml of $CHCl_3$. The insoluble sucrose was filtered off and washed with $CHCl_3$. The combined $CHCl_3$ extracts were evapd almost to dryness at room temperature under reduced pressure. The residue was triturated with 20ml of MeOH and the fumagillin was filtered off by suction. It was crystd twice from 500ml of hot MeOH by standing overnight in a refrigerator. (The long chain fatty ester used as antifoam agent

was still present, but was then removed by repeated digestion, on a steam bath, with 100ml of ethyl ether.) For further purification, the fumagillin (10g) was dissolved in 150ml of 0.2M ammonia, and the insoluble residue was filtered off. The ammonia soln (cooled in running cold water) was then brought to pH 4 by careful addn of M HCl with constant shaking in the presence of 150ml of $CHCl_3$. (Fumagillin is acid-labile and must be removed rapidly from the aq acid soln.) The $CHCl_3$ extract was washed several times with distd water, dried (Na_2SO_4) and evaporated under reduced pressure. The solid residue was washed with 20ml of MeOH. The fumagillin was filtered by suction, then crystd from 200ml of hot MeOH. [Tarbell et al. *JACS* **77** 5610 *1955*]. Alternatively, 10g of fumagillin in 100ml $CHCl_3$ was passed through a silica gel (5g) column to remove tarry material, and the $CHCl_3$ was evaporated to leave an oil which gave fumagillin on crystn from amyl acetate. It recrystallises from MeOH (charcoal). The fumagillin was stored in dark bottles in the absence of oxygen and at low temperatures. [Schenk, Hargie and Isarasena *JACS* **77** 5606 *1955*].

Fumaraldehyde bis-(dimethyl acetal) (1,1,4,4-tetramethoxybut-2*t*-ene) *[6068-62-8]* **M 176.2, b 100-103°/15mm, 101-103°/25mm,** d_4^{20} **1.011,** n_D^{20} **1.425.** Dry over fused $CaCl_2$ and dist *in vacuo*. The maleic (cis) isomer has **b** 112°/11mm, and d^{23} 0.932 and n_D^{25}1.4243. [Zeik and Heusner *B* **90** 1869 *1957*; Clauson-Kaas et al. *Acta Chem Scand* **9** 111 *1955;* Clauson-Kaas *Acta Chem Scand* **6** 569 *1952*].

Fumaric acid *[110-17-8]* **M 116.1, m 289.5-291.5° (sealed tube).** Crystd from hot M HCl or water. Dried at 100°.

Furan *[110-00-9]* **M 68.1, b 31.3°, d 1.42, n 1.4214.** Shaken with aqueous 5% KOH, dried with $CaSO_4$ or Na_2SO_4, then distd under nitrogen, from KOH or sodium, immediately before use. A trace of hydroquinone could be added as an inhibitor of oxidation.

2-Furanacrylic acid *[539-47-9]* **M 138.1, m 141°.** Crystd from H_2O or pet ether (b 80-100°)(charcoal).

Furan-2-carboxylic acid *[88-14-2]* **M 112.1, m 133-134°, b 141-144°/20mm, 230-232°/760mm.** Crystd from hot water (charcoal), dried at 120° for 2h, then recrystd from $CHCl_3$, and again dried at 120° for 2h. For use as a standard in volumetric analysis, good quality commercial acid should be crystd from $CHCl_3$ and dried as above or sublimed at 130-140° at 50-60mm or less.

Furan-3-carboxylic acid *[488-93-7]* **M 112.1, m 122-123°,**
Furan-3,4-dicarboxylic acid *[3387-26-6]* **M 156.1, m 217-218°.** Crystd from water.

Furfural *[98-01-1]* **M 96.1, b 54-56°/11mm, 59-60°/15mm, 67.8°/20mm, 90°/65mm, 161°/760mm,** d_4^{20} **1.159,** n_D^{20} **1.52608.** Unstable to air, light and acids. Impurities include formic acid, ß-formylacrylic acid and furan-2-carboxylic acid. Distd over an oil bath from 7% (w/w) Na_2CO_3 (added to neutralise acids, especially pyromucic acid). Redistd from 2% (w/w) Na_2CO_3, and then, finally fractionally distd under vacuum. It is stored in the dark. [Evans and Aylesworth *IECAE* **18** 24 *1926*].
Impurities resulting from storage can be removed by passage through chromatographic grade alumina. Furfural can be separated from impurities other than carbonyl compounds by the bisulphite addition compound. The aldehyde is steam volatile.
It has been purified by distn (using a Claisen head) under reduced pressure. This is essential as is the use of an oil bath with temperatures of no more than 130° are highly recommended. When furfural is distd at atm press (in a stream of N_2), or under reduced pressure with a free flame (caution because the aldehyde is flammable) an almost colourless oil is obtained. After a few days and sometimes a few hours the oil gradually darkens and finally becomes black. This change is accelerated by light but occurs more slowly when kept in a brown bottle. However, when the aldehyde is distd under vacuum and the bath temperature kept below 130° during the distn, the oil develops only a slight colour when exposed to direct sunlight during several days. The distn of very impure material should NOT be attempted at atm pressure otherwise the product darkens rapidly. After one distn under vacuum a distn at atmospheric pressure can be carried out without too much decomposition and darkening. The liquid **irritates mucous membranes.** Store in dark containers under N_2. [Adams and Voorhees *Org Synth* Coll Vol I 280 *1941*].

2-Furfuraldehyde see **furfural.**

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Furfuryl alcohol *[98-00-0]* **M 98.1, b 68-69°/20mm, 170.0°/750mm, d 1.132, n 1.4873, n^{30} 1.4801.** Distd under reduced pressure to remove tarry material, shaken with aqueous $NaHCO_3$, dried with Na_2SO_4 and fractionally distd under reduced pressure from Na_2CO_3. Further dried by shaking with Linde 5A molecular sieves.

Furfuryl amine *[617-89-0]* **M 97.1, b 142.5-143°/735mm, d 1.059, n 1.489.** Distd under nitrogen from KOH through a column packed with glass helices.

Furil *[492-94-4]* **M 190.2, m 165-166°.** Crystd from MeOH or benzene (charcoal).

2-Furoic acid see **furan-2-carboxylic acid.**

Furoin *[552-86-3]* **M 192.2, m 135-136°.** Crystd from MeOH (charcoal).

Furylacrylic acid see **2-furanacrylic acid.**

Galactaric Acid (mucic acid)

[526-99-6] **M 210.1, m 212-213°(dec).** Dissolved in the minimum volume of dil aq NaOH, and ppted by adding dil HCl. The temperature should be kept below 25°.

D-Galactonic acid *[576-36-3]* **M 196.2, m 148°.** Crystd from EtOH.

D(-)-Galactono-1,4-lactone *[2782-07-2]* **M 178.1, m 134-137°, $[\alpha]_D^{20}$ -78° (in H_2O).** Crystd from EtOH.

D(+)-Galactosamine hydrochloride *[1772-03-8]* **M 215.6, m 181-185°, $[\alpha]_D^{25}$ +96.4° (after 24h, c 3.2 in H_2O).** Dissolved in a small volume of H_2O. Then added three volumes of EtOH, followed by acetone until faintly turbid and stood overnight in a refrigerator. [Roseman and Ludoweig *JACS* **76** 301 *1954*].

α-D-Galactose *[59-23-4]* **M 180.2, m 167-168°, $[\alpha]_D^{20}$ +80.4° (after 24h, c 4 in H_2O).** Crystd twice from aqueous 80% EtOH at -10°, then dried under vacuum over P_2O_5.

Gallic acid (H_2O) *[149-91-7]* **M 188.1, m 253°(dec).** Crystd from water.

Genistein *[446-72-0]* **M 270.2, m 297-298°.** Crystd from 60% aqueous EtOH or water.

Genistin *[529-59-9]* **M 432.4, m 256°.** Crystd from 80% EtOH/water.

α-Gentiobiose *[16750-26-8]* **M 342.3, m 86°.** Crystd from MeOH (retains solvent of crystn).

β-Gentiobiose *[554-91-6]* **M 342.3, m 190-195°.** Crystd from EtOH.

Geraniol *[106-24-1]* **M 154.3, b 230°, d 0.879, n 1.4766.** Purified by ascending chromatography or by thin layer chromatography on plates of kieselguhr G with acetone/water/liquid paraffin (130:70:1) as solvent system. Hexane/ethyl acetate (1:4) is also suitable. Also purified by GLC on a silicone-treated column of Carbowax 20M (10%) on Chromosorb W (60-80 mesh). [Porter *PAC* **20** 499 *1969*]. Stored in full, tightly sealed containers in the cool, protected from light.

Geranylgeranyl pyrophosphate *[6699-20-3]* **M 450.5.** Purified by counter-current distribution between two phases of a butanol/isopropyl ether/ammonia /water mixture (15:5:1:19) (v/v), or by chromatography on DEAE-cellulose (linear gradient of 0.02M KCl in 1mM Tris buffer, pH 8.9). Stored as a powder at 0°.

Geranyl pyrophosphate *[763-10-0]* **M 314.2.** Purified by paper chromatography on Whatman No 3 MM paper in a system of isopropyl alcohol/isobutyl alcohol/ammonia/water (40:20:1:39), R_F 0.77-0.82. Stored in the dark as the ammonium salt at 0°.

Gibberillic acid *[77-06-5]* **M 346.4, m 233-235°(dec), $[\alpha]_{546}^{20}$ +92° (c 1, MeOH).** Crystd from ethyl acetate.

Girard Reagent T *[123-46-6]* **M 167.6, m 192°.** Crystd from absolute EtOH.

Glucamine *[488-43-7]* **M 181.2, m 127°.** Crystd from MeOH.

D-Gluconamide *[3118-85-2]* **M 197.2, m 144°, $[\alpha]_D^{23}$ +31° (c 2, H_2O).** Crystd from EtOH.

D-Glucono-δ-lactone *[90-80-2]* **M 178.1, m 152-153°, $[\alpha]_{546}^{20}$ +76° (c 4, H_2O).** Crystd from ethylene glycol monomethyl ether and dried for 1h at 110°.

Glucosamine *[3416-24-8]* **M 179.2, m 110°(dec).** Crystd from MeOH.

D-Glucosamine hydrochloride *[66-84-2]* **M 215.6, m >300°, $[\alpha]_D^{25}$ +71.8° (after 20h, c 4, H_2O).** Crystd from 3M HCl, water, and finally water/EtOH/acetone as for galactosamine hydrochloride.

α-D-Glucose *[492-62-6]* **M 180.2, m 146°, $[\alpha]_D^{20}$ +52.5° (after 24h, c 4, H_2O).** Recrysts slowly from aqueous 80% EtOH, then vacuum dried over P_2O_5. Alternatively, crystd from water at 55°, then dried for 6h in a vacuum oven between 60-70° at 2mm.

β-D-Glucose *[50-99-7]* **M 180.2, m 148-150°.** Crystd from hot glacial acetic acid.

α-D-Glucose pentaacetate *[604-68-2]* **M 390.4, m 110-111°, $[\alpha]_{546}^{20}$ +119° (c 5, $CHCl_3$),**
β-D-Glucose pentaacetate *[604-69-3]* **M 390.4, m 131-132°, $[\alpha]_{546}^{20}$ +5° (c 5, $CHCl_3$).** Crystd from MeOH or EtOH.

D-Glucose phenylhydrazone *[534-97-4]* **M 358.4, m 208°.** Crystd from aqueous EtOH.

Glucose-1-phosphate *[59-56-3]* **M 260.1.** Two litres of 5% aq soln was brought to pH 3.5 with glacial acetic acid (+ 3g of charcoal, and filtered). An equal volume of EtOH was added, the pH was adjusted to 8.0 (glass electrode) and the soln was stored at 3° overnight. The ppte was filtered off, dissolved in 1.2L of distd water, filtered and an equal volume of EtOH was added. After standing at 0° overnight, the crystals were collected at the centrifuge, and washed with 95% EtOH, then absolute EtOH, ethanol/ethyl ether (1:1), and ethyl ether. [Sutherland and Wosilait, *JBC* **218** 459 *1956*]. Its barium salt can be crystd from water and EtOH. Heavy metal impurities can be removed by passage of an aqueous soln (*ca* 1%) through an Amberlite IR-120 column (in the appropriate H^+, Na^+ or K^+ forms).

Glucose-6-phosphate ***[sodium salt** 54010-71-8]* **M 260.1.** Can be freed from metal impurities as described for glucose-1-phosphate. Its barium salt can be purified by solution in dilute HCl and pptn by neutralising the soln. The ppte is washed with small volumes of cold water and dried in air.

D-Glucuronic acid *[6556-12-3]* **M 194.1, m 165°, $[\alpha]_D^{20}$ +36° (c 3, H_2O).** Crystd from EtOH or ethyl acetate.

D-Glucuronolactone *[32449-92-6]* **M 176.1, m 175-177°, $[\alpha]_{546}^{20}$ +22° (after 24h, c 10, H_2O).** Crystd from water.

L-Glutamic acid *[56-86-0]* **M 147.1, m 224-225°(dec), $[\alpha]_D^{25}$ +31.4° (c 5, 5M HCl).** Crystd from H_2O acidified to pH 3.2 by adding 4 volumes of EtOH, and dried at 110°. Likely impurities are aspartic acid and cysteine.

L-Glutamic acid-5-benzyl ester *[1676-73-9]* **M 237.3, m 179-181°** $[\alpha]_{589}^{20}$ **19.3° (c 1, HOAc.** Recrystd from H_2O and stored at 0°. [Estrin *Biochem Preps* **13** 25 *1971*].

L-Glutamine *[56-85-9]* **M 146.2, m 184-185°,** $[\alpha]_D^{25}$ **+31.8° (M HCl).** Likely impurities are glutamic acid, ammonium pyroglutamate, tyrosine, asparagine, isoglutamine, arginine. Crystd from water.

Glutaraldehyde *[111-30-8]* **M 100.1, b 71°/10mm, as 50% aq soln.** Likely impurities are oxidation products - acids, semialdehydes and polymers. It can be purified by repeated washing with activated charcoal (Norit XX) followed by vacuum filtration, using 15-20g charcoal/100ml of glutaraldehyde soln.
Vacuum distn at 60-65°/15mm, discarding the first 5-10%, was followed by dilution with an equal volume of freshly distilled water at 70-75°, using magnetic stirring under nitrogen. The soln is stored at low temp (3-4°), in a tightly stoppered container, and protected from light. Standardised by titration with hydroxylamine. [Anderson *J Histochem Cytochem* **15** 652 *1967*].

Glutaric acid *[110-94-1]* **M 132.1, m 97.5-98°.** Crystd from benzene, $CHCl_3$, distilled water or benzene containing 10% (w/w) of ethyl ether. Dried under vacuum.

Glutathione *[70-18-8]* **M 307.3, m 195°(dec),** $[\alpha]_D^{27}$ **-21.3° (c 2, H_2O).** Crystd from 50% aq EtOH.

***dl*-Glyceraldehyde** *[56-82-6]* **M 90.1, m 145°.** Crystd from EtOH/ethyl ether.

Glycerol *[56-81-5]* **M 92.1, m 18.2°, b 182°/20mm, 290°/760mm, d 1.261,** n^{25} **1.47352.** Glycerol was dissolved in an equal volume of *n*-butanol (or *n*-propanol, amyl alcohol or liquid ammonia) in a water-tight container, cooled and seeded while slowly revolving in an ice-water slurry. The crystals were collected by centrifugation, then washed with cold acetone or isopropyl ether. [Hass and Patterson *IEC* **33** 615 *1941*]. Coloured impurities can be removed from substantially dry glycerol by extraction with 2,2,4-trimethylpentane. Alternatively, glycerol can be decolorized and dried by treatment with activated charcoal and alumina, followed by filtering. Glycerol can be distd at 15mm in a stream of dry nitrogen, and stored in a desiccator over P_2O_5. Crude glycerol can be purified by digestion with conc H_2SO_4 and saponification with a lime paste, then re-acidified with H_2SO_4, filtered, treated with an anion exchange resin and fractionally distd under vacuum.

Glycinamide hydrochloride *[1668-10-6]* **M 110.5, m 186-189° (207-208°).** Crystd from EtOH.

Glycine see **aminoacetic acid.**

Glycine ethyl ester hydrochloride *[623-33-6]* **M 136.9, m 145-146°,**
Glycine hydrochloride *[6000-43-7]* **M 111.5, m 176-178°.** Crystd from absolute EtOH.

Glycine methyl ester hydrochloride *[5680-79-5]* **M 125.6, m 174°(dec).** Crystd from MeOH.

Glycine *p*-nitrophenyl ester hydrobromide. *[7413-60-7]* **M 277.1, m 214° (dec).** Recryst from MeOH by adding ethyl ether. [Alners et al. *Biochem Preps* **13** 22 *1971*].

Glycocholic acid *[475-31-0]* **M 465.6, m 154-155°,** $[\alpha]_{546}^{20}$ **+37° (c 1, EtOH).** Crystd from hot water. Dried at 100°.

Glycol dimethyl ether see **1,2-Dimethoxyethane.**

Glycollic acid *[79-14-1]* **M 76.1, m 81°.** Crystd from ethyl ether.

***N*-Glycylaniline** *[555-48-6]* **M 150.2.** Crystd from water.

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Glycylglycine *[556-50-3]* **M 132.1, m 260-262°(dec).** Crystd from aqueos 50% EtOH or water at 50-60° by addition of EtOH. Dried at 110°.

Glycylglycine hydrochloride *[13059-60-4]* **M 168.6.** Crystd from 95% EtOH.

Glycylglycylglycine see **diglycylglycine.**

Glycyl-L-proline *[704-15-4]* **M 172.2, m 185°.** Crystd from water at 50-60° by addition of EtOH.

***dl*-Glycylserine** *[687-38-7]* **M 162.2, m 207°(dec).** Crystd from H_2O (charcoal) by addition of EtOH.

Glycyrrhizic acid ammonium salt ($3H_2O$) *[53956-04-0]* **M 823.0, m 210°(dec).** Crystd from glacial acetic acid, then dissolved in ethanolic ammonia and evaporated.

Glyoxal bis(2-hydroxyanil) *[1149-16-2]* **M 240.3, m 210-213°, ε_{294nm} 9880.** Crystd from MeOH or EtOH.

Glyoxaline see **imidazole.**

Glyoxylic acid *[298-12-4]* **M 74.0, m 98°(anhydr), 50-52°(monohydrate).** Crystd from water as the monohydrate.

Gramicidin S *[113-73-5]* **M 1141.4, m 268-270°.** Crystd from EtOH.

Gramine *[87-52-5]* **M 174.3, m 134°.** Crystd from ethyl ether, ethanol or acetone.

Griseofulvin *[126-07-8]* **M 352.8, m 220°, $[\alpha]_D^{22}$ +365° (c 1, acetone).** Crystd from benzene.

Guaiacic acid *[500-40-3]* **M 328.4, m 99-100.5°.** Crystd from EtOH.

Guaiacol *[90-05-1]* **M 124.1, m 32°, b 106°/24mm, 205°/746mm.** Crystd from benzene/pet ether or distd.

Guaiacol carbonate *[553-17-3]* **M 274.3, m 88.1°.** Crystd from EtOH.

Guanidine *[113-00-8]* **M 59.1.** Crystd from water/EtOH under nitrogen. Very deliquescent and absorbs CO_2 from the air readily.

Guanidine carbonate *[593-85-1]* **M 180.2, m 197°.** Crystd from MeOH.

Guanidine hydrochloride *[50-01-1]* **M 95.5, m 181-183°.** Crystd from hot methanol by chilling to about -10°, with vigorous stirring. The fine crystals were filtered through fritted glass, washed with cold (-10°) methanol, dried at 50° under vacuum for 5h. (The product is more pure than that obtained by crystn at room temperature from methanol by adding large amounts of ethyl ether.) [Kolthoff et al. *JACS* **79** 5102 *1957*].

Guanosine (H_2O) *[118-00-3]* **M 283.2, m 240-250°(dec), $[\alpha]_{546}^{20}$ -86° (c 1, 0.1M NaOH),**
Guanylic acid *[85-32-5]* **M 363.2, m 208°(dec).** Crystd from water. Dried at 110°.

Haematin *[15489-90-4]* M 633.5, m 200°(dec). Crystd from pyridine. Dried at 40° *in vacuo*.

Haematoporphyrin dimethyl ester *[33070-12-1]* **M 626.7, m 212°.** Crystd from $CHCl_3$/MeOH.

Haematoxylin *[517-28-2]* **M 302.3, m 100-120°.** Crystd from dil aqueous $NaHSO_3$ until colourless.

Haemin *[16009-13-5]* **M 652.0, m >300°(dec).** Crystd from glacial acetic acid or $CHCl_3$/pyridine/acetic acid.

Hagemann's ester see **4-carbethoxy-3-methyl-2-cyclohexen-1-one.**

Harmine *[442-51-3]* **M 212.3, m 261°(dec).** Crystd from MeOH.

Harmine hydrochloride (hydrate) *[343-27-1]* **M 248.7, m 280°(dec).** Crystd from water.

Hecogenine acetate *[915-35-5]* **M 472.7, m 265-268°, $[\alpha]_D^{23}$ -4.5° (c 1, $CHCl_3$).** Crystd from MeOH.

Heptadecanoic acid *[506-12-7]* **M 270.5, m 60-61°, b 227°/100mm.** Crystd from MeOH or pet ether.

1-Heptadecanol *[1454-85-9]* **M 256.5, m 54°.** Crystd from acetone.

Heptafluoro-2-iodopropane *[677-69-0]* **M 295.9, b 41°.** Purified by gas chromatography on a triacetin column, followed by bulb-to-bulb distn at low temperature. Stored over Cu powder to stabilise it.

***n*-Heptaldehyde** *[111-71-7]* **M 114.2, b 40.5°/12mm, 152.8°/760mm, d 0.819, n^{25} 1.4130.** Dried with $CaSO_4$ or Na_2SO_4 and fractionally distd under reduced pressure. More extensive purification by pptn as the bisulphite compound (formed by adding the aldehyde to saturated aqueous $NaHSO_3$) which was filtered off and recrystd from hot H_2O. The crystals, after being filtered and washed well with H_2O, were hydrolysed by adding 700ml of aqueous Na_2CO_3 (12.5% w/w of anhydrous Na_2CO_3) per 100g of aldehyde. The aldehyde was then steam distd, separated, dried with $CuSO_4$ and distd under reduced pressure in a slow stream of nitrogen. [McNesby and Davis *JACS* **76** 2148 *1954*].

***n*-Heptaldoxime** *[629-31-2]* **M 129.2, m 53-55°.** Crystd from 60% aqueous EtOH.

***n*-Heptane** *[142-18-5]* **M 100.2, b 98.4°, d 0.684, n 1.38765, n^{25} 1.38512.** Passage through a silica gel column greatly reduces the ultraviolet absorption of *n*-heptane. (The silica gel is previously heated to 350° before use.) For more extensive purification, heptane is shaken with successive small portions of conc H_2SO_4 until the lower (acid) layer remains colourless. The heptane is then washed successively with water, aq 10% Na_2CO_3, water (twice), and dried with $CaSO_4$, $MgSO_4$ or $CaCl_2$. It is distd from sodium. *n*-Heptane can be distd azeotropically with methanol, then the methanol can be washed out with water and, after drying, the heptane is redistd. Other purification procedures include passage through activated basic alumina, drying with CaH_2, storage with sodium, and stirring with 0.5*N* $KMnO_4$ in 6N H_2SO_4 for 12h after treatment with conc H_2SO_4. Carbonyl-containing impurities have been removed by percolation through a column of impregnated Celite made by dissolving 0.5g of 2,4-dinitrophenylhydrazine in 6ml of 85% H_3PO_4 by grinding together, then adding 4ml of distilled water and 10g Celite. [Schwartz and Parks *AC* **33** 1396 *1961*].

4-Heptanone see **di-isopropyl ketone.**

Hept-1-ene *[592-76-7]* **M 98.2, b 93°/771mm, d 0.698, n 1.400.** Distd from sodium, then carefully fractionally distd using an 18-in gauze-packed column. Can be purified by azeotropic distn with EtOH. Contained the 2- and 3-isomers as impurities. These can be removed by gas chromatography using a Carbowax column at 70°.

***n*-Heptyl alcohol** *[111-70-6]* **M 116.2, b 175.6°, d 0.825, n 1.425.** Shaken with successive lots of alkaline $KMnO_4$ until the colour persisted for 15min, then dried with K_2CO_3 or CaO, and fractionally distd.

***n*-Heptylamine** *[111-68-2]* **M 115.2, b 155°, d 0.775, n 1.434.** Dried in contact with KOH pellets for 24h, then decanted and fractionally distd.

***n*-Heptyl bromide** *[629-04-9]* **M 179.1, b 70.6°/19mm, 180°/760mm, d 1.140, n 1.45.** Shaken with conc H_2SO_4, washed with water, dried with K_2CO_3, and fractionally distd.

Heptyl-β–D-glucopyranoside *[78617-12-6]* **M 278.4, m 74-77°, 76-77°, $[\alpha]_D^{20}$ -34.2° (c 5, H_2O).** Purified by several recrystns from M_2CO which is a better solvent than EtOAc. The *acetate* has **m** 66-68.5°, $[\alpha]_D^{20}$ -20.5° (c 4, $CHCl_3$) [Pigman and Richtmyer *JACS* **64** 369 *1942*].

Heptyl-β–D-1-thioglucopyranoside *[85618-20-8]* **M 294.4, m 98-99°.** The *tetra-acetyl derivative* is purified by silica gel column chromatography and eluted with a C_6H_6-Me_2CO (gradient up to 5% of Me_2CO) and recrystd from *n*-hexane as colourless needles **m** 72-74° (Erbing and Lindberg *Acta Chem Scand* **B30** 611 *1976* gave **m** 69-70°). Hydrolysis using an equivalent of base in methanol gave the desired glucoside. This is a non-ionic detergent for reconstituting membrane proteins and has a critical micelle concentration of 30 mM. [Shimamoto et al. *J Biochem (Tokyo) 97* 1807 *1985*; Saito and Tsuchiya *Chem Pharm Bull Japan* **33** 503 *1985*].

Hesperetin *[520-33-2]* **M 302.3, m 227-228°.** Crystd from ethyl acetate.

Hesperidin *[520-26-3]* **M 610.6, m 258-262°, $[\alpha]_{546}^{20}$ -82° (c 2, pyridine).** Dissolved in dilute aqueous alkali and ppted by adjusting the pH to 6-7.

Hexachlorobenzene *[118-74-1]* **M 284.8, m 230.2-231.0°.** Crystd repeatedly from benzene. Dried under vacuum over P_2O_5.

Hexachloro-1,3-butadiene *[87-68-3]* **M 260.8, m 39°, b 283-284° (dec)/733mm, d 1.665.** Vacuum distd at less than 15mm pressure.

1,2,3,4,5,6-Hexachlorocyclohexane *[319-84-6]* **M 290.8, m 158° (α–), 312° (ß-), 112.5° (Á-isomer).** Crystd from EtOH. Purified by zone melting.

Hexachlorocyclopentadiene *[77-47-4]* **M 272.8, b 80°/1mm, d 1.702, n^{25} 1.5628.** Dried with $MgSO_4$. Distd under vacuum in nitrogen.

Hexachloroethane *[67-72-1]* **M 236.7, m 187°.** Steam distd, then crystd from 95% EtOH. Dried in the dark under vacuum.

Hexacosane *[630-01-3]* **M 366.7, m 56.4°, b 169°/0.05mm, 205°/1mm, 262°/15mm.** Distd under vacuum and crystd from ethyl ether.

Hexacosanoic acid *[506-46-7]* **M 396.7, m 88-89°.** Crystd from EtOH.

1,14-Hexadecanedioic acid. *[505-54-4]* **M 286.4, m 126°.** Crystd from EtOH or ethyl acetate.

***n*-Hexadecane (Cetane)** *[544-76-3]* **M 226.5, m 18.2°, b 105°/0.1mm, d 0.773, n 1.4345, n^{25} 1.4325.** Passed through a column of silica gel and distd under vacuum in a column packed with Pyrex helices. Stored over silica gel. Crystd from acetone, or fractionally crystd by partial freezing.

Hexadecanoic acid *[57-10-3]* **M 256.4, m 126°.** Purified by slow (overnight) recrystn from hexane. Some samples were also crystd from acetone, EtOH or ethyl acetate. Crystals were stood in air to lose solvent, or were pumped on a vacuum line. [Iwahashi et al. *JCSFT 1* **81** 973 *1985*].

1-Hexadecyl- see **cetyl-.**

Hexadecyltrimethylammonium bromide (CTAB) *[57-09-0]* **M 364.4.** Recrystd once from acetone, acetone/water or acetone and <5% MeOH and dried under vacuum at 60°. Also crystd from absolute EtOH. [Dearden and Wooley *JPC* **91** 2404 *1987*]

1,5-Hexadiene *[592-42-7]* **M 82.2, b 59.6°, d 0.694, n 1.4039.** Distd from $NaBH_4$.

Hexadimethrine bromide see **1,5-dimethyl-1,5-diazaundecamethylene polymethobromide**

Hexaethylbenzene *[87-85-4]* **M 246.3, m 128.7-129.5°.** Crystd from benzene or benzene/EtOH.

Hexafluoroacetone *[684-16-2]* **M 166.1, m -129°, (trihydrate m 18-21°), b -28°.** Dehydrated by passage of the vapour over P_2O_5. Ethylene was removed by passing the dried vapour through a tube containing Pyrex glass wool moistened with conc H_2SO_4. Further purification was by low temperature distn using Warde-Le Roy stills. Stored in the dark at -78°. [Holmes and Kutschke *TFS* **58** 333 *1962*].

Hexafluoroacetylacetone (1,1,1,5,5,5-hexafluoro-2,4-pentanedione) *[1522-22-1]* **M 208.1, b 68°/736mm, 70-70.2°/760mm, 68-71°/atm, d_4^{20} 1.490, n_D^{20} 1.333.** It forms a dihydrate which has no UV spectrum compared with λmax ($CHCl_3$) 273nm (ε 7,800) for the anhydrous ketone. The dihydrate dec at ~90°. The hydrate (10g) plus anhyd $CaSO_4$ (Drierite, 30g) are heated and distd; the distillate is treated with more $CaSO_4$ and redist. When the distillate is treated with aqueous NaOH and heated, the dihydrate crystallises on cooling. The Cu complex has **m** 135° (after sublimation). [Gilman et al. *JACS* **78** 2790 *1956*; Belford et al. *JINC* **2** 11 *1956*].

Hexafluorobenzene *[392-56-3]* **M 186.1, m 5.1°, b 79-80°, d 1.61, n 1.378.** Main impurities are incompletely fluorinated benzenes. Purified by standing in contact with oleum for 4h at room temperature, repeating until the oleum does not become coloured. Washed several times with water, then dried with P_2O_5. Final purification was by repeated fractional crystn.

Hexafluoroethane *[76-16-4]* **M 138.0, b -79°.** Purified for pyrolysis studies by passage through a copper vessel containing CoF_3 at *ca* 270°, and held for 3h in a bottle with a heated (1300°) platinum wire. It was then fractionally distd. [Steunenberg and Cady *JACS* **74** 4165 *1962*.]

1,1,1,3,3,3-Hexafluoropropan-2-ol *[920-66-1]* **M 168.1, b 57-58°/760mm, d 1.4563, n^{22} 1.2750.** Distd from 3A molecular sieves, retaining the middle fraction.

***R*-(-)-** *[53585-93-6]* ***S*-(+)-** *[61475-31-8]* **Hexahydromandelic acid M 158.2, m 127-129°, 128-129°, 129.7°, $[\alpha]_d^{20}$ ±25.5° (c 1, AcOH) and $[\alpha]_d^{20}$ ±13.6° (c 7.6, EtOH).** For hexagonal clusters by recrystallisation from CCl_4 or Et_2O. [Wood and Comley *JCS* 2638 *1924*; Lettré et al. *B* **69** 1594 *1936*]. The *racemate* has **m** 137.2-137.6° (134-135°) [Smith et al. *JACS* **71** 3772 *1949*].

Hexamethylbenzene *[87-85-4]* **M 162.3, m 165-165.5°.** Sublimed, then crystd from abs EtOH, benzene, EtOH/benzene or EtOH/cyclohexane. Also purified by zone melting. Dried under vacuum over P_2O_5.

Hexamethyl(Dewar)benzene *[7641-77-2]* **M 162.3, m 7°, b 60°/20mm, d 0.803, n 1.4480.** Purified by passage through alumina [Traylor and Miksztal *JACS* **109** 2770 *1987*].

Hexamethylenediamine *[124-09-4]* **M 116.2, m 42°, b 46-47°/1mm, 84.9°/9mm, 100°/20mm, 204-205°/760mm.** Crystd in a stream of nitrogen. Sublimed in a vacuum.

Hexamethylenediamine dihydrochloride *[6055-52-3]* **M 189.2, m 248°.** Crystd from water or EtOH.

Hexamethylene glycol *[629-11-8]* **M 118.2, m 41.6°.** Fractionally crystd from its melt.

Hexamethylenetetramine *[100-97-0]* **M 140.2.** Crystd from EtOH and stored in a vacuum.

Hexamethylphosphoric triamide (HMPT) see Chapter 4.

Hexanamide see ***n*-caproamide.**

***n*-Hexane** *[110-54-3]* **M 86.2, b 68.7°, d 0.660, n 1.37486, n^{25} 1.37226.** Purification as for *n*-heptane. Modifications include the use of chlorosulphonic acid or 35% fuming H_2SO_4 instead of conc H_2SO_4 in washing the alkane, and final drying and distn from sodium hydride. Unsatd compounds can be removed by shaking the hexane with nitrating acid (58% H_2SO_4, 25% conc HNO_3, 17% water, or 50% HNO_3, 50% H_2SO_4), then washing the hydrocarbon layer with conc H_2SO_4, followed by H_2O, drying, and distg over sodium or *n*-butyl lithium. Also purified by distn under nitrogen from sodium benzophenone ketyl solubilised with tetraglyme. Also purified by chromatography on silica gel followed by distn [Kajii et al. *JPC* **91** 2791 *1987*].

1,6-Hexanediol *[629-11-8]* **M 118.2, m 43-45°.** Recrystd from water.

Hexanenitrile see **capronitrile.**

1-Hexene *[592-41-6]* **M 84.2, b 63°, d 0.674, n 1.388,**
cis*-2-Hexene** *[7688-21-3]M 84.2, b 68-70°, d 0.699, n 1.399,**
***trans*-2-Hexene** *[4050-45-7]* **M 84.2, b 65-67°, n 1.390,**
***trans*-3-Hexene** *[13269-52-8]* **M 84.2, b 67-69°, d 0.678, n 1.393.** Purified by stirring over Na/K alloy for at least 6h, then fractionally distd from sodium under nitrogen.

***meso*-Hexoestrol** *[84-16-2]* **M 270.4, m 185-188°.** Crystd from benzene or aqueous EtOH.

***n*-Hexyl alcohol** *[111-27-3]* **M 102.2, b 157.5°, d 0.818, n^{15} 1.4198, n^{25} 1.4158.** Commercial material usually contains other alcohols which are difficult to remove. A suitable method is to esterify with hydroxybenzoic acid, recrystallise the ester and saponify. [Olivier *Rec Trav chim* **55** 1027 *1936*]. Drying agents include K_2CO_3 and $CaSO_4$, followed by filtration and distn. (Some decomposition to the olefin occurred when Al amalgam was used as drying agent at room temperature, even though the amalgam was removed prior to distn.) If the alcohol is required anhydrous, the redistd material can be refluxed with the appropriate alkyl phthalate or succinate, as described under *Ethanol.*

***n*-Hexylamine** *[111-26-2]* **M 101.2, b 131°, d 0.765, n 1.419.** Dried with, and fractionally distd from, KOH or CaH_2.

***n*-Hexyl bromide** *[111-25-1]* **M 165.1, b 87-88°/90mm, 155°/743mm, d 1.176, n 1.448.** Shaken with H_2SO_4, washed with water, dried with K_2CO_3 and fractionally distd.

***n*-Hexyl methacrylate** *[142-09-6]* **M 154.2.** Purified as for *methyl methacrylate.*

Hexyltrimethylammonium bromide *[2650-53-5]* **M 224.3.** Recrystd from acetone. Extremely *hygroscopic* salt.

1-Hexyne *[693-02-7]* **M 82.2, b 12.5°/75mm, 71°/760mm, d 0.7156, n 1.3989,**
2-Hexyne *[764-35-2]* **M 82.2, b 83.8°/760mm, d 0.73146, n 1.41382,**
3-Hexyne *[928-49-4]* **M 82.1, b 81°/760mm, d 0.7231, n 1.4115.** Distd from $NaBH_4$ to remove peroxides. Stood with sodium for 24h, then fractionally distd under reduced pressure. Also dried by repeated vac transfer into freshly activated 4A molecular sieves, followed by vacuum transfer into Na/K alloy and stirring for 1h before fractionally distilling.

Hippuric acid *[495-69-2]* **M 178.2, m 187.2°.** Crystd from water. Dried over P_2O_5.

Histamine *[51-45-6]* **M 111.2, m 86°(sealed tube), b 167°/0.8mm, 209°/18mm.** Crystd from benzene or chloroform.

Histamine dihydrochloride *[56-92-8]* **M 184.1, m 249-252° (244-245°).** Crystd from aq EtOH.

L-Histidine *[71-00-1]* **M 155.2, m 287°(dec), $[\alpha]_D^{25}$ -39.7° (H_2O), +13.0° (6M HCl).** Likely impurity is arginine. Adsorbed from aqueous soln on to Dowex 50-H^+ ion-exchange resin, washed with 1.5M HCl (to remove other amino acids), then eluted with 4M HCl as the dihydrochloride. Histidine is also purified as the dihydrochloride which is finally dissolved in water, the pH adjusted to 7.0, and the free zwitterionic base crystallises out on addition of EtOH.

Histidine dihydrochloride *[1007-42-7]* **M 242.1, m 252°.** Crystd from water or aqueous EtOH, and washed with acetone, then ethyl ether. Converted to the histidine di-(3,4-dichlorobenzenesulphonate) salt by dissolving 3,4-dichlorobenzenesulphonic acid (1.5g/10ml) in the aqueous histidine soln with warming, and then the soln is cooled in ice. The resulting crystals (**m** 280° dec) can be recrystd from 5% aqueous 3,4-dichlorobenzenesulphonic acid, then dried over $CaCl_2$ under vacuum, and washed with ethyl ether to remove excess reagent. The dihydrochloride can be regenerated by passing the soln through a Dowex-1 (Cl^- form) ion-exchange column. The solid is obtained by evapn of the soln on a steam bath or better in a vacuum. [Greenstein and Winitz, The Amino Acids **Vol 3**, p 1976 *1961*].

L-Histidine monohydrochloride (H_2O) *[7048-02-4]* **M 209.6, $[\alpha]_D^{25}$ +13.0° (6M HCl),** ***dl*-Homocysteine** *[6027-13-0]* **M 135.2.** Crystd from aqueous EtOH.

Homocystine *[626-72-2]* **M 268.4, m 260-265°(dec).** Crystd from water.

Homophthalic acid *[89-51-0]* **M 180.2, m 182-183° (varies with the rate of heating).** Crystd from boiling water (25ml/g). Dried at 100°.

Homopiperazine (1,4-diazepane) *[505-66-8]* **M 100.2, m 38-40°, 43°, b 60°/10mm, 92°/50mm, 169°/atm.** Purified by fractionation through a column of 10 theoretical plates with a reflux ratio of 3:1. It boiled at 169° and the cool distillate crystallises in plates **m** 43°. [Poppelsdorf and Myerly *JOC* **26** 131 *1961*]. Its pKa values are 6.89 and 10.65 at 40°, and 6.28 and 9.86 at 40° [Pagano et al. *JPC* **65** 1062 *1961*]. The *1,4-bis(4-bromobenzoyl* derivative has **m** 194-198° (from EtOH); the *hydrochloride* has **m** 270-290° (from EtOH) and the *picrate* has **m** 265° (dec) [Lloyd et al. *JCS (C)* 780 *1966*].

L-Homoserine *[672-15-1]* **M 119.1, m 203°, $[\alpha]_D^{26}$ +18.3°(in 2M HCl).** Likely impurities are *N*-chloroacetyl-L-homoserine, *N*-chloroacetyl-D-homoserine, L-homoserine, homoserine lactone, homoserine anhydride (formed in strong solns of homoserine if slightly acidic). Cyclises to the lactone in strongly acidic soln. Crystd from water by adding 9 volumes of EtOH.

Homoveratronitrile (3,4-dimethoxybenzylnitrile) *[93-17-4]* **M 177.2, m 62-64°, 68°, b 184°/20mm, 195-196°/2mm, 208°/atm.** Its solubility is 10% in MeOH. and has been recrystd from EtOH or MeOH. Purified by distillation followed by recrystn. [Niederl and Ziering *JACS* **64** 885 *1952*; Julian and Sturgis *JACS* **57** 1126 *1935*].

Homoveratrylamine (2-[3,4-dimethoxypheyl]ethylamine) *[120-20-7]* **M 181.2, b 99.3-101.3°/0.5mm, 157-160°/12mm, 168-170°/15mm, d_4^{20} 1.091, n_D^{20} 1.5460.** Purified by fractionation through an efficient column in an inert atmosphere as it is a relatively strong base. [Horner and Sturm *A* **608** 12819 *1957*; Jung et al. *JACS* **75** 4664 *1953*]. The *hydrochloride* has **m** 152°, 154°, 156° (from EtOH, Me_2CO or EtOH/Et_2O) and the *picrate* has **m** 165-167° dec, and the *4-nitrobenzoyl* derivative has **m** 147° [Buck *JACS* **55** 2593 *1933*].

Hordenine *[539-15-1]* **M 165.2, m 117-118°.** Crystd from EtOH or water.

Humulon *[26472-41-3]* **M 362.5, m 65-66.5°.** Crystd from ethyl ether.

Hyamine 1622 [(diisobutylphenoxyethoxyethyl)dimethylbenzylammonium chloride, benzethionium chloride] *[121-54-0]* **M 448.1, m 164-166° (sinters at 120°, monohydrate).**

Crystd from boiling acetone after filtering, or from $CHCl_3$-pet ether. The ppte was filtered off, washed with ethyl ether and dried for 24h in a vacuum desiccator.

Hydantoin (2,4-dihydroxyimidazole) *[461-72-3]* **M 100.1, m 216°, 220°.** Crystd from MeOH. The *diacetate* has **m** 104-105°.

Hydrazine *N,N'*-dicarboxylic acid diamide *[110-21-4]* **M 116.1, m 248°,**
4-Hydrazinobenzoic acid *[619-67-0]* **M 152.2, m 217°(dec).** Crystd from water.

1-Hydrazinophthalazine hydrochloride (hydralazine hydrochloride) *[304-20-1]* **M 196.6, m 172-173°.** Crystd from MeOH.

Hydrazinopyridine *[4930-98-7]* **M 109.1, m 41-44°, 46-47°, 49-50°, b 105°/0.5mm, 128-135°/13mm.** Purified by distn and by recrystn from Et_2O-hexane. [Kauffmann et al. *A* **656** 103 *1962*, Potts and Burton *JOC* **31** 251 *1966*]. The *mono-hydrochloride* has **m** 183° (dec) from aq HCl and the *di-hydrochloride* has **m** 214-215°.

Hydrazobenzene *[122-66-7]* **M 184.2, m 128°.** Crystd from pet ether (b 60-100°) to constant absorption spectrum.

Hydrobenzamide *[92-29-5]* **M 298.4, m 101-102°.** Crystd from absolute EtOH or cyclohexane/benzene. Dried under vacuum over P_2O_5.

***dl*-Hydrobenzoin** *[655-48-1]* **M 214.3, m 120°.** Crystd from ethyl ether/pet ether.

meso*-Hydrobenzoin** *[579-43-1]M 214.3, m 139°.** Crystd from EtOH or water.

Hydrocinnamic acid (3-phenylpropionic acid) *[501-52-0]* **M 150.2, m 48-48.5°.** Crystd from benzene, $CHCl_3$ or pet ether (b 40-60°). Dried in a vacuum.

Hydroquinone *[123-31-9]* **M 110.1, m 175.4, 176.6°.** Crystd from acetone, benzene, EtOH, EtOH/benzene, water or acetonitrile (25g in 30ml), preferably under nitrogen. Dried under vacuum. [Wolfenden et al. *JACS* **109** 463 *1987*].

Hydroquinone dimethyl ether see ***p*-dimethoxybenzene.**

Hydroquinone monobenzyl ether see ***p*-benzyloxyphenol.**

Hydroquinone monomethyl ether see ***p*-methoxyphenol.**

Hydroquinone-2-monosulphonate (K salt) *[21799-87-1]* **M 228.3, m 250°(dec).** Recrystd from water.

4'-Hydroxyacetanilide *[103-90-2]* **M 151.2, m 169-170.5°.** Crystd from water.

***p*-Hydroxyacetophenone** *[99-93-4]* **M 136.2, m 109°.** Crystd from ethyl ether, aqueous EtOH or benzene/pet ether.

4-Hydroxyacridine *[18123-20-1]* **M 195.2, m 116.5°.** Crystd from EtOH.

1-Hydroxyadamantane see **1-adamantanol**

2-Hydroxyadamantane see **2-adamantanol**

3-Hydroxyanthranilic acid *[548-93-6]* **M 153.1, m >240°(dec), λ_{max} 298nm, log ε 3000 (0.1M HCl).** Crystd from water. Sublimes below its melting point in a vacuum.

***erythro*-3-Hydroxy-*RS*-aspartic acid** *[6532-76-9]* **M 149.1.** Likely impurities are 3-chloromalic acid, ammonium chloride, *threo*-3-hydroxyaspartic acid. Crystd from water.

p-**Hydroxyazobenzene** see *p*-**phenylazophenol.**
o-**Hydroxybenzaldehyde** see **salicylaldehyde.**

m-**Hydroxybenzaldehyde** *[100-83-4]* **M 122.1, m 108°.** Crystd from water.

p-**Hydroxybenzaldehyde** *[123-08-0]* **M 122.1, m 115-116°.** Crystd from water (containing some H_2SO_4). Dried over P_2O_5 under vacuum.

m-**Hydroxybenzoic acid** *[99-06-9]* **M 138.1, m 200.8°.** Crystd from absolute EtOH.

p-**Hydroxybenzoic acid** *[99-96-7]* **M 138.1, m 213-214°,**
p-**Hydroxybenzonitrile** *[767-00-0]* **M 119.1, m 113-114°.** Crystd from water.

4-Hydroxybenzophenone *[1137-42-4]* **M 198.2, m 135°,**
2-Hydroxybenzothiazole *[934-34-9]* **M 183.1, m 117-118°,**
1-Hydroxybenzotriazole (H_2O) *[2592-95-2]* **M 135.1, m 159-160°.** Crystd from aqueous EtOH or water. [Dryland and Sheppard *JCSPT* 125 *1986*].

2-Hydroxybenzyl alcohol *[90-01-7]* **M 124.1, m 87°.** Crystd from water or benzene.

3-Hydroxybenzyl alcohol *[620-24-6]* **M 124.1, m 71°.** Crystd from benzene.

4-Hydroxybenzyl alcohol *[623-05-2]* **M 124.1, m 114-115°.** Crystd from water.

2-Hydroxybiphenyl *[90-43-7]* **M 170.2, m 56°, b 145°/14mm, 275°/760mm.** Crystd from pet ether.

4-Hydroxybiphenyl *[92-69-3]* **M 170.2, m 164-165°, b 305-308°/760mm.** Crystd from aqueous EtOH.

3-Hydroxy-2-butanone *[513-86-0]* **M 88.1, b 144-145°, [m 100-105° dimer].** Washed with EtOH until colourless, then with ethyl ether or acetone to remove biacetyl. Air dried by suction and further dried in a vacuum desiccator.

(±)-α-Hydroxy-γ-butyrolactone *[19444-84-9]* **M 1102.1, b 84°/0.2mm, 133°/10mm, d_4^{20} 1.310, n_D^{20} 1.4656.** It has been purified by repeated fractionation, forms a colourless liquid. It has to be distd at high vacuum otherwise it will dehydrate. The *acetoxy* derivative has **b** 94°/0.2mm, [NMR: Daremon and Rambaud *Bull Soc Chim France* 294 *1971*; Schmitz et al. *B* **108** 1010 *1975*].

2-Hydroxycaprylic acid see **2-hydroxyoctadecanoic acid.**

4-Hydroxycinnamic acid (***p*-coumaric acid**) *[501-98-4]* **M 164.2, m 210-213°, 214-215°, 215°.** Crystd from H_2O (charcoal). Needles from conc aqueous solutions as the *anhydrous acid* , but from hot dilute solutions the *monohydrate acid* separates on slow cooling. The acid (33g) has been recrystd from 2.5L of H_2O (1.5g charcoal) yielding 28.4g of recrystd acid, **m** 207°. It is insol in C_6H_6 or pet ether. The UV in 95% EtOH has λ_{max} 223 and 286nm (ε 14,450 and 19000 $M^{-1}cm^{-1}$). [UV Wheeler and Covarrubias *JOC* **28** 2015 *1963*; Corti *HCA* **32** 681 *1949*].

4-Hydroxycoumarin *[1076-38-6]* **M 162.1, m 206°,**

3-(4-Hydroxy-3,5-dimethoxyphenyl)acrylic acid *[2107-59-6]* **M 234.1, m 204-205°(dec),**
R-2-Hydroxy-3,3-dimethyl-γ-butyrolactone *[79-50-5]* **M 130.1, m 89-91°,** $[\alpha]_{546}^{20}$ **-62°** (c 3, H_2O). Crystd from water.

4-Hydroxydiphenylamine *[122-37-2]* **M 185.2, m 72-73°.** Crystd from chlorobenzene/pet ether.

12-Hydroxydodecanoic acid *[505-95-3]* **M 216.3, m 86-88°.** Crystd from toluene [Sadowik et al. *JACS* **108** 7789 *1986*].

2-Hydroxy-4-(*n*-dodecyloxy)benzophenone *[2985-59-3]* **M 382.5, m 50-52°.** Recryst from *n*-hexane and then 10% (v/v) EtOH in acetonitrile [Valenty et al. *JACS* **106** 6155 *1984*].

***N*-[2-Hydroxyethyl]ethylenediamine** *[111-41-1]* **M 104.1, b 91.2°/5mm, 238-240°/752mm, n 1.485, d 1.030.** Distd twice through a Vigreux column. Redistd from solid NaOH, then from CaH_2. Alternatively, converted to the dihydrochloride and recrystd from water. Dried, mixed with excess of solid NaOH and the free base distd from the mixture. Redistd from CaH_2. [Drinkard, Bauer and Bailar *JACS* **82** 2992 *1960*].

***N*-[2-Hydroxyethyl]ethylenediaminetriacetic acid** *[150-39-0]* **M 278.3, m 212-214°(dec).** Crystd from warm H_2O, after filtering, by addition of 95% EtOH and allowing to cool. The crystals, collected on a sintered-glass funnel, were washed three times with cold absolute EtOH, then again crystd from H_2O. After leaching with cold H_2O, the crystals were dried at 100° under vacuum. [Spedding, Powell and Wheelwright *JACS* **78** 34 *1956*].

***N*-Hydroxyethyliminodiacetic acid** *[93-62-9]* **M 177.2, m 181°(dec).** Crystd from water.

2-Hydroxyethylimino-tris(hydroxymethyl)methane (Mono-Tris) *[7343-51-3]* **M 165.2, m 91°.** Crystd twice from EtOH. Dried under vacuum at 25°.

2-Hydroxyethyl methacrylate *[868-77-9]* **M 130.1, b 67°/3.5mm, d 1.071, n 1.452.** Dissolved in water and extracted with *n*-heptane to remove ethylene glycol dimethacrylate (checked by gas-liquid chromatography) and distd twice under reduced pressure [Strop, Mikes and Kalal *JPC* **80** 694 *1976*].

***N*-2-Hydroxyethylpiperazine-*N'*-2-ethanesulphonic acid (HEPES)** *[7365-45-9]* **M 238.3.** Crystd from hot EtOH and water.

3-Hydroxyflavone *[577-85-5]* **M 238.2, m 169-170°.** Recrystd from MeOH, EtOH or hexane. Also purified by repeated sublimation under high vacuum, and dried by high vacuum pumping for at least one hour [Bruker and Kelly *JPC* **91** 2856 *1987*].

ß-Hydroxyglutamic acid *[533-62-0]* **M 163.1, m 100°(dec).** Crystd from water.

4-Hydroxyindane *[1641-41-1]* **M 134.2, m 49-50°, b 120°/12mm,**
5-Hydroxyindane *[1470-94-6]* **M 134.2, m 55°, b 255°/760mm.** Crystd from pet ether.

2-Hydroxy-5-iodobenzoic acid see **5-iodosalicylic acid.**

α-Hydroxyisobutyric acid see **2-hydroxy-2-methylpropionic acid.**

5-Hydroxy-L-lysine monohydrochloride *[32685-69-1]* **M 198.7,** $[\alpha]_D^{25}$ **+17.8° (6M HCl).** Likely impurities are 5-*allo*-hydroxy-(D and L)-lysine, histidine, lysine, ornithine. Crystd from water by adding 2-9 volumes of EtOH stepwise.

4-Hydroxy-3-methoxyacetophenone *[498-02-2]* **M 166.2, m 115°.** Crystd from water, or EtOH/pet ether.

4-Hydroxy-3-methoxycinnamic acid (ferulic acid) *[1135-24-6]* **M 194.2, m 174°.** Crystd from H_2O.

1-Hydroxymethyladamantane *[770-71-8]* **M 166.3, m 115°.** Dissolve in Et_2O, wash with aqueous 0.1N NaOH and H_2O, dry over $CaCl_2$, evaporate and recryst residue from aqueous MeOH. [*B* **92** 1629 *1959*].

17β-Hydroxy-17α-methyl-3-androsterone *[521-11-9]* **M 304.5°, m 192-193°.** Crystd from ethyl acetate.

3-Hydroxy-4-methylbenzaldehyde *[57295-30-4]* **m 116-117°, b 179°/15mm.** Crystd from water.

***dl*-2-Hydroxy-2-methylbutyric acid** *[3739-30-8]* **M 118.1, m 72-73°.** Crystd from benzene, and sublimed at 90°.

***dl*-2-Hydroxy-3-methylbutyric acid** *[600-37-3]* **M 118.1, m 86°.** Crystd from ether/pentane.

***R*-γ-Hydroxymethyl-γ-butyrolactone** *[52813-63-5]* **M 116.1, b 101-102°/0.048mm, d_4^{20} 1.2238, n_D^{20} 1.471, $[\alpha]_{546}^{20}$ -38°, $[\alpha]_D^{20}$ -33° (c 3, EtOH), $[\alpha]_D^{30}$ -53.5° (c 3, EtOH).** Purified by column chromatography in Silica gel 60 (Merck 70-230 mesh) and eluting with 7% EtOH-73% $CHCl_3$. IR (film): 3400 (OH), 1765 (C=O) and 1180 (COC) cm^{-1}. [Eguchi and Kakuta *Bull Chem Soc Japan* **47** 1704 *1974*; IR and NMR: Ravid et al. *TET* **34** 1449 *1978*].

7-Hydroxy-4-methylcoumarin (4-methylumbelliferone) *[90-33-5]* **M 176.2, m 185-186°.** Crystd from absolute EtOH.

2-Hydroxymethyl-12-crown-4 *[75507-26-5]* **M 206.2, d_4^{20} 1.186, n_D^{20} 1.480.** Purified by chromatography on Al_2O_3 with EtOAc as eluent to give a *hygroscopic* colourless oil with IR 3418 (OH) and 1103 (COC) cm^{-1}, NMR δ 3.70 (s). [Pugia et al. *JOC* **52** 2617 *1987*].

***S*-(-)-5-Hydroxymethyl-2(5*H*)-furanone** *[78508 -96-0]* **M 114.1, 39-42°, 40-44°, b 130°/0.3mm, 130°/0.9mm, $[\alpha]_{546}^{20}$ -180°, $[\alpha]_D^{20}$ -148° (c 1.4, H_2O).** It has been purified by chromatography on Silica gel using hexane-EtOAc (1:1) to give a colourless oil which was distd using a Kügelrohr apparatus and the distillate crystallises on cooling. It has R_F 0.51 on Whatman No 1 paper using pentan-1-ol and 85% formic acid (1:1) and developing with ammoniacal $AgNO_3$. [Boll *Acta Chem Scand* **22** 3245 *1968*; NMR: Oppolzer et al. *HCA* **68** 2100 *1985*].

5-(Hydroxymethyl)furfural *[67-47-0]* **M 126.1, m 33.5°, b 114-116°/1mm.** Crystd from ethyl ether/pet ether.

3-Hydroxy-3-methylglutaric acid *[503-49-1]* **M 162.1, m 99-102°.** Recrystd from ethyl ether/hexane and dried under vac at 60° for 1h.

2-Hydroxymethyl-2-methyl-1,3-propanediol see **1,1,1-tris(hydroxymethyl)ethane.**

***dl*-3-Hydroxy-*N*-methylmorphinan** *[297-90-5]* **M 257.4, m 251-253°.** Crystd from anisole + aqueous EtOH.

5-Hydroxy-2-methyl-1,4-naphthaquinone see **plumbagin.**

6-Hydroxy-2-methyl-1,4-naphthaquinone *[633-71-6]* **M 188.2.** Crystd from aqueous EtOH. Sublimes on heating.

2-(Hydroxymethyl)-2-nitro-1,3-propanediol *[126-11-4]* **M 151.1, m 174-175°(dec).** Crystd from $CHCl_3$/ethyl acetate or ethyl acetate/benzene.

4-Hydroxy-4-methyl-2-pentanone *[123-42-2]* **M 116.2, b 166°, d 0.932, n 1.4235, n^{25} 1.4213.** Loses water when heated. Can be dried with $CaSO_4$, then fractionally distd under reduced pressure.

17α-Hydroxy-6α-methylprogesterone *[520-85-4]* **M 344.5, m 220°, $[\alpha]_D^{25}$ +75°.** Crystd from chloroform.

2-Hydroxy-2-methylpropionic acid *[594-61-6]* **M 104.1, m 79°, b 114°/12mm, 84°/15mm, 212°/760mm.** Distd in steam, crystd from ethyl ether or benzene, sublimed at 50° and dried under vacuum.

8-Hydroxy-2-methylquinoline *[826-81-3]* **M 159.2, m 74-75°, b 266-267°.** Crystd from EtOH or aqueous EtOH.

2-Hydroxymyristic acid see **2-hydroxytetradecanoic acid.**

2-Hydroxy-1-naphthaldehyde *[708-06-5]* **M 172.2, m 82°, b 192°/27mm.** Crystd from EtOH (1.5ml/g), ethyl acetate or water.

2-Hydroxy-1-naphthaleneacetic acid *[10441-45-9]* **M 202.2.** Treated with activated charcoal and crystd from EtOH/water (1:9, v/v). Dried under vacuum, over silica gel, in the dark. Stored in the dark at -20° [Gafni, Modlin and Brand *JPC* **80** 898 *1976*]. Forms a lactone (**m** 107°) readily.

6-Hydroxy-2-naphthalenepropionic acid *[553-39-9]* **M 216.2, m 180-181°.** Crystd from aqueous EtOH or aqueous MeOH.

3-Hydroxy-2-naphthalide *[92-77-3]* **M 263.3, m 248.0-248.5°,**
3-Hydroxy-2-naphtho-4'-chloro-*o*-toluidide *[92-76-2]* **M 311.8, m 243.5-244.5°,**
3-Hydroxy-2-naphthoic-a-naphthalide *[94966-09-2]* **M 314.3, m 217-.5-218.0°,**
3-Hydroxy-2-naphthoic-ß-naphthalide *[550-57-2]* **M 305.3, m 243.5-244.5°, and other naphthol AS derivatives.** Crystd from xylene [Schnopper, Broussard and La Forgia *AC* **31** 1542 *1959*].

1-Hydroxy-2-naphthoic acid see **1-naphthol-2-carboxylic acid.**

3-Hydroxy-2-naphthoic acid see **3-naphthol-2-carboxylic acid.**

2-Hydroxy-1,4-naphthaquinone (Juglone) *[83-72-7]* **M 174.2, m 192°(dec).** Crystd from benzene.

5-Hydroxy-1,4-naphthaquinone *[481-39-0]* **M 174.2, m 155°.** Crystd from benzene/pet ether.

6-Hydroxy-2-naphthyl disulphide *[6088-51-3]* **M 350.5, m 220-223°, 221-222°.** Crystallises as leaflets from AcOH and is slightly soluble in EtOH, and AcOH, but is soluble in C_6H_6 and in alkalis to give a yellow soln. [Zincke and Dereser *B* **51** 352 *1918*]. The *acetoxy* derivative has **m** 198-200° (from AcOH or dioxane-MeOH) and the *diacetyl* derivative has **m** 167-168° (from AcOH). A small amount of impure disulphide can be purified by dissolving in a small volume of Me_2CO and adding a large volume of toluene, filter rapidly and concentrate to one third of its volume. The hot toluene soln is filtered rapidly from any tarry residue, and crystals separate on cooling. After recrystn from hot acetic acid gives crystals **m** 220-223° [Barrett and Seligman *Science* **116** 323 *1952*].

6-Hydroxynicotinic acid see **2-hydroxypyridine-5-carboxylic acid.**

2-Hydroxy-5-nitrobenzyl bromide *[772-33-8]* **M 232.0, m 147°.** Crystd from benzene or benzene/ligroin.

4-Hydroxy-2-*n*-nonylquinoline *N*-oxide *[316-66-5]* **M 287.4, m 148-149°.** Crystd from EtOH.

***N*-Hydroxy-5-norbornene-2,3-dicarboxylic acid imide** *[21715-90-2]* **M 179.2, m 165-166°, 166-169°** Dissolve in $CHCl_3$, filter, evaporate and recrystallise from EtOAc. IR (nujol): 1695, 1710 and 1770 (C=O), and 3100 (OH) cm^{-1}. *O-Acetyl* derivative has **m** 113-114° (from EtOH) with IR bands at 1730, 1770 and 1815 cm^{-1} only, and the *O-benzoyl* derivative has **m** 143-144° (from propan-2-ol or C_6H_6). [Bauer and Miarka *JOC* **24** 1293 *1959*; Fujino et al. *Chem Pharm Bull Japan* **22** 1857 *1974*].

DL-*erythro*-3-Hydroxynorvaline (2-amino-3-hydroxypentanoic acid) *[34042-00-7]* **M 133.2, m 257-259° (dec), 263° (dec).** Purified by recrystn from aqueous EtOH. The *Cu salt* has **m** 255-256° (dec), the *benzoyl* derivative has **m** 181°, and the *N-phenylcarbamoyl* derivative has **m** 164°. [Buston et al. *JBC* **204** 665 *1953*].

2-Hydroxyoctanoic acid *[617-73-2]* **M 160.2, m 69.5°.** Crystd from EtOH/pet ether or ether/ligroin.

1-Hydroxyphenazine *[528-71-2]* **M 196.2, m 157-158°.** Chromatographed on acidic alumina with benzene/ether. Crystd from benzene/heptane, and sublimed.

2-Hydroxyphenylacetic acid *[614-75-5]* **M 152.2, m 148-149°, b 240-243°/760mm.** Crystd from ether or chloroform.

3-Hydroxyphenylacetic acid *[621-37-4]* **M 152.2, m 137°.** Crystd from benzene/ligroin.

4-Hydroxyphenylacetic acid *[156-38-7]* **M 152.2, m 150-151°.** Crystd from water.

2-(2-Hydroxyphenyl)benzothiazole *[3411-95-8]* **M 227.2, m 132-133°, b 173-179°/3mm.**
2-(2-Hydroxyphenyl)benzoxazole *[835-64-3]* **M 211.2, m 127°, b 338°/760mm,**
Recrystd several times from aqueous EtOH and by sublimation. [Itoh and Fujiwara *JACS* **107** 1561 *1985*].

3-Hydroxy-2-phenylcinchoninic acid *[485-89-2]* **M 265.3, m 206-207°(dec).** Crystd from EtOH.

***N*-(*p*-Hydroxyphenyl)glycine** *[122-87-2]* **M 167.2, m >240°(dec).** Crystd from water.

***N*-(4-Hydroxyphenyl)-3-phenylsalicylamide** *[550-57-2]* **M 305.3, m 183-184°.** Crystd from aqueous MeOH.

L-2-Hydroxy-3-phenylpropionic acid (phenyl lactic acid) *[20312-36-1]* **M 166.2, m 125-126°, $[\alpha]_D^{12}$ -18.7° (EtOH).** Crystd from water, MeOH, EtOH or benzene.

***dl*-2-Hydroxy-3-phenylpropionic acid** *[828-01-3]* **M 166.2, m 97-98°, b 148-150°/15mm.** Crystd from benzene or chloroform.

3-Hydroxy-2-phenylpropionic acid see **tropic acid.**

3-*p*-Hydroxyphenylpropionic acid *[501-97-3]* **M 166.2, m 129-130°.** Crystd from ether.

***p*-Hydroxyphenylpyruvic acid** *[156-39-8]* **M 180.2, m 220°.** Crystd three times from 0.1M HCl/EtOH (4:1, v/v) immediately before use [Rose and Powell *BJ* **87** 541 *1963*].

***N*-Hydroxyphthalimide** *[524-38-9]* **M 163.1, m 230°, ~235° (dec), 237-240°.** Dissolve in H_2O by adding Et_3N to form the salt and while hot acidify, cool and pour into a large volume of H_2O. Filter off the solid, wash with H_2O, dry over P_2O_5 in vacuum. [Nefken And Teser *JACS* **83** 1263 *1961*; Fieser **1** 485 *1976;* Nefkens et al. *Rec Trav Chim Pays Bas* **81** 683 *1962*] The *O-acetyl* derivative has **m** 178-180° (from EtOH).

3-β-Hydroxy-5-pregnen-20-one *[145-13-1]* **M 316.5, m 189-190°,** $[\alpha]_D^{20}$ **+30° (EtOH),** $[\alpha]_{546}$ **+34° (c 1, EtOH).** Crystd from MeOH.

17α-Hydroxyprogesterone *[604-09-1]* **M 330.5, m 222-223°,** $[\alpha]_{546}^{20}$ **+141° (c 2, dioxane),** λ_{max} **240nm.** Crystd from acetone or EtOH. **Acetate: m 239-240°** and **caproate: m 119-121°** crystallised from $CHCl_3$/MeOH.

21-Hydroxyprogesterone see **11-desoxycorticosterone.**

***R*-(+)-3-Hydroxyproline** *[2799-21-5]* **M 87.1, b 215-216°,** d_4^{20} **1.078,** n_D^{20} **1.490,** $[\alpha]_D^{20}$ **+6.5° (c 1.5, MeOH).** Purified by distn. The *HCl* has a +ve rotation. [Uno et al. *JHC* **24** 1025 *1987*].

***trans*-L-4-Hydroxyproline** *[51-35-4]* **M 131.1, m 274°,** $[\alpha]_D^{20}$ **-76.0° (c 5, H_2O).** Crystd from MeOH/EtOH (1:1). Separation from normal *allo*-isomer can be achieved by crystn of the copper salts (see *Biochem Prep* **8** 114 *1961*).

4'-Hydroxypropiophenone *[70-70-2]* **M 150.2, m 149°.** Crystd from water.

2-(α-Hydroxypropyl)piperidine *[24448-89-3]* **M 143.2, m 121°, b 226°.** Crystd from ether.

7-(2-Hydroxypropyl)theophylline *[603-00-9]* **M 238.2, m 135-136°.** Crystd from EtOH.

6-Hydroxypurine *[68-94-0]* **M 136.1, m 150°(dec).** Crystd from hot water. Dried at 105°.

2-Hydroxypyridine *[142-08-5]* **M 95.1, m 105-107°, b 181-185°/24mm,** ε_{293nm} **5900 (H_2O).** Distd under vacuum to remove coloured impurity, then crystd from benzene, CCl_4, EtOH or $CHCl_3$/ethyl ether. It can be sublimed under high vacuum. [DePue et al. *JACS* **107** 2131 *1985*].

3-Hydroxypyridine *[109-00-2]* **M 95.1, m 129°.** Crystd from water or EtOH.

4-Hydroxypyridine *[626-64-2]* **M 95.1, m 65°(hydrate), 148.5° (anhydr), b >350°/760mm.** Crystd from H_2O. Loses H_2O on drying *in vacuo* over H_2SO_4. Stored over KOH because it is *hygroscopic*.

2-Hydroxypyridine-5-carboxylic acid *[5006-66-6]* **M 139.1, m 304°(dec),**
4-Hydroxypyridine-2,6-dicarboxylic acid (chelidamic acid) *[138-60-3]* **M 183.1, m 254°(dec).** Crystd from water.

2-Hydroxypyrimidine *[557-01-7]* **M 96.1, m 179-180°.** Crystd from EtOH or ethyl acetate.

4-Hydroxypyrimidine *[4562-27-0]* **M 96.1, m 164-165°.** Crystd from benzene or ethyl acetate.

2-Hydroxypyrimidine hydrochloride *[38353-09-2]* **M 132.5, m 205°(dec).** Crystd from EtOH.

***R*-3-Hydroxypyrrolidine** *[2799-21-5]* **M 87.2, b 215-216°,** d_4^{20} **1.078,** n_D^{20} **1.490,** $[\alpha]_D^{20}$ **+6.5° (c 3.5, MeOH).** Purify by repeated distn. The *hydrochloride* has -ve rotation and the *dimethiodide* has **m** 230° and $[\alpha]_D^{24}$ -8.02°. [Suyama and Kanno *J Pharm Soc Japan* **85** 531 *1965*; Uno et al. *JHC* **24** 1025 *1987*; Flanagan and Joullie *Heterocycles* **26** 2247 *1947*].

2-Hydroxyquinoline *[59-31-4]* **M 145.2, m 199-200°.** Crystd from MeOH.

8-Hydroxyquinoline (oxine, 8-quinolinol) *[148-24-3]* **M 145.2, m 71-73°, 75-76°, 76°, b ~ 267°.** Crystd from hot EtOH, acetone, pet ether (b 60-80°) or water. Crude oxine can be purified by pptn of copper oxinate, followed by liberation of free oxine with H_2S or by steam distn after acidification with H_2SO_4. Stored in the dark. Forms metal complexes. [Manske et al. *Canad J Research* **27F** 359 *1949;* Phillips *Chemical Reviews* **56** 271 *1956*].

8-Hydroxyquinoline-5-sulphonic acid (H_2O) *[84-88-8]* **M 243.3, m >310°.** Crystd from water or dil HCl (*ca* 2% by weight).

5-Hydroxysalicylic acid *[490-79-9]* **M 154.1, m 204.5-205°.** Crystd from hot water.

***trans*-5-Hydroxystilbene** *[6554-98-9]* **M 196.3, m 189°.** Crystd from benzene or acetic acid.

***N*-Hydroxysuccinimide** *[6066-32-6]* **M 115.1, m 96-98°.** Recrystd from EtOH/ethyl acetate [Manesis and Goodmen *JOC* **52** 5331 *1987*].

***dl*-2-Hydroxytetradecanoic acid** *[2507-55-3]* **M 244.4, m 81-82°,**
R-2-Hydroxytetradecanoic acid *[26632-17-7]* **M 244.4, m 88-2-88.5°, $[\alpha]_D^{20}$ -31° ($CHCl_3$).** Crystd from chloroform.

4-Hydroxy-2,2,6,6-tetramethylpiperidine *[2403-88-5]* **M 157.3, m 130-131°.** Crystd from water as hydrate, and crystd from ether as the anhydrous base.

4-Hydroxy-2,5,6-triaminopyrimidine sulphate *[35011-47-3]* **M 257.22, m >340°.** This salt has very low solubility in H_2O. It is best purified by conversion into the dihydrochloride salt which is then reconverted to the insoluble sulphate salt. The sulphate salt (2.57g, 10mmoles) is suspended in H_2O (20ml) containing $BaCl_2$ (10mmoles) and stirred in a boiling water bath for 15min. After cooling the insoluble $BaSO_4$ is filtered off and washed with boiling H_2O (10ml). The combined filtrate and washings are made acidic with HCl and evaporated to dryness. The residual hydrochloride salt is recrystd from H_2O by adding conc HCl whereby the *dihydrochloride salt* separates as clusters which darken at 260° and dec > 300° [Baugh and Shaw *JOC* **29** 3610 *1964*; King and Spengley *JCS* 2144 *1952*]. The hydrochloride is then dissolved in H_2O and while hot an equivalent of H_2SO_4 is added when the sulphate separates as a white microcrystalline solid which is filtered off washed liberally with H_2O and dried in vacuum over P_2O_5. [Albert and Wood *J Applied Chem* **3** 521 *1953*; UV: Cavalieri et al. *JACS* **70** 3875 *1948*; see also Pfleiderer *B* **90** 2272 *1957*; Traube *B* **33** 1371 *1900*].

9-Hydroxytriptycene *[73597-16-7]* **M 270.3, m 245-246.5°.** Crystd from benzene/pet ether. Dried at 100° in a vacuum [Imashiro et al. *JACS* **109** 729 *1987*].

5-Hydroxy-L-tryptophan *[4350-09-8]* **M 220.2, m 273°(dec), $[\alpha]_D^{22}$ -32.5°, $[\alpha]_{546}^{20}$ -73.5° (c 1, H_2O).** Likely impurities are 5-hydroxy-D-tryptophan and 5-benzyloxytryptophan. Crystd under nitrogen from water by adding EtOH. Stored under nitrogen.

Hydroxyurea *[127-07-1]* **M 76.1, m 70-72° (unstable form), 141°.** Crystd from H_2O by addition of EtOH.

3-Hydroxyxanthone *[3722-51-8]* **M 212.2, m 246°.** Purified by chromatography on SiO_2 gel with pet ether/benzene). Recrystd from benzene or EtOH [Itoh et al. *JACS* **107** 4819 *1985*].

α-Hyodeoxycholic acid *[83-49-8]* **M 392.6, m 196-197°, $[\alpha]_{546}^{20}$ +8° (c 2,EtOH).** Crystd from ethyl acetate.

Hyoscine (scopolamine, atroscine) *[114-49-8]* **M 321.4, m 59°, $[\alpha]_D^{20}$ -18° (c 5, EtOH), -28° (c 2, H_2O), $[\alpha]_{546}^{20}$ -30° (c 5, $CHCl_3$).** Crystd from benzene/pet ether. Racemate has **m** 56-57° (H_2O), 37-38° ($2H_2O$), syrup (anhydr), *l* and *d* isomers can separate as syrups when anhydrous.

Hypericin *[548-04-9]* **M 504.4, m 320°(dec).** Crystd from pyridine by addition of methanolic HCl.

Hypoxanthine see **6-hydroxypurine.**

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Ibogaine *[83-74-9]* **M 300.3, m 152-153°.** Crystd from aqueous EtOH.

Imidazole *[288-32-4]* **M 68.1, m 89.5-91°, b 256°.** Crystd from benzene, CCl_4, CH_2Cl_2, EtOH, pet ether, acetone/pet ether and distd deionized water. Dried at 40° under vacuum over P_2O_5. Distd at low pressure. Also purified by sublimation or by zone melting. [Caswell and Spiro *JACS* **108** 6470 *1986*]. ^{15}N-imidazole was crystd from benzene [Scholes et al. *JACS* **108** 1660 *1986*].

2-Imidazolidinethione see **ethylene thiourea.**

2-Imidazolidone see **ethylene urea.**

4-(Imidazol-1-yl)acetophenone *[10041-06-2]* **M 186.2, m 104-107°.** Twice recrystd from CH_2Cl_2/hexane [Collman et al. *JACS* **108** 2588 *1986*].

4,4'-(imidocarbonyl)bis(*N,N'*-dimethylaniline) monohydrochloride see **Auramine O.**

Iminodiacetic acid *[142-73-4]* **M 133.1, m 225°(dec).** Crystd from water.

2,2'-Iminodiethanol see **diethanolamine.**

1,3-Indandione *[606-23-5]* **M 146.2, m 129-132°.** Recrystd from EtOH [Bernasconi and Paschalis *JACS* **108** 2969 *1986*].

Indane *[496-11-7]* **M 118.1, b 177°, d 0.960, n 1.538.** Shaken with conc H_2SO_4, then water, dried and fractionally distd.

Indanthrone *[81-77-6]* **M 442.4, m 470-500°.** Crystd repeatedly from 1,2,4-trichlorobenzene.

Indazole *[271-44-3]* **M 118.1, m 147°.** Crystd from water, sublimed under a vacuum, then pet ether (b 60-80°).

Indene *[95-13-6]* **M 116.2, f.p. -1.5°, b 114.5°/100mm, d 0.994, n 1.5763.** Shaken with 6M HCl for 24h (to remove basic nitrogenous material), then refluxed with 40% NaOH for 2h (to remove benzonitrile). Fractionally distd, then fractionally crystd by partial freezing. The higher-melting portion was converted to its sodium salt by adding a quarter of its weight of sodamide under nitrogen and stirring for 3h at 120°. Unreacted organic material was distd off at 120°/1mm. The sodium salts were hydrolysed with water, and the organic fraction was separated by steam distn, followed by fractional distn. Before use, the distillate was passed, under nitrogen, through a column of activated silica gel. [Russell *JACS* **78** 1041 *1956*].

Indigo *[482-89-3]* **M 262.3, and halogen-substituted indigo dyes.** Reduced in alkaline soln with sodium hydrosulphite, and filtered. The filtrate was then oxidised by air, and the resulting ppte was filtered off, dried at 65-70°, ground to a fine powder, and extracted with $CHCl_3$ in a Soxhlet extractor. Evapn of the $CHCl_3$ gave the purified dye. [Brode, Pearson and Wyman *JACS* **76** 1034 *1954*; spectral characteristics are listed].

Indigocarmine (2[1,3-dihydro-3-oxo-5-sulpho-2*H*-indol-2-ylidene]-2,3-dihydro-3-oxo-1*H*-indole-5-sulpfonic acid disodium salt) *[860-22-0]* **M 466.4.** Its solubility in H_2O is 1g/100ml at 25°. Could be purified by dissolving in H_2O, filtering and adding EtOH to cause the salt to separate. Wash the solid with EtOH, Et_2O and dry *in vacuo*. It has pKa values of 2.8 and 12.3 in H_2O. [Vörlander and Schubert *B* **34** 1860 *1901*; UV: Smit et al. *AC* **27** 1159 *1955;* Preisler et al. *JACS* **81** 1991 *1959*].

Indole *[120-72-9]* **M 117.2, m 52°, 124°/5mm, b 253-254°/760mm.** Crystd from benzene, hexane, water or EtOH/water (1:10). Further purified by sublimation in a vacuum or zone melting.

Indole-3-acetic acid *[87-51-4]* **M 175.2, m 167-169°.** Recrystd from EtOH/water [James and Ware *JPC* **89** 5450 *1985*].

3-Indoleacetonitrile *[771-51-7]* **M 156.2, m 33-36°, 36-38°, b 157°/0.2mm, 158-160°/0.1mm, viscous oil n_D^{20} 1.6097.** Distil in very high vacuum and the viscous distillate crystallises on standing after a few days; the *picrate* has **m** 127-128° (from EtOH) [Coker et al. *JOC* **27** 850 *1962*; Thesing and Schülde *B* **85** 324 *1952*]. The *N-acetate* has **m** 118° (from MeOH) and has R_F = 0.8, on Silica Gel F_{254} in $CHCl_2$-MeOH 19:1 [Buzas et al. *S* 129 *1977*].

Indole-3-butanoic acid *[133-32-4]* **M 203.2, m 124-125°,**
Indole-3-propionic acid *[830-96-6]* **M 189.2, m 134-135°.** Recrystd from EtOH/water [James and Ware *JPC* **89** 5450 *1985*].

(-)-Inosine *[58-63-9]* **M 268.2, m 215°, $[\alpha]_{546}^{20}$ -76° (c 1, 0.1M NaOH).** Crystd from aqueous 80% EtOH.

***i*-Inositol** *[87-88-8]* **M 180.2, m 228°.** Crystd from water or aqueous 50% EtOH. Dried under vacuum.

***meso*-Inositol** *[87-89-8]* **M 180.2, m 223-225°.** Crystd from aqueous EtOH.

Inositol monophosphate *[15421-51-9]* **M 260.1, m 195-197°(dec).** Crystd from water and EtOH.

Inulin *[9005-80-5]* **M $(162.14)_n$.** Crystd from water.

Iodoacetamide *[144-48-9]* **M 185.0, m** *ca* **143°(dec).** Crystd from water or CCl_4.

Iodoacetic acid *[64-69-7]* **M 160.6, m 78°.** Crystd from pet ether (b 60-80°) or $CHCl_3$/CCl

1-Iodoadamantane see **1-adamantyl iodide.**

2-Iodoaniline *[615-43-0]* **M 219.0, m 60-61°.** Distd with steam and crystd from benzene/pet ether.

4-Iodoaniline *[540-37-4]* **M 219.0, m 62-63°.** Crystd from pet ether (b 60-80°) by refluxing, then cooling in an ice-salt bath freezing mixture. Dried in air. Also crystd from EtOH and dried in a vacuum for 6h at 40° [Edidin et al. *JACS* **109** 3945 *1987*].

4-Iodoanisole *[696-62-8]* **M 234.0, m 51-52°, b 139°/35mm, 237°/726mm.** Crystd from aqueous EtOH.

Iodobenzene *[591-50-4]* **M 204.0, b 63-65°/10mm, 188°/atm, d 1.829, n^{25} 1.6169.** Washed with dilute aqueous $Na_2S_2O_3$, then water. Dried with $CaCl_2$ or $CaSO_4$. Decolorised with charcoal. Distd under reduced pressure and stored with mercury or silver powder to stabilise it.

***o*-Iodobenzoic acid** *[88-67-5]* **M 248.4, m 162°,**
***m*-Iodobenzoic acid** *[618-51-9]* **M 248.4, m 186.6-186.8°,**
***p*-Iodobenzoic acid** *[619-58-9]* **M 248.4, m 271-272°.** Crystd repeatedly from water and EtOH. Sublimed under vacuum at 100°.

4-Iodobiphenyl *[1591-31-7]* **M 280.1,m 113.7-114.3°.** Crystd from EtOH/benzene and dried under vacuum over P_2O_5.

1-Iodobutane see ***n*-butyl iodide.**

2-Iodobutane *[513-48-4]* **M 184.0, b 120.0, d 1.50, n^{25} 1.4973.** Purified by shaking with conc H_2SO_4, then washing with water, aq Na_2SO_3 and again with water. Dried with $MgSO_4$ and distd. Alternatively, passed through a column of activated alumina before distn, or treated with elemental bromine, followed by extraction of the free halogen with aqueous $Na_2S_2O_3$, thorough washing with water, drying and distilling. It is stored over silver powder and distd before use.

1-Iodo-2,4-dinitrobenzene *[709-49-9]* **M 294.0, m 88°.** Crystd from ethyl acetate.

Iodoethane see **ethyl iodide.**

Iodoform *[75-47-8]* **M 393.7, m 119°.** Crystd from MeOH, EtOH or EtOH/ethyl acetate.

1-Iodo-2-methylpropane see **isobutyl iodide.**

1-Iodo-4-nitrobenzene *[636-98-6]* **M 249.0, m 171-172°.** Ppted from acetone by addition of water, then recrystd from EtOH.

o-**Iodophenol** *[533-58-4]* **M 280.1, m 42°.** Crystd from $CHCl_3$ or ethyl ether.

p-**Iodophenol** *[540-38-5]* **M 280.1, m 94°.** Crystd from pet ether (b 80-100°).

1-Iodopropane see *n*-**propyl iodide.**

2-Iodopropane see **isopropyl iodide**

3-Iodopropene see **allyl iodide.**

5-Iodosalicylic acid *[119-30-2]* **M 264.0, m 197°.** Crystd from water.

o-**Iodosobenzoic acid** *[304-91-6]* **M 264.0, m >200°.** Crystd from EtOH.

N-**Iodosuccinimide** *[512-12-1]* **M 225.0, m 200-201°.** Crystd from dioxane/CCl_4.

p-**Iodotoluene** *[624-31-7]* **M 218.0, m 35°, b 211-212°.** Crystd from EtOH.

3-Iodo-L-tyrosine *[70-78-0]* **M 307.1, m 205-208°(dec), $[\alpha]_D^{25}$ -4.4° (1M HCl).** Likely impurities are tyrosine, diiodotyrosine and iodide. Crystd by soln in dilute ammonia, at room temperature, followed by addition of dilute acetic acid to pH 6. Stored in the cold.

α-Ionone *[127-41-3]* **M 192.3, b 131°/13mm, d 0.931, n 1.520, $[\alpha]_D^{23}$ +347° (neat).** Purified on a spinning band fractionating column.

β-Ionone *[79-77-6]* **M 192.3, b 150-151°/24mm, d 0.945, n 1.5211, ε_{296nm} 10,700.** Converted to the *semicarbazone* (**m** 149°) by adding 50g of semicarbazide hydrochloride and 44g of potassium acetate in 150ml of water to a soln of 85g of ß-ionone in EtOH. (More EtOH was added to redissolve any ß-ionone that ppted.) The semicarbazone crystallised on cooling in an ice-bath and was recrystallised from EtOH or 75% MeOH to constant **m** (148-149°). The semicarbazone (5g) was shaken at room temperature for several days with 20ml of pet ether and 48ml of M H_2SO_4, then the ether layer was washed with water and dilute aqueous $NaHCO_3$, dried and the solvent was evaporated. The ß-ionone was distilled under vacuum. (The customary steam distillation of ß-ionone semicarbazone did not increase the purity.) [Young et al. *JACS* **66** 855 *1944*].

Iproniazid phosphate *[305-33-9]* **M 277.2, m 178-179°.** Crystd from water and acetone.

(±)-Irone (6-methyl-ionone, ±-*trans*-(α)-4*t*-[2,5,6,6-tetramethyl-cyclohex-2-yl]but-3*t*-en-2-one) *[79-69-6]* **M 206.3, b 85-86°/0.05mm, 109°/0.7mm, d_4^{20} 0.9340, n_D^{20} 1.4998.** If large amounts are available then fractionate through a Podbielniak column or an efficient spinning band column, but small amounts are distilled using a Kügelrohr apparatus. The *4-phenyl-semicarbazone* has **m** 174-175° (165-165.5°). [IR: Seidel and Ruzocka *HCA* **35** 1826 *1952*; Naves *HCA* **31** 1280 *1948*; Lecomte and Naves *J Chimique Physique* **53** 462 *1956*].

Isatin *[91-56-5]* **M 147.1, m 200°.** Crystd from amyl alcohol.

Isatoic anhydride (3,1-benzoxazin-2,4[1-*H*]-dione) *[118-48-9]* **M 1633.1, m 235-240°, 240-243°, 243°, 243-245°.** Recryst from EtOH or 95% EtOH (30ml/g) or dioxane (10ml/g) and dried in a vacuum. [Wagner and Fegley *Org Synth* Coll Vol III 488 *1955*; Ben-Ishai and Katchalski *JACS* **74** 3688 *1952*; UV: Zentmyer and Wagner *JOC* **14** 967 *1949*].

Isoamyl acetate *[123-92-2]* **M 130.2, b 142.0°, d 0.871, n 1.40535.** Dried with finely divided K_2CO_3 and fractionally distd.

Isoamyl alcohol *[123-51-3]* **M 88.2, b 132°/760mm, d 0.809, n 1.408.** Dried with K_2CO_3 or $CaSO_4$, then fractionally distd. If more nearly anhydrous alcohol is required, the distillate can be refluxed with the appropriate alkyl phthalate or succinate as described for *ethanol.*

Isoamyl bromide *[107-82-4]* **M 151.1, f.p. -112°, b 119.2°/737mm, d 1.208, n 1.444.** Shaken with conc H_2SO_4, washed with water, dried with K_2CO_3 and fractionally distd.

Isoamyl chloride *[513-36-0]* **M 106.6, b 99°/734mm, d 0.8704, n 1.4084.** Shaken vigorously with 95% H_2SO_4 until the acid layer no longer became coloured during 12h, then washed with water, saturated aq Na_2CO_3, and more water. Dried with $MgSO_4$, filtered and fractionally distd. Alternatively, a stream of oxygen containing 5% of ozone was passed through the chloride for a time, three times longer than was necessary to cause the first coloration of starch iodide paper by the exit gas. Subsequent washing of the liquid with aqueous $NaHCO_3$ hydrolysed the ozonides and removed organic acids. After drying and filtering, the isoamyl chloride was distd. [Chien and Willard *JACS* **75** 6160 *1953*].

Isoamyl ether *[544-01-4]* **M 158.3, b 173.4°, d 0.778, n 1.40850.** This is a mixture of 2- and 3-methylbutyl ether. It is purified by refluxing with sodium for 5h, then distilled under reduced pressure, to remove alcohols. Isoamyl ether can also be dried with $CaCl_2$ and fractionally distd from P_2O_5.

Isoascorbic acid *[89-65-6]* **M 176.1, m 174°(dec), $[\alpha]_D^{25}$ -16.8° (c 2, H_2O).** Crystd from H_2O or dioxane.

***dl*-Isoborneol** *[124-76-5]* **M 154.3, m 212° (sealed tube).** Crystd from EtOH or pet ether (b 60-80°). Sublimes in a vacuum.

Isobutane *[75-28-5]* **M 58.1, b -10.2°, d 0.557.** Olefines and moisture can be removed by passage at 65° through a bed of silica-alumina catalyst which has previously been evacuated at about 400°. Alternatively, water and CO_2 can be taken out by passage through P_2O_5 then asbestos impregnated with NaOH. Treatment with anhydrous $AlBr_3$ at 0° then removes traces of olefines. Inert gases can be separated by freezing the isobutane at -195° and evacuating out the system.

Isobutene *[115-11-7]* **M 56.1, b -6.6°/760mm.** Dried by passage through anhydrous $CaSO_4$ at 0°. Purified by freeze-pump-thaw cycles and trap-to-trap distn.

Isobutyl alcohol *[78-83-1]* **M 74.1, b 108°/760mm, d 0.801, n 1.396.** Dried with K_2CO_3, $CaSO_4$ or $CaCl_2$, filtered and fractionally distd. For further drying, the redistd alcohol can be refluxed with the appropriate alkyl phthalate or succinate as described under *ethanol.*

Isobutyl bromide *[78-77-3]* **M 137.0, b 91.2°, d 1.260, n 1.437.** Partially hydrolysed to remove any tertiary alkyl halide, then fractionally distd, washed with conc H_2SO_4, water and aqueous K_2CO_3, then redistd from dry K_2CO_3. [Dunbar and Hammett *JACS* **72** 109 *1950*].

Isobutyl chloride *[513-36-0]* **M 92.3, b 68.8°/760mm, d 0.877, n 1.398.** Same methods as described under *isoamyl chloride.*

Isobutylene see **Isobutene.**

Isobutyl formate *[543-27-1]* **M 102.1, b 98.4°, d 0.885, n 1.38546.** Washed with saturated aqueous $NaHCO_3$ in the presence of saturatedd NaCl, until no further reaction occurred, then with saturated aqueous NaCl, dried ($MgSO_4$) and fractionally distd.

Isobutyl iodide *[513-38-2]* **M 184.0, b 83°/250mm, 120°/760mm, d 1.60, n 1.495.** Shaken with conc H_2SO_4, and washed with water, aqueous Na_2SO_3, and water, dried with $MgSO_4$ and distd. Alternatively, passed through a column of activated alumina before distn. Stored under nitrogen with mercury in a brown bottle or in the dark.

Isobutyl mercaptan see **2-methylpropane-1-thiol.**

Isobutyl vinyl ether *[109-53-5]* **M 100.2, b 108-110°, d 0.768, n 1.398.** Washed three times with equal volumes of aqueous 1% NaOH, dried with CaH_2, refluxed with sodium for several hours, then fractionally distd from sodium.

Isobutyraldehyde *[78-84-2]* **M 72.1, b 62.0°, d 0.789, n 1.377.** Dried with $CaSO_4$ and used immediately after distn under nitrogen because of the great difficulty in preventing oxidation. Can be purified through its acid bisulphite derivative.

Isobutyramide *[563-83-7]* **M 87.1, m 128-129°, b 217-221°.** Crystd from acetone, benzene, $CHCl_3$ or water, then dried under vacuum over P_2O_5 or 99% H_2SO_4. Sublimed under vacuum.

Isobutyric acid *[79-31-2]* **M 88.1. b 154-154.5°, d 0.949, n 1.393.** Distd from $KMnO_4$, then redistd from P_2O_5.

Isobutyronitrile *[78-82-0]* **M 69.1, b 103.6°, d^{25} 0.7650, n 1.378.** Shaken with conc HCl (to remove isonitriles), then with water and aq $NaHCO_3$. After a preliminary drying with silica gel or Linde type 4A molecular sieves, it is shaken or stirred with CaH_2 until hydrogen evolution ceases, then decanted and distd from P_2O_5 (not more than 5g/L, to minimize gel formation). Finally it is refluxed with, and slowly distd from CaH_2 (5g/L), taking precautions to exclude moisture.

(-)-γ-Isocaryophyllene (8-methylene-4,11,11-trimethylbicyclo[7,2,0]undec-4-ene) *[118-65-0]* **M 204.4, b 122-124°/12mm, 131-133°/16mm, 130-131°/24mm, 271-273°/atm, d_4^{20} 0.8959, n_D^{20} 1.496, $[\alpha]_{546}^{20}$ -31°, $[\alpha]_D^{20}$ -27° (neat).** Purified by vac dist or GLC using a nitrile-silicone column [Corey et al. *JACS* **86** 485 *1964*; Ramage and Simonsen *JCS* 741 *1936*; Kumar et al. *S* 461 *1976*].

Isodurene see **1,2,3,5-tetramethylbenzene.**

L-Isoleucine *[73-32-5]* **M 131.2, m 285-286°(dec), $[\alpha]_D^{20}$ +40.6° (6M HCl).** Crystd from water by addition of 4 volumes of EtOH.

(-)-β-Isolongifolene (1-*R*02,2,7,7-tetramethyltricyclo[6.2.1.$0^{1,6}$]undec-5-ene) *[1135-66-6]* **M 204.4, b82-83°/0.4mm, 144-146°/30mm, 255-256°/atm, d_4^{20} 0.930, n_D^{20} 1.4992, $[\alpha]_{546}^{20}$ -166°, $[\alpha]_D^{20}$ -138° (c 1, EtOH).** Refluxed over and distd from Na. [Zeiss and Arakawa *JACS* **76** 1653 *1954*; IR: Reinaecker and Graafe *Angew Chemie, Engl Edn.* **97** 348 *1985*; UV and NMR: Ranganathan et al. *TET* **26** 621 *1970*].

Isolysergic acid *[478-95-5]* **M 268.3, m 218°(dec), $[\alpha]_D^{20}$ +281° (c 1, pyridine).** Crystd from water.

Isonicotinamide *[1453-82-3]* **M 122.1, m 155.5-156°.** Recrystd from hot water.

Isonicotinic acid *[55-22-1]* **M 123.1, m 320°.** Crystd repeatedly from water. Dried under vac at 110°.

Isonicotinic acid hydrazide *[54-87-3]* **M 137.1, m 172°.** Crystd from 95% EtOH.

1-Isonicotinic acid 2-isopropylhydrazide *[54-92-2]* **M 179.2, m 112.5-113.5°.** Crystd from benzene/pet ether.

1-Isonicotinyl-2-salicylidenehydrazide *[495-84-1]* **M 241.2, m 232-233°.** Crystd from EtOH.

Isonitrosoacetone *[31915-82-9]* **M 87.1, m 69°.** Crystd from ether/pet ether or CCl_4.

Isonitrosoacetophenone *[532-54-7]* **M 149.2, m 126-128°.** Crystd from water.

5-Isonitrosobarbituric acid (violuric acid) *[87-39-8]* **M 175.1, m 245-250°.** Crystd from water or EtOH.

Isononane *[34464-40-9]* **M 128.3, b 142°/760mm.** Passed through columns of activated silica gel and basic alumina (activity 1). Distd under high vacuum from Na/K alloy.

Isooctane see **2,2,4-trimethylpentane.**

Isopentane see **2-methylbutane.**

Isopentenyl pyrophosphate see Chapter 5.

Isopentyl- see **isoamyl-.**

Isopentyl formate *[110-45-2]* **M 116.2, b 121-123°/atm, 123-123.6°/atm, 123-124°/atm, d_4^{20} 0.8713, n_D^{20} 1.391.** Colourless liquid which is soluble in 300 volumes of H_2O and is soluble in common organic solvents. It is purified by repeated distn using an efficient column at atmospheric pressure.

Isophorone *[78-59-1]* **M 138.2, b 94°/16mm, d 0.921, n^{18} 1.4778.** Washed with aqueous 5% Na_2CO_3 and then distd under reduced pressure, immediately before use. Alternatively, can be purified *via* the semicarbazone. [Erskine and Waight *JCS* 3425 *1960*].

Isophthalic acid *[121-91-5]* **M 166.1, m 345-348°.** Crystd from aqueous EtOH.

(+)-(1*S*,2*S*,3*S*,5*R*) *[27779-29-9]* **and (-)-(1*R*,2*R*,3*R*,5*S*)** *[25465-65-0]* **Isopinocampheol (pinan-3-ol, 2,6,6-trimethylbicyclo[3.1.1]heptan-3-ol) M 154.25, m 52-55°, 55-56°, 55-57°, b 103°/11mm, n_D^{20} 1.4832, $[\alpha]_{546}^{20}$ ±43°, $[\alpha]_D^{20}$ ±36° (c 20, EtOH).** Dissolve in Et_2O, dry $MgSO_4$, filter, evaporate, then recryst from pet ether. Also recryst from aqueous EtOH and has been distd in a vacuum. [Kergomard and Geneix *Bull Soc Chim France* 394 *1958*; Zweifel and Brown *JACS* **86** 393 *1964*]. The *3,4-dinitrobenzoyl* deriv has **m** 100-101°, the *phenylcarbamoyl* derivative has **m** 137-138° and the *acid -phthallate* has **m** 125-126°.

Isoprene *[78-79-5]* **M 68.1, b 34.5-35°/762mm, d 0.681, n^{25} 1.4225.** Refluxed with sodium. Distd from sodium or $NaBH_4$ under nitrogen, then passed through a column containing KOH, $CaSO_4$ and silica gel. *tert*-Butylcatechol (0.02% w/w) was added, and the isoprene was stored in this way until redistd before use. The inhibitor (*tert*-butylcatechol) in isoprene can be removed by several washings with dil NaOH and water. The isoprene is then dried over CaH_2, distd under nitrogen at atmospheric pressure, and the fraction distilling at 32° is collected. Stored under nitrogen at -15°.

Isopropanol *[67-63-0]* **M 60.1, b 82.5°, d 0.783, $n^{25.8}$ 1.3739.** Isopropyl alcohol is prepared commercially by dissolution of propene in H_2SO_4, followed by hydrolysis of the sulphate ester. Major impurities are water, lower alcohols and oxidation products such as aldehydes and ketones. Purification of isopropanol follows substantially the same procedure as for ***n*-propyl alcohol.**

Isopropanol forms a constant-boiling mixture, b 80.3°, with water. Most of the water can be removed from this 91% isopropanol by refluxing with CaO (200g/L) for several hours, then distilling. The distillate can be dried further with CaH_2, magnesium ribbon, BaO, $CaSO_4$, calcium, anhydrous $CuSO_4$ or Linde type 5A molecular sieves. Distn from sulphanilic acid removes ammonia and other basic impurities. Peroxides [indicated by liberation of iodine from weakly acid (HCl) solns of 2% KI] can be removed by refluxing with solid stannous chloride or with $NaBH_4$ then fractionally distilling. To obtain isopropanol containing only 0.002M of water, sodium (8g/L) has been dissolved in material dried by distn from $CaSO_4$, 35ml of isopropyl benzoate has been added and, after refluxing for 3h, the alcohol has been distd through a 50-cm Vigreux column. [Hine and Tanabe *JACS* **80** 3002 *1958*]. Other purification steps for isopropanol include refluxing with solid aluminium isopropoxide, refluxing with $NaBH_4$ for 24h, and the removal of acetone by treatment with, and distn from 2,4-dinitrophenylhydrazine. Peroxides re-form in isopropanol if it is stood for several days.

Isopropenylcyclobutane *[3019-22-5]* **M 98.1.** Purified by preparative chromatography (silicon oil column). Dried with molecular sieves.

Isopropyl acetate *[108-22-5]* **M 102.1, b 88.4°, d 0.873, n 1.3773.** Washed with 50% aq K_2CO_3 (to remove acid), then with saturated aq $CaCl_2$ (to remove any alcohol). Dried with $CaCl_2$ and fractionally distd.

Isopropyl alcohol see **isopropanol.**

Isopropyl benzene see **cumene.**

Isopropyl bromide *[75-26-3]* **M 123.0, b 0°/69.2mm, 59.4°/760mm, d 1.31, n^{15} 1.42847, n 1.4251.** Washed with 95% H_2SO_4 (conc acid partially oxidised it) until a fresh portion of acid did not become coloured after several hours, then with water, aq $NaHSO_3$, aq 10% Na_2CO_3 and again with water. (The H_2SO_4 can be replaced by conc HCl.) Prior to this treatment, isopropyl bromide has been purified by bubbling a stream of oxygen containing 5% ozone through it for 1h, followed by shaking with 3% hydrogen peroxide soln, neutralising with aq Na_2CO_3, washing with distilled water and drying. Alternatively, it has been treated with elemental bromine and stored for 4 weeks, then extracted with aq $NaHSO_3$ and dried with $MgSO_4$. After the acid treatment, isopropyl bromide can be dried with Na_2SO_4, $MgSO_4$ or CaH_2, and fractionally distd.

***N*-Isopropylcarbazole** *[1484-09-9]* **M 209.3.** Crystd from isopropanol. Sublimed under vacuum. Zone refined.

Isopropyl chloride *[75-29-6]* **M 78.5, b 34.8°, d 0.864, n 1.3779, n^{25} 1.3754.** Purified with 95% H_2SO_4 as described for *isopropyl bromide*, then dried with $MgSO_4$, P_2O_5 or CaH_2, and fractionally distd from Na_2CO_3 or CaH_2. Alternatively, a stream of oxygen containing *ca* 5% ozone has been passed through the chloride for about three times as long as was necessary to obtain the first coloration of starch iodide paper by the exit gas, and the liquid was then washed with $NaHCO_3$ soln to hydrolyse ozonides and remove organic acids before drying and distilling.

Isopropyl ether *[108-20-3]* **M 102.2, b 68.3°, d 0.719, n 1.3688, n^{25} 1.36618.** Common impurities are water and peroxides [detected by the liberation of iodine from weakly acid (HCl) solns of 2% KI]. Peroxides can be removed by shaking with aqueous Na_2SO_3 or with acidified ferrous sulphate (0.6g $FeSO_4$ and 6ml conc H_2SO_4 in 110ml of water, using 5-10g of soln per L of ether), or aqueous $NaBH_4$ soln. The ether is then washed with water, dried with $CaCl_2$ and distd. Alternatively, refluxing with $LiAlH_4$ or CaH_2, or drying with $CaSO_4$, then passage through an activated alumina column, can be used to remove water and peroxides. Other dehydrating agents used with isopropyl ether include P_2O_5, sodium amalgam and sodium wire. (The ether is often stored in brown bottles, or in the dark, with sodium wire.) Bonner and Goishi (*JACS* **83** 85 *1961*) treated isopropyl ether with dil sodium dichromate/sulphuric acid soln, followed by repeated shaking with a 1:1 mixture of 6M NaOH and saturated $KMnO_4$. The ether was washed several times with water, dilute aqueous HCl, and water, with a final washing with, and storage over, ferrous ammonium sulphate acidified with H_2SO_4. Blaustein and Gryder (*JACS* **79** 540 *1957*), after washing with alkaline $KMnO_4$, then water, treated the ether with ceric nitrate in nitric acid, and again washed with water. Hydroquinone was added before drying with $CaCl_2$ and $MgSO_4$, and refluxing with sodium amalgam (108g Hg/100g Na) for 2h under nitrogen. The distillate

(nitrogen atmosphere) was made 2 x 10^{-5}M in hydroquinone to inhibit peroxide formation (which was negligible if the ether was stored in the dark). Pyrocatechol and resorcinol are alternative inhibitors.

4,4'-Isopropylidenediphenol *[80-05-7]* **M 228.3, m 158°.** Crystd from acetic acid/water (1:1).

Isopropyl iodide *[75-30-9]* **M 170.0, b 88.9°, d 1.70, n 1.4987.** Treated with elemental bromine, followed by extraction of free halogen with aqueous $Na_2S_2O_3$ or $NaHSO_3$, washing with water, drying ($MgSO_4$ or $CaCl_2$) and distn. (The treatment with bromine is optional.) Other purification methods include passage through activated alumina, or shaking with copper powder or mercury to remove iodine, drying with P_2O_5 and distn. Washing with conc H_2SO_4, water, aqueous Na_2SO_3, water and aqueous Na_2CO_3 has also been used. Treatment with silica gel causes some liberation of iodine. Distillations should be carried out at slightly reduced pressure. Purified isopropyl iodide is stored in the dark in the presence of a little mercury.

Isopropyl mercaptan see **propane-2-thiol.**

Isopropyl methyl ether *[598-53-8]* **M 74.1, b 32.5°/777mm, d^{15} 0.724, n 1.3576.** Purified by drying with $CaSO_4$, passage through a column of alumina (to remove peroxides) and fractional distn.

Isopropyl *p*-nitrobenzoate *[13756-40-6]* **M 209.2, m 105-106°.** Dissolved in ethyl ether, washed with aqueous alkali, then water and dried. Evapn of the ether and recrystn from EtOH gave pure material.

***p*-Isopropyl toluene** *[99-87-6]* **M 134.2, b 176.9°/744mm, d 0.856, n 1.4902.** Dried with CaH_2 and fractionally distd. Stored with CaH_2.

Isoquinoline *[119-65-3]* **M 129.2, m 24°, b 120°/18mm, d 1.0986, n 1.6148.** Dried with Linde type 5A molecular sieves or Na_2SO_4 and fractionally distd at reduced pressure. Alternatively, it was refluxed with, and distd from, BaO. Also purified by fractional crystn from the melt and distd from zinc dust. Converted to its *phosphate* (**m** 135°) or *picrate* (**m** 223°), which were purified by crystn and the free base recovered and distd. [Packer, Vaughn and Wong *JACS* **80** 905 *1958*]. The procedure for purifying *via* the picrate comprises the addition of quinoline to picric acid dissolved in the minimum volume of 95% EtOH to yield yellow crystals which are washed with EtOH and air dried before recrystn from acetonitrile. The crystals are dissolved in dimethyl sulphoxide (previously dried over 4A molecular sieves) and passed through a basic alumina column, on which picric acid is adsorbed. The free base in the effluent is extracted with *n*-pentane and distd under vacuum. Traces of solvent are removed by vapour phase chromatography. [Mooman and Anton *JPC* **80** 2243 *1976*].

Isovaleric acid *[502-74-2]* **M 102.1, b 176.5°/762mm, d 0.927, n^{15} 1.4064, n 1.40331.** Dried with Na_2SO_4, then fractionally distd.

L-Isovaline *[595-40-4]* **M 117.2, m** *ca* **300° (sublimes in vac), $[\alpha]_D^{18}$ +9° (2M HCl).** Crystd from aqueous acetone.

Isovanillin (3-hydroxy-4-methoxybenzaldehyde) *[621-59-0]* **M 152.2, m 117°, b 175°/14mm.** Cryst from H_2O or C_6H_6. The *oxime* has **m** 147°.

Isoviolanthrone *[128-64-3]* **M 456.5, m 510-511°(uncorrected).** Dissolved in 98% H_2SO_4 and ppted by adding water to reduce the acid concentration to about 90%. Sublimes *in vacuo*. [Parkyns and Ubblehode *JCS* 4188 *1960*].

Itaconic acid *[97-65-4]* **M 130.1, m 165-166°.** Crystd from EtOH, EtOH/water or EtOH/benzene.

Itaconic anhydride (2-propen-1,2-dicarboxylic anhydride) *[2170-03-8]* **M 112.1, m 66-68°, 67-68°, 68°, b 139-140°/30mm.** Crystd from $CHCl_3$/pet ether. Can be distd under reduced press. Distn at atm press, or prolonged distn causes rearrangement to citraconic anhydride (2-methylmaleic anhydride). If the material (as seen in the IR spectrum) contains much free acid then heat with acetyl chloride or $SOCl_2$, evaporate

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and distil at as high a vacuum as possible. The crude anhydride deposits crystals of itaconic acid on standing probably due to hydrolysis by H_2O — store in sealed ampoules under dry N_2. [*Org Synth* Coll Vol II 369 *1943*; IR: Nagai *Bull Chem Soc Japan* **37** 369 *1964*; Kelly and Segura *JACS* **56** 2497 *1934*].

Janus Green B (3-dimethylamino-7-[4-dimethylaminoazo]-5-phenylphenazonium chloride *[2869-83]* **M 511.1.** Dissolves in H_2O to give a bluish violet soln which becomes colourless when made 10M in. NaOH. Dissolve in EtOH to give a blue-violet colour, filter from insoluble material then add dry Et_2O whereby the dye separates out leaving a small amount of blue colour in soln. Filter off the solid and dry in vacuum. Store in a dark bottle.

Janus Red B *[2636-31-9]* **M 460.0.** Crystd from EtOH/H_2O (1:1 v/v) and dry in vacuum. Store in a dark bottle.

Jervine *[469-59-0]* **M 425.6, m 241-243°, $[\alpha]_D^{20}$ -147° (in EtOH).** Crystd from MeOH by addition of water.

Juglone see **2-hydroxy-1,4-naphthaquinone.**

Julolidine (2,3,6,7-tetrahydro-1*H*,5*H*-benzo[*ij*]quinolizidine) *[479-59-4]* **M 173.3, m 34-36°, 40°, b 105-110°/1mm, 155-156°/17mm, 280° (dec).** Purified by dissolving in dilute HCl, steam is bubbled through the soln and the residual acidic soln is basified with 10N NaOH, extracted with Et_2O, washed with H_2O, dried (NaOH pellets), filtered, evaporated and distd *in vacuo*. The distillate crystallises on standing (**m** 39-40°). On standing in contact with air for several days it develops a red colour. The colour can be removed by distilling or dissolving in 2-3 parts of hexane, adding charcoal, filtering and cooling in Me_2CO-Dry-ice when julolidine crystallises (85-90% yield). The *hydrochloride* *[83646-41-7]* has **m** 218° (239-242°), the *picrate* has **m** 165° and the *methiodide* crystallises from MeOH, **m** 186° [Glass and Weisberger *Org Synth* Coll Vol III 304 *1955*]. **Highly TOXIC.**

Kainic acid monohydrate (2*S*,3*S*,4*S*-2-carboxy-4-isoprenyl-3-pyrrolidine- acetic acid) *[487-79-6]* **M 231.4, m 235-245° (dec), $[\alpha]_D^{20}$ -14.6° (c 1.46, H_2O).** Purified by adsorbing on to a strongly acidic ion exchange resin (Merck I), elution of the diacid with aqueous M NaOH, the eluate is evaporated, H_2O is added, and filtered through a weakly acidic ion exchange resin (Merck IV). The filtrate is then evaporated and recrystd from EtOH. Its solubility is 0.1g in 1ml of 0.5N HCl. (±)-α-Kainic acid recryst from H_2O, **m** 230-260°. UV (MeOH): λmax 219 (logε 3.9); ^{1}H NMR (CCl_4, 100MHz, Me_4Si standard) δ: 1.64 (s iH), 1.70 (s 3H), 3.24 (d *J* 7.5, 2H), 3.3-4.2 (1H), 3.70 (s 3H), 3.83 (s 3H), 4.35 (dd *J* 7.5, *J* 14.5, 1H), 5.21 (t *J* 7.5, 1H), 7.26 (*t* J 7.5, 1H) ppm. [Oppolzer and Andres *HCA* **62** 2282 *1979*].

Kerosene *[8008-20-6]* **(mixture of hydrocarbons) d 0.75-0.82, n 1.443.** Stirred with conc H_2SO_4 until a fresh portion of acid remains colourless, then washed with water, dried with solid KOH and distd in a Claisen flask. For more complete drying, the kerosene can be refluxed with, and distilled from, sodium.

Ketanserine ([+]-3{4-*p*-fluorobenzoylpiperidinyl-N-ethyl}quinazolin-2,4-dione) *[74050-98-9]* **M 395.4, m 227-235°.** Solubility is 0.001%in H_2O, 0.038% in EtOH and 2.34 in Me_2NCHO. It has been purified by recrystn from 4-methyl-3-pentanone. It has a pKa of 7.5 [Peeters et al. *Cryst Structure Commun* **11** 375 *1982*; Kacprowicz et al. *JC* **272** 417 *1983*; Davies et al. *JC* **275** 232 *1983*].

Ketene *[463-51-4]*, **M 42.0, dimer** *[674-82-8]*, **M 84.1, b 127-130°, d 1.093, n 1.441.** Prepared by pyrolysis of acetic anhydride. Purified by passage through a trap at -75° and collected in a liquid-nitrogen-

cooled trap. Ethylene was removed by evacuating the ethylene in an isopentane-liquid-nitrogen slush pack at -160°. Stored at room temperature in a blackened bulb.

α-Ketoglutaric acid *[328-50-7]* **M 146.1, m 111-113°.** Crystd from acetone/benzene.

2-Keto-L-gulonic acid *[526-98-7]* **M 194.1, m 171°.** Crystd from water and washed with acetone.

Ketone moschus (4-*tert*-butyl-2,6-dimethyl-3,5-dinitroacetophenone) *[81-14-1]* **M 234.1, m 134-137°, 137-138°.** Purified by recryst from MeOH. [Fuson et al. *JOC* 12 587 *1947*].

Khellin *[82-02-0]* **M 260.3, m 154-155°, b 180-200°/0.05mm.** Crystd from MeOH or ethyl ether.

Kojic acid *[501-30-4]* **M 142.1, m 154-155°.** Crystd from MeOH (charcoal) by adding ethyl ether. Sublimed at 0.1mm pressure.

Kynurenic acid *[492-27-3]* **M 189.1, m 282-283°.** Crystd from absolute EtOH.

L-Kynurenine *[2922-83-0]* **M 208.2, m 190°(dec).** Crystd from water.

L-Kynurenine sulphate *[16055-80-4]* **M 306.3, m 194°, monohydrate m 178°, $[\alpha]_D^{25}$ +9.6° (H_2O).** Crystd from water by addition of EtOH.

L-Lactic acid *[79-33-4]* **M 90.1, m 52.8°, b 105°/0.1mm, $[\alpha]_D^{20}$ +3.82° (H_2O).** Purified by fractional distn at 0.1mm pressure, followed by fractional crystn from ethyl ether/isopropyl ether (1:1, dried with sodium). [Borsook, Huffman and Liu *JBC* **102** 449 *1933*]. The solvent mixture, benzene/ethyl ether (1:1) containing 5% pet ether (b 60-80°) has also been used.

Lactobionic acid *[96-82-2]* **M 358.3, m 128-130°, $[\alpha]_{546}^{20}$ +28° (c 3, after 24h in H_2O).** Crystd from water by addition of EtOH.

α-Lactose (H_2O) *[16984-38-6]* **M 360.3, m 220°(dec), $[\alpha]_D^{20}$ +52.3° (c 4.2, H_2O).** Crystd from water below 93.5°.

Lactulose *[4618-18-2]* **M 342.2, m 167-169°(dec), $[\alpha]_{546}^{20}$ -57° (c 1, H_2O),**

Lanatoside A *[17575-20-1]* **M 969.1, m 245-248°, $[\alpha]_D^{20}$ +32° (EtOH),**

Lanatoside B *[17575-21-2]* **M 985.1, m 233°(dec), $[\alpha]_D^{20}$ +35° (MeOH),**

Lanatoside C *[17575-22-3]* **M 297.1, m 246-248°, $[\alpha]_D^{20}$ +34° (EtOH).** Crystd from MeOH.

Lanosterol *[79-63-0]* **M 426.7, m 138-140°, $[\alpha]_D^{20}$+62.0° (c 1, $CHCl_3$).** Recrystd from anhydrous MeOH. Dried *in vacuo* over P_2O_5 for 3h at 90°. Purity checked by proton magnetic resonance.

Lanthanide shift reagents A variety of these reagents are available commercially and they are generally quite stable and should not deteriorate on long storage in a dry state and in the absence of light. See G.R.Sullivan in *Topics in Stereochemistry* (Eliel and Allinger eds) J Wiley & Sons **Vol 10** 287 *1978*; T.C.Morrill ed *Lanthanide Shift Reagents* Deerfield Beach Florida *1986*.

Lapachol *[84-79-7]* **M 226.3, m 140°.** Crystd from EtOH or ethyl ether.

***dl*-Laudanosine** *[1699-51-0]* **M 357.4, m 114-115°.** Crystd from EtOH.

Lauraldehyde (1-dodecanal) *[112-54-9]* **M 184.3, b 99.5-100°/3.5mm, $n^{24.7}$ 1.4328.** Converted to the addition compound by shaking with saturated aqueous $NaHSO_3$ for 1h. The ppte was filtered off, washed with ice cold water, EtOH and ether, then decomposed with aqueous Na_2CO_3. The aldehyde was extracted into ethyl ether which, after drying and evaporation, gave an oil which was fractionally distd under vacuum.

Lauric acid (1-dodecanoic acid) *[143-07-7]* **M 200.3, m 44.1°, b 141-142°/0.6-0.7mm, 225°/100mm.** Vacuum distd. Crystd from absolute EtOH, or from acetone at -25°. Alternatively, purified *via* its *methyl ester* (b 140.0°/15mm), as described for *capric* acid. Also purified by zone melting.

***N*-Lauroyl-*N*-methyltaurine sodium salt (sodium *N*-decanoyl-*N*-methylethane sulphonate)** *[4337-75-1]* **M 343.5.** Prepared from methyldecanoate (at 180° under N_2) or decanoyl chloride and sodium *N*-methylethane sulphonate and purified by dissolving in H_2O and precipitating by addition of Et_2O. Decomposes on heating. [Desseigne and Mathian *Mém Services Chim etat Paris* **31** 359 *1944*, *Chem Abs* **41** 705 *1947*].

Lauryl peroxide (dodecyl peroxide) *[105-74-8]* **M 398.6, m 53-54°.** Crystd from benzene and stored below 0°. Can be **EXPLOSIVE.**

L-Leucine *[61-90-5]* **M 131.2, m 293-295°(dec), $[\alpha]_D^{25}$ +15.6° (5M HCl).** Likely impurities are isoleucine, valine, and methionine. Crystd from water by adding 4 volumes of EtOH.

Leucomalachite Green *[129-73-7]* **M 330.5, m 92-93°.** Crystd from 95% EtOH (10ml/g), then from benzene/EtOH, and finally from pet ether.

Lissamine Green B *[3087-16-9]* **M 576.6.** Crystd from EtOH/water (1:1, v/v).

Lithocholic acid *[434-13-9]* **M 376.6, m 184-186°, $[\alpha]_D$ +33.8° (c 1.5, EtOH).** Crystd from EtOH or acetic acid.

Lumazine see **2,4(1*H*,3*H*)-pteridinedione.**

Lumichrome *[1086-80-2]* **M 242.2, m >290°.** Recrystd twice from glacial AcOH and dried at 100° in a vacuum.

Luminol *[521-31-3]* **M 177.2, m 329-332°.** Dissolved in KOH soln, treated with Norit (charcoal), filtered and ppted with conc HCl. [Hardy, Sietz and Hercules *Talanta* **24** 297 *1977*]. Stored in the dark in an inert atmosphere, because its structure changes during its luminescence. It has been recrystd from 0.1M KOH [Merenyi et al. *JACS* **108** 77716 *1986*].

***dl*-Lupinane** *[10248-30-3]* **M 169.3, m 98-99°.** Crystd from acetone.

Lupulon *[468-28-0]* **M 414.6, m 92-94°.** Crystd from 90% MeOH.

Lutein *[127-40-2]* **M 568.9, m 196°, $\varepsilon_{1cm}^{1\%}$ 1750 (423nm), 2560 (446nm), 2340 (477.5nm) in EtOH; λ_{max} in CS_2 446, 479 and 511nm.** Crystd from MeOH (copper-coloured prisms) or from ethyl ether by adding MeOH. Also purified by chromatography on columns of magnesia or calcium hydroxide, and crystd from CS_2/EtOH. May be purified *via* the dipalmitate ester. Stored in the dark, in an inert atmosphere.

Lutidine (mixture). For the preparation of pure 2,3-, 2,4- and 2,5-lutidine from commercial "2,4- and 2,5-lutidine" see Coulson et al. *JCS* 1934 *1959*, and Kyte, Jeffery and Vogel *JCS* 4454 *1960.*

2,3-Lutidine *[583-61-9]* **M 107.2, f.p. -14.8°, b 160.6°, d 0.9464, n 1.50857.** Steam distd from a soln containing about 1.2 equivalents of 20% H_2SO_4, until *ca* 10% of the base has been carried over with the non-basic impurities. The acid soln was then made alkaline, and the base was separated, dried over NaOH or BaO, and fractionally distd. The distd lutidine was converted to its urea complex by stirring 100g with 40g of urea in 75ml of H_2O, cooling to 5°, filtering at the pump, and washing with 75ml of H_2O. The

complex, dissolved in 300ml of H_2O was steam distd until the distillate gave no turbidity with a little solid NaOH. The distillate was then treated with excess solid NaOH, and the upper layer was removed: the aqueous layer was then extracted with ethyl ether. The upper layer and the ether extract were combined, dried (K_2CO_3), and distd through a short column. Final purification was by fractional crystn using partial freezing. [Kyte, Jeffery and Vogel *JCS* 4454 *1960*].

2,4-Lutidine *[108-47-4]* **M 107.2, b 157.8°, d 0.9305, n 1.50087, n^{25} 1.4985.** Dried with Linde type 5A molecular sieves, BaO or sodium, and fractionally distd. The distillate (200g) was heated with benzene (500ml) and conc HCl (150ml) in a Dean and Stark apparatus on a water bath until water no longer separated, and the temperature just below the liquid reached 80°. When cold, the supernatant benzene was decanted and the 2,4-lutidine hydrochloride, after washing with a little benzene, was dissolved in water (350ml). After removing any benzene by steam distn, an aqueous soln of NaOH (80g) was added, and the free lutidine was steam distd. It was isolated by saturating the distillate with solid NaOH, and distd through a short column. The pptn cycle was repeated, then the final distillate was partly frozen in an apparatus at -67.8-68.5° (cooled by acetone/CO_2). The crystals were then melted and distd. [Kyte, Jeffery and Vogel *JCS* 4454 *1960*]. Alternative purifications are *via* the picrate [Clarke and Rothwell *JCS* 1885 *1960*], or the hydrobromide [Warnhoff *JOC* **27** 4587 *1962*]. The latter is ppted from a soln of lutidine in benzene by passing dry HBr gas: the salt is recrystd from $CHCl_3$/methyl ethyl ketone, then decomposed with NaOH, and the free base is extracted into ethyl ether, dried, evaporated and the residue distd.

2,5-Lutidine *[589-93-5]* **M 107.2, m -15.3°, b 156.7°/759mm, d 0.927, n^{25} 1.4982.** Steam distd from a soln containing 1-2 equivalents of 20% H_2SO_4 until about 10% of the base had been carried over with the non-basic impurities, then the acid soln was made alkaline, and the base separated, dried with NaOH and fractionally distd twice. Dried with Na and fractionally distd through a Todd column packed with glass helices.

2,6-Lutidine *[108-48-5]* **M 107.2, m -59°, b 144.0°, d 0.92257, n 1.49779.** Likely contaminants include 3- and 4-picoline (similar boiling points). However, they are removed by using BF_3, with which they react preferentially, by adding 4ml of BF_3 to 100ml of dry fractionally distd 2,6-lutidine and redistilling. Distn of commercial material from $AlCl_3$ (14g per 100ml) can also be used to remove picolines (and water). Alternatively, lutidine (100ml) can be refluxed with ethyl benzenesulphonate (20g) or ethyl *p*-toluenesulphonate (20g) for 1h, then the upper layer is cooled, separated and distd. The distillate is refluxed with BaO or CaH_2, then fractionally distd, through a glass helices-packed column.
2,6-Lutidine can be dried with KOH or sodium, or by refluxing with (and distilling from) BaO, prior to distn. For purification via its picrate, 2,6-lutidine, dissolved in abs EtOH, is treated with an excess of warm ethanolic picric acid. The ppte is filtered off, recrystd from acetone (to give **m** 163-164.5°), and partitioned between ammonia and $CHCl_3$/ethyl ether. The organic soln, after washing with dilute aqueous KOH, is dried with Na_2SO_4 and fractionally distd. [Warnhoff *JOC* **27** 4587 *1962*]. Alternatively, 2,6-lutidine can be purified *via* its urea complex, as described under 2,3-lutidine. Other purification procedures include azeotropic distn with phenol [Coulson et al. *J Appl Chem (London)* **2** 71 *1952*], fractional crystn by partial freezing, and vapour-phase chromatography using a 180-cm column of polyethylene glycol-400 (Shell, 5%) on Embacel (May and Baker) at 100°, with argon as carrier gas [Bamford and Block *JCS* 4989 *1961*].

3,5-Lutidine *[591-22-0]* **M 107.2, f.p. -6.3°, b 172.0°/767mm, d 0.9419, n 1.50613, n^{25} 1.5035.** Dried with sodium and fractionally distd through a Todd column packed with glass helices. Dissolved (100ml) in dil HCl (1:4) and steam distd until 1L of distillate was collected. Excess conc NaOH was added to the residue which was again steam distd. The base was extracted from the distillate, using ethyl ether. The extract was dried with K_2CO_3, and distd. It was then fractionally crystd by partial freezing.

Lycopene *[502-65-8]* **M 536.9, m 172-173°, $\varepsilon^{1\%}_{1cm}$ 2250 (446nm), 3450 (472nm), 3150 (505nm) in pet ether.** Crystd from CS_2/MeOH, ethyl ether/pet ether, or acetone/pet ether, and purified by column chromatography on deactivated alumina, $CaCO_3$, calcium hydroxide or magnesia. Stored in the dark, in an inert atmosphere.

Lycorine *[476-28-8]* **M 552.9, m 275-280°(dec).** Crystd from EtOH.

Lycoxanthin *[19891-74-8]* **M 268.3, m 173-174°, $\varepsilon_{1cm}^{1\%}$ 3360 (472.5nm), also κ_{max} 444 and 503nm in pet ether.** Crystd from ethyl ether/light petroleum, benzene/pet ether or CS_2. Purified by chromatography on columns of $CaCO_3$, $Ca(OH)_2$ or deactivated alumina, washing with benzene and eluting with 3:1 benzene/MeOH. Stored in the dark, in an inert atmosphere, at -20°.

Lysergic acid *[82-58-6]* **M 268.3, m 240°(dec), $[\alpha]_D^{20}$ +40° (pyridine).** Crystd from water.

L-Lysine *[56-87-1]* **M 146.2, m >210°(dec).** Crystd from aqueous EtOH.

L-Lysine dihydrochloride *[657-26-1]* **M 219.1, m 193°, $[\alpha]_D^{25}$ +25.9° (5M HCl).** Crystd from MeOH, in the presence of excess HCl, by adding ethyl ether.

L-Lysine monohydrochloride *[657-27-2]* **M 182.7, [α] as above.** Likely impurities are arginine, D-lysine, 2,6-diaminoheptanedioic acid and glutamic acid. Crystd from water at pH 4-6 by adding 4 volumes of EtOH. Above 60% relative humidity it forms a dihydrate.

β-D-Lyxose *[1114-34-7]* **M 150.1, m 118-119°, $[\alpha]_D^{20}$ -14° (c 4, H_2O).** Crystd from EtOH or aqueous 80% EtOH. Dried under vacuum at 60°, and stored in a vacuum desiccator over P_2O_5 or $CaSO_4$.

Malachite Green (carbinol) *[510-13-4]* M 346.4, m 112-114°.

The oxalate was recrystd from hot water and dried in air. The carbinol was ppted from the oxalate (1g) in distd water (100ml) by adding M NaOH (10ml). The ppte was filtered off, recrystd from 95% EtOH containing a little dissolved KOH, then washed with ether, and crystd from pet ether. Dried in a vacuum at 40°. An acid soln (2 x 10^{-5}M in 6 x 10^{-5}M H_2SO_4) rapidly reverted to the dye. [Swain and Hedberg *JACS* **72** 3373 *1950*].

***Z*-Maleamic acid** *[557-24-4]* **M 115.1, m 172-173°(dec).** Crystd from EtOH.

Maleic acid *[110-16-7]* **M 116.1, m 143.5°.** Crystd from acetone/pet ether (b 60-80°) or hot water. Dried at 100°.

Maleic anhydride *[108-31-6]* **M 98.1, m 54°, b 94-96°/20mm, 199°/760mm.** Crystd from benzene, $CHCl_3$, CH_2Cl_2 or CCl_4. Sublimed under reduced pressure. [Skell et al. *JACS* **108** 6300 *1986*].

Maleic hydrazide *[123-3-1]* **M 112.1, m 144°(dec).** Crystd from water.

Maleuric acid *[105-61-3]* **M 158.1, m 167-168°(dec).** Crystd from hot water.

***dl*-Malic acid** *[6915-15-7]* **M 134.1, m 128-129°.** Crystd from acetone, then from acetone/CCl_4, or from ethyl acetate by adding pet ether (b 60-70°). Dried at 35° under 1mm pressure to avoid formation of the anhydride.

L-Malic acid *[617-48-1]* **M 134.1, m 104.5-106°, $[\alpha]_D^{20}$ -2.3° (c 8.5, H_2O).** Crystd (charcoal) from ethyl acetate/pet ether (b 55-56°), keeping the temperature below 65°. Or, dissolved by refluxing in fifteen parts of anhydrous ethyl ether, decanted, concentrated to one-third volume and crystd at 0°, repeatedly to constant melting point.

Malonamide *[108-13-4]* **M 102.1, m 170°.** Crystd from water.

Malonic acid *[141-82-2]* **M 104.1, m 136°.** Crystd from benzene/ethyl ether (1:1) containing 5% of pet ether (b 60-80°), washed with ethyl ether, then recrystd from H_2Oor acetone. Dried under vac over conc H_2SO_4.

Malononitrile *[109-77-3]* **M 66.1, m 32-34°, b 220°/760mm.** Crystd from water, EtOH, benzene or chloroform. Distd from, and stored over, P_2O_5. [Bernasconi et al. *JACS* **107** 7692 *1985*; Gratenhuis *JACS* **109** 8044 *1987*].

Maltol *[118-71-8]* **M 126.1, m 161-162°.** Crystd from $CHCl_3$ or aqueous 50% EtOH. Volatile in steam. It can be readily sublimed in a vacuum.

Maltose (H_2O) *[63-63-53-7]* **M 360.3, m 118°.** Purified by chromatography from aqueous soln on to a charcoal/Celite (1:1) column, washed with water to remove glucose and other monosaccharides, then eluted with aqueous 75% EtOH. Crystd from water, aqueous EtOH or EtOH containing 1% nitric acid. Dried as the monohydrate at room temperature under vacuum over H_2SO_4 or P_2O_5.

S-(+)- *[17199-29-0]* *R*-(-)- *[611-71-2]* **Mandelic acid (α-hydroxyphenylacetic acid) M 152.2, m 130-133°, 133°, 133.1° (evacuated capillary), 133-133.5°, $[\alpha]^{20}_{546}$ ±188° (c 5, H_2O), $[\alpha]^{20}_{D}$ ±155° (c 5,H_2O) and ±158° (c 5, Me_2CO).** Purified by recrystn from H_2O, C_6H_6 or $CHCl_3$. [Roger *JCS* 2168 *1932*; Jamison and Turner *JCS* 611 *1942*]. They have acidic pKa values of 3.41 (H_2O, 25°) and 3.39 (H_2O, 18°) and the solubility in H_2O is *ca* 11% at 25°. [Banks and Davies *JCS* 73 *1938*]. The *S-benzylisothiuronium salt* has **m** 180° (from H_2O) and $[\alpha]^{25}_{D}$ ±57° (c 20, EtOH) [El Masri et al. *BJ* **68** 199 *1958*].

***RS*-(±)-Mandelic acid** *[61-72-3]* **M 152.2, m 118°, 120-121°.** Purified by Soxhlet extraction with benzene (about 6ml/g), allowing the extract to crystallise. Also crystallises from $CHCl_3$. The *S-benzylisothiuronium salt* has **m** 169° (166°) (from H_2O). Dry at room temperature under vacuum.

D-Mannitol *[69-65-8]* **M 182.2, m 166.1°, $[\alpha]^{20}_{546}$ + 29° (c 10, after 1h in 8% borax soln).** Crystd from EtOH or distilled water and dried at 100°.

Mannitol hexanitrate *[130-39-2]* **M 452.2, m 112-113°.** Crystd from EtOH. **EXPLOSIVE on concussion.**

α-D-Mannose *[3458-58-4]* **M 180.2, m 132°, $[\alpha]^{20}_{D}$ +14.1° (c 4, H_2O).** Crystd repeatedly from EtOH or aq 80% EtOH, then dried under vacuum over P_2O_5 at 60°.

Margaric acid see **heptadecanoic acid.**

Meconic acid (3-hydroxy-γ-pyrone-2,6-dicarboxylic acid) *[497-59-6]* **M 200.1, m 100° (-H_2O).** Crystd from water and dried at 100° for 20min.

Melamine *[108-78-1]* **M 126.1, m 353°.** Crystd from water or dilute aqueous NaOH.

D(+)-Melezitose (H_2O) *[597-12-6]* **M 540.5, m 153-154°(dec), $2H_2O$ m 160°(dec), $[\alpha]^{20}_{D}$ +88° (c 4, H_2O).** Crystallises from water as the dihydrate, then dried at 110° (anhydrous).

D(+)-Melibiose (H_2O) *[585-99-9]* **M 360.3, m 84-85°, $[\alpha]^{20}_{D}$+135° (c 5, after 10h H_2O).** Crystallises as a hydrate from water or aqueous EtOH.

(±)-Mellein [(±)-3,4-dihydro-8-hydroxy-3-methyl-2-benzopyran-1-one] *[1200-93-7]* **M 178.2, m 37-39°, 39°.** Purified by recrystn from aqueous EtOH. It has UV max at 247 and 314nm. [Arakawa et al. *A* 728 152 *1969*; Blair and Newbold *Chemistry and Industry (London)* 93 *1955*, *JCS* 2871 *1955*]. The *methyl ether* has **m** 66-67° and UV: λmax 242nm (ε 7,400) and 305nm (ε 4,600).

Melphalan (4-[bis-{2-chloroethyl}amino]-L-phenylalanine) *[148-82-3]* **M 305.2, m 182-183° (dec), 183-185°, $[\alpha]^{25}_{D}$ +7.5° (c 1.33, 1.0 N HCl).** Purified by recrystn from MeOH and its solubility is 5% in 95% EtOH containing one drop of 6N HCl. It is soluble in EtOH and propylene glycol but

is almost insoluble in H_2O. The *RS-form* has **m** 180-181° and the *R-form* crystallises from MeOH with a **m** 181.5-182° and $[\alpha]_D^{21}$ -7.5° (c 1.26, 1.0 N HCl). [Bergel and Stock *JCS* 2409 *1954*].

***p*-Menta-1,5-diene** see **α-phellandrene.**

(-)-Menthol *[2216-51-5]* **M 156.3, m 44-46.5°, $[\alpha]_D$ 50° (c 10, EtOH).** Crystd from $CHCl_3$, pet ether or EtOH/water.

1*R*-(-)-Menthyl chloride (1*S*,2*R*,4*R*-2-chloro-1-isopropyl-1-methylcyclohexane) *[16052-42-9]* **M 174.7, m -20.1° to -16.5°, b 88.5°/12.5mm, 101-105°/21mm, d_{546}^{20} -61.5°, n_D^{20} -52.5° (neat).** Dissolve in pet ether (b 40-60°), wash with H_2O, conc H_2SO_4 until no discoloration of the organic layer occurs (care with the use of conc H_2SO_4 during shaking in a separating funnel), again with H_2O and dry over $MgSO_4$. Evaporate the pet ether and dist the residual oil through a Claisen head with an indented neck (head) of *ca* 40 cm length. [Smith and Wright *JOC* **17** 1116 *1952*; Barton et al. *JCS* 453 *1952*].

Meprobamate *[57-53-4]* **M 246.3, m 104-106°.** Crystd from hot water.

2-Mercaptobenzimidazole *[583-39-1]* **M 150.2, m 302-304°.** Crystd from aq EtOH or aq ammonia.

2-Mercaptobenzothiazole *[149-30-4]* **M 167.2, m 182°.** Crystd repeatedly from 95% EtOH, or purified by incomplete pptn by dilute H_2SO_4 from a basic soln, followed by several crystns from acetone/H_2O or benzene.

2-Mercaptoethanol *[60-24-2]* **M 78.1, b 44°/4mm, 53.5°/10mm, 58°/12mm, 68°/20mm, 78.5°/40mm, 96-97° (92°)/100mm, 157°/748mm, d_4^{20} 1.114, n_D^{20} 1.500.** Purified by distn in a vacuum. Distn at atmospheric pressure causes some oxidation and should be done in an inert atmosphere. [Woodward *JCS* 1892 *1948*]. **It has a foul odour, is irritating to the eyes, nose and skin — should be handled in an efficient fumecupboard.** It is miscible with H_2O, EtOH, Et_2O and C_6H_6 and has a pKa in H_2O at 25° of 9.5 (9.6) and UV max at 235nm. The *2,4-dinitrophenyl thioether* has **m** 101-102°(from EtOH or aq MeOH) [Grogen et al. *JOC* **20** 50 *1955*].

2-Mercaptoethylamine (cysteamine) *[60-23-1]* **M 77.2, m 97-98.5°.** Sublimed under vacuum, and stored under nitrogen.

2-Mercaptoimidazole *[872-35-5]* **M 100.1, m 221-222°.** Crystd from water.

2-Mercapto-1-methylimidazole *[60-56-0]* **M 114.2, m 145-147°.** Crystd from EtOH.

2-Mercaptopurine (H_2O) *[6112-76-1]* **M 170.2, m >315°(dec).** Crystd from pyridine (30ml/g), washed with pyridine, then triturated with water (25ml/g), adjusting to pH 5 by adding M HCl. Recrystd by heating, then cooling, the soln. Filtered, washed with water and dried at 110°. Has also been crystd from water (charcoal).

8-Mercaptoquinoline ($2H_2O$, thioxine) *[491-33-8]* **M 197.3, m 58-59°.** Easily oxidised in air to give diquinolyl-8,8'-disulphide (which is stable). It is more convenient to make 8-mercaptoquinoline by reduction of the material. [Nakamura and Sekido *Talanta* **17** 515 *1970*].

Mercaptosuccinic acid see **thiomalic acid.**

Mesaconic acid *[498-24-8]* **M 130.1, m 204-205°.** Crystd from water or EtOH [Katakis et al. *JCSDT* 1491 *1986*].

Mescaline sulphate [2-(3,4,5-trimethoxyphenyl)ethylamine sulphate] *[5967-42-0]* **M 309.3, m 183-184°.** Crystd from water.

Mesitoic acid see **2,4,6-trimethylbenzoic acid.**

Mesitylene (1,3,5-trimethylbenzene) *[108-67-8]* **M 120.2, m -44.7°, b 99.0-99.8°/100mm, 166.5-167°/760mm, m 1.4962, n^{25} 1.4967, d 0.865.** Dried with $CaCl_2$ and distd from Na in a glass helices packed column. Treated with silica gel and redistd. Alternative purifications include vapour-phase chromatography, or fractional distn followed by azeotropic distn with 2-methoxyethanol (which is subsequently washed out with H_2O), drying and fractional distn. More exhaustive purification uses sulphonation by dissolving in two volumes of conc H_2SO_4, precipitating with four volumes of conc HCl at 0°, washing with conc HCl and recrystallising from $CHCl_3$. The mesitylene sulphonic acid is hydrolysed with boiling 20% HCl and steam distd. The separated mesitylene is dried ($MgSO_4$ or $CaSO_4$) and distd. It can also be fractionally crystd.

Mesityl oxide *[141-79-7]* **M 98.2, b 112°/760mm, n^{24} 1.4412, d 0.854.** Purified *via* the *semicarbazone* (**m** 165°). [Erskine and Waight *JCS* 3425 *1960*].

Metalphthalein (H_2O) *[2411-89-4]* **M 636.6, m 186°.** Dissolved in sodium acetate and fractionally ppted with HCl. This removed unsubstituted and monosubstituted cresol phthaleins (which separated at lower acidities). Washed with cold water, dried to mononhydrate at 30° *in vacuo.*

Metanilic acid *[121-47-1]* **M 173.2, decomposes on heating.** Crystd from water (as the hydrate), under CO_2 in a semi-darkened room. (The soln is photosensitive.) Dried over 90% H_2SO_4 in a vac desiccator.

α-Methacraldehyde *[78-85-3]* **M 68.1, b 68.4°.** Fractionally distd under nitrogen through a short Vigreux column. Stored in sealed ampoules. (Slight polymerisation may occur.)

Methacrylamide *[79-39-0]* **M 85.1, m 111-112°.** Crystd from benzene or ethyl acetate and dried under vacuum at room temperature.

Methacrylic acid *[79-41-4]* **M 86.1, b 72°/14mm, 160°/760mm, d 1.015, n 1.431.** Aq methacrylic acid (90%) was satd with NaCl (to remove the bulk of the water), then the organic phase was dried with $CaCl_2$ and distd under vacuum. Polymerisation inhibitors include 0.25% *p*-methoxyphenol, 0.1% hydroquinone, or 0.05% *N,N'*-diphenyl-*p*-phenylenediamine.

Methacrylic anhydride *[760-93-0]* **M 154.2, b 65°/2mm, d 1.040, n 1.454.** Distd at 2mm pressure, immediately before use, in the presence of hydroquinone.

Methacrylonitrile *[126-98-7]* **M 67.1, b 90.3°, d 0.800, n 1.4007. n^{30} 1.3954.** Washed (to remove inhibitors such as *p-tert*-butylcatechol) with satd aq $NaHSO_3$, 1% NaOH in saturated NaCl and then with saturated NaCl. Dried with $CaCl_2$ and fractionally distd under nitrogen to separate from impurities such as methacrolein and acetone.

Methadone hydrochloride *[1095-90-5]* **M 345.9, m 241-242°.** Crystd from EtOH.

Methane *[74-82-8]* **M 16.0, m -184°, b -164°/760mm, -130°/6.7atm, d^{-164} 0.466 (air 1).** Dried by passage over $CaCl_2$ and P_2O_5, then passed through a Dry-ice trap and fractionally distd from a liquid-nitrogen trap. Oxygen can be removed by prior passage in a stream of hydrogen over reduced copper oxide at 500°, and higher hydrocarbons can be removed by prechlorinating about 10% of the sample: the hydrocarbons, chlorides and HCl are readily separated from the methane by condensing the sample in the liquid-nitrogen trap and fractionally distilling it. Methane has also been washed with conc H_2SO_4, then solid NaOH and then 30% NaOH soln. It was dried with $CaCl_2$, then P_2O_5, and condensed in a trap at liquid air temperature then transferred to another trap cooled in liquid nitrogen. CO_2, O_2, N_2 and higher hydrocarbons can be removed from methane by adsorption on charcoal. [Eiseman and Potter *J Res Nat Bur Stand* **58** 213 *1957*]. *Highly flammable.*

Methanesulphonic acid *[76-75-2]* **M 96.1, m 20°, b 134.5-135°/3mm, d 1.483, n 1.432.** Dried, either by azeotropic removal of water with benzene or toluene, or by stirring 20g of P_2O_5 with 500ml of the acid at 100° for 0.5h. Then distd under vacuum and fractionally crystd by partial freezing. Sulphuric acid, if present, can be removed by prior addition of $Ba(OH)_2$ to a dilute soln, filtering off the $BaSO_4$ and concentrating under reduced pressure, and is sufficiently pure for most applications.

Methanesulphonyl chloride *[124-63-0]* **M 114.5. b 55°/11mmm, d 1.474, n 1.452.** Distd from P_2O_5 under vacuum.

Methanol *[67-56-1]* **M 32.0, b 64.5°, d^{15} 0.79609, d^{25} 1.32663, n^{15} 1.33057, n^{25} 1.32663.** Almost all methanol is now obtained synthetically. Likely impurities are water, acetone, formaldehyde, ethanol, methyl formate and traces of dimethyl ether, methylal, methyl acetate, acetaldehyde, carbon dioxide and ammonia. Most of the water (down to about 0.01%) can be removed by fractional distn. Drying with CaO is unnecessary and wasteful. Anhydrous methanol can be obtained from "absolute" material by passage through Linde type 4A molecular sieves, or by drying with CaH_2, $CaSO_4$, or with just a little more sodium than required to react with the water present; in all cases the methanol is then distd. Two treatments with sodium reduces the water content to about 5 X 10^{-5}%. {Friedman, Gill and Doty *JACS* **83** 4050 *1961*]. Lund and Bjerrum [*B* **64** 210 *1931*] warmed clean dry magnesium turnings (5g) and iodine (0.5g) with 50-75ml of "absolute" methanol in a flask until the iodine disappeared and all the magnesium was converted to methoxide. Up to 1L of methanol was added and, after refluxing for 2-3h, it was distd off, excluding moisture from the system. Redistn from tribromobenzoic acid removes basic impurities and traces of magnesium oxides, and leaves conductivity-quality material. The method of Hartley and Raikes [*JCS* **127** 524 *1925*] gives a slightly better product. This consists of an initial fractional distn, followed by distn from aluminium methoxide, and then ammonia and other volatile impurities are removed by refluxing for 6h with freshly dehydrated $CuSO_4$ (2g/L) while dry air is passed through: the methanol is finally distd. (The aluminium methoxide is prepared by warming with aluminium amalgam (3g/L) until all the aluminium has reacted. The amalgam is obtained by warming pieces of sheet aluminium with a soln of $HgCl_2$ in dry methanol). This treatment also removes aldehydes.
If acetone is present in the methanol, it is usually removed prior to drying. Bates, Mullaly and Hartley [*JCS* 401 *1923*] dissolved 25g of iodine in 1L of methanol and then poured the soln, with constant stirring, into 500ml of M NaOH. Addition of 150ml of water ppted iodoform. The soln was stood overnight, filtered, then boiled under reflux until the odour of iodoform disappeared, and fractionally distd. (This treatment also removes formaldehyde.) Morton and Mark [*IECAE* **6** 151 *1934*] refluxed methanol (1L) with furfural (50ml) and 10% NaOH soln (120ml) for 6-12h, the refluxing resin carrying down with it the acetone and other carbonyl-containing impurities. The alcohol was then fractionally distd. Evers and Knox [*JACS* **73** 1739 *1951*], after refluxing 4.5L of methanol for 24h with 50g of magnesium, distd off 4L of it, which they then refluxed with $AgNO_3$ for 24h in the absence of moisture or CO_2. The methanol was again distd, shaken for 24h with activated alumina before being filtered through a glass sinter and distd under nitrogen in an all-glass still. Material suitable for conductivity work was obtained. It has a pKa^{25} of 15.5.
Variations of the above methods have also been used. For example, a sodium hydroxide soln containing iodine has been added to methanol and, after standing for 1day, the soln has been poured slowly into about a quarter of its volume of 10% $AgNO_3$, shaken for several hours, then distd. Sulphanilic acid has been used instead of tribromobenzoic acid in Lund and Bjerrum's method. A soln of 15g of magnesium in 500ml of methanol has been heated under reflux, under nitrogen, with hydroquinone (30g), before degassing and distilling the methanol, which was subsequently stored with magnesium (2g) and hydroquinone (4g per 100ml). Refluxing for about 12h removes the bulk of the formaldehyde from methanol: further purification has been obtained by subsequent distn, refluxing for 12h with dinitrophenylhydrazine (5g) and H_2SO_4 (2g/L), and again fractionally distilling.
A simple purification procedure consists of adding 2g of $NaBH_4$ to 1.5L methanol, gently bubbling with argon and refluxing for a day at 30°, then adding 2g of freshly cut sodium (washed with methanol) and refluxing for 1day before distilling. The middle fraction is taken. [Jou and Freeman *JPC* **81** 909 *1977*].

***dl*-Methionine** *[59-51-8]* **M 149.2, m 281°(dec).** Crystd from hot water.

L-Methionine *[63-68-3]* **M 149.2, m 283°(dec), $[\alpha]_D^{25}$ +21.2° (0.2M HCl).** Crystd from aqueous EtOH.

***dl*-Methionine sulphoxide** *[454-41-1]* **M 165.2, m >240°(dec).** Likely impurities are *dl*-methionine sulphone and *dl*-methionine. Crystd from water by adding EtOH in excess.

Methoxyacetic acid *[625-45-6]* **M 90.1, b 97°/13-14mm, n 1.417, d 1.175.** Fractionally crystd by repeated partial freezing, then fractionally distd under vacuum through a vacuum-jacketed Vigreux column 20cm long.

***p*-Methoxyacetophenone** *[100-06-1]* **M 150.2, m 39°, b 139°/15mm, 264°/736mm.** Crystd from ethyl ether/pet ether.

Methoxyamine hydrochloride *[593-56-6]* **M 83.5, m 151-152°.** Crystd from absolute EtOH or EtOH by addition of ethyl ether. [Kovach et al. *JACS* **107** 7360 *1985*].

3-Methoxybenzanthrone *[3688-79-7]* **M 274.3.** Crystd from benzene.

***p*-Methoxybenzene** *[2396-60-3]* **M 212.3, m 54-56°.** Crystd from EtOH.

***m*-Methoxybenzoic acid** *[586-38-9]* **M 152.2, m 110°.** Crystd from EtOH/water.

***p*-Methoxybenzoic acid** *[100-09-4]* **M 152.2, m 184.0-184.5°.** Crystd from EtOH, water, EtOH/water or toluene.

4-Methoxybenzyl chloride (anisyl chloride) *[824-94-2]* **M 156.6, m -1°, b 76°/0.1mm, 95°/5mm, 110°/10mm, 117-117/5°/14mm, 117°/18mm, d_4^{20} 1.15491, n_D^{20} 1.55478.** Purified by fractional distn under vacuum and the middle fraction is redistd at 10^{-6} mm at room temperature by intermittent cooling of the receiver in liquid N_2, and the middle fraction is collected. [Mohammed and Kosower *JACS* **93** 2709 *1971*].

3-Methoxycarbonyl-2,5-dihydrothiophen-1,1-dioxide *[67488-50-0]* **M 176.1, m 57-58°, 60-62°.** If IR show CO bands then dissolve in $CHCl_2$, wash with aqueous Na_2CO_3 and H_2O, dry over $MgSO_4$, filter, evaporate and wash the residue with cold Et_2O and dry *in vacuo*. NMR ($CDCl_3$): δ 7.00 (m 1H), 3.98 (bs, 4H) and 3.80 (s, Me) ppm. [Mcintoch and Sieber *JOC* **43** 4431 *1978*].

"Methoxychlor", 1,1-Bis(*p*-methoxyphenyl)-2,2,2-trichloroethane (dimorphic) *[72-43-5]* **M 345.7, m 78-78.2°, or 86-88°.** Freed from 1,1-bis(*p*-chlorophenyl)-2,2,2-trichloroethane by crystn from EtOH.

***trans*-*p*-Methoxycinnamic acid** *[830-09-1]* **M 178.2, m 173.4-174.8°.** Crystd from MeOH to constant melting point and UV spectrum.

2-Methoxyethanol *[109-86-4]* **M 76.1, b 124.4°, d 0.964, n 1.4017.** Peroxides can be removed by refluxing with stannous chloride or by filtration under slight pressure through a column of activated alumina. 2-Methoxyethanol can be dried with K_2CO_3, $CaSO_4$, $MgSO_4$ or silica gel, with a final distn from sodium. Aliphatic ketones (and water) can be removed by making the solvent 0.1% in 2,4-dinitrophenylhydrazine and allowing to stand overnight with silica gel before fractionally distilling.

β-Methoxyethylamine *[109-85-3]* **M 75.1, b 94°, d 0.874, n 1.407.** An aqueous 70% soln was dehydrated by azeotropic distn with benzene and the amine was distd twice.

6-Methoxy-1-indanone *[13623-25-1]* **M 162.2, m 151-153°.** Crystd from MeOH, then sublimed.

5-Methoxyindole *[1006-94-6]* **M 147.2, m 55°, b 176-178°/17mm.** Crystd from cyclohexane or pet ether.

1-Methoxynaphthalene *[2216-69-5]* **M 158.2, b 268.4-268.5°, d 1.094, n 1.621.** Fractionally distd from CaH_2.

2-Methoxynaphthalene *[93-04-9]* **M 158.2, m 73.0-73.6°, b 273°/760mm.** Fractionally distd under vacuum. Crystd from absolute EtOH, aqueous EtOH, benzene or *n*-heptane, and dried under vacuum in an Abderhalden pistol or distd *in vacuo*. [Kikuchi et al. *JPC* **91** 574 *1987*].

4-Methoxynitrobenzene see **nitroanisole.**

1-Methoxy-4-nitronaphthalene *[4900-63-4]* **M 203.2, m 85°.** Purified by chromatography on silica gel and recrystd from MeOH. [Bunce et al. *JOC* **52** 4214 *1987*].

p-**Methoxyphenol** *[150-76-5]* **M 124.1, m 54-55°, b 243°.** Crystd from benzene, pet ether or H_2O, and dried under vacuum over P_2O_5 at room temp. Sublimes *in vacuo*. [Wolfenden et al. *JACS* **109** 463 *1987*].

***R*-(-)-** *[3966-32-3]* **and *S*-(+)-** *[26164-26-1]* **α-Methoxyphenylacetic acid (*O*-methyl mandelic acid), M 166.2, m 62.9°, 62-65°, 65-66°, $[\alpha]_{546}^{20}$ ±179° (169.8°), $[\alpha]_D^{20}$ ±150.7° (148°) (c 0.5, EtOH).** Purified by recrystn from C_6H_6-pet ether (b 80-100°). [Neilson and Peters *JCS* 1519 *1962*; Weizmann et al. *JACS* **70** 1153 *1948*; Pirie and Smith *JCS* 338 *1932*; NMR: Dale and Mosher *JACS* **95** 512 *1973*; for resolution: Roy and Deslongchamps *Canad J Chem* **63** 651 *1985;* Trost et al. JACS **108** 4974 *1986*]. The *racemic acid* has **m** 72°, **b** 121-122°b/0.4mm, 165°/18mm (from pet ether) [Braun et al. *B* **63** 2847 *1930*].

m-**Methoxyphenylacetic acid** *[1798-09-0]* **M 166.2, m 71.0-71.2°.** Crystd from H_2O, or aq EtOH.

p-**Methoxyphenylacetic acid** *[104-01-8]* **M 166.2, m 85-87°.** Crystd from EtOH/water.

5-(*p*-Methoxyphenyl)-1,2-dithiole-3-thione *[42766-10-9]* **M 240.2, m 111°.** Crystd from butyl acetate.

***N*-(*p*-Methoxyphenyl)-*p*-phenylenediamine** *[101-64-4]* **M 214.3, m 102°, b 238°/12mm.** Crystd from ligroin.

8-Methoxypsoralen *[298-81-7]* **M 216.2, m 148°.** Crystd from EtOH/ether or benzene/pet ether.

4-Methoxystyrene *[637-69-4]* **M 134.2, b 41-42°/0.5mm. d 1.009, n 1.5622.** Distd from CaH_2 and stored under argon at -10° [Hall et al. *JOC* **52** 5528 *1987*].

***R*-(+)-** *[20445-31-2]* **and *S*-(-)-** *[17257-71-5]* **α-Methoxy-α-trifluoromethylphenylacetic acid (MTPA) M 234.2, m 43-45°, 90°/0.1mm, 105-107°/1mm, $[\alpha]_{546}^{20}$ ±87°, $[\alpha]_D^{20}$ ±73° (c 2, MeOH).** A likely impurity is phenylethylamine from the resolution. Dissolve acid in ether-benzene (3:1), wash with 0.5N H_2SO_4, then H_2O, dry over $MgSO_4$, filter, evaporate and distil. [Dale et al. *JOC* **34** 2543 *1969*, *JACS* **75** 512 *1973*].

***R*-(-)-** *[39637-99-5]* **and *S*-(+)-** *[20445-33-4]* **α-Methoxy-α-trifluoromethylphenylacetyl chloride M 252.6, b 54-56°/1mm, 213-214°/atm, d_4^{20} 1.353, n_D^{20} 1.468, $[\alpha]_{546}^{20}$ ±167°, $[\alpha]_D^{20}$ ±137° (c 4, CCl_4), $[\alpha]_D^{24}$±10.0° (neat).** The most likely impurity is the free acid due to hydrolysis and should be checked by IR. If free from acid then distil taking care to keep moisture out of the apparatus. Otherwise add $SOCl_2$ and reflux for 50h and distil Note that shorter reflux times resulted in a higher boiling fraction (b 130-155°/1mm) which has been identified as the anhydride. [Dale et al. *JOC* **34** 2543 *1969*; for enantiomeric purity see *JACS* **97** 512 *1973*].

***N*-Methylacetamide** *[79-16-3]* **M 73.1, m 30°, b 70-71°/2.5-3mm.** Fractionally distd under vacuum, then fractionally crystd twice from its melt. Impurities include acetic acid, methyl amine and H_2O. For detailed purification procedure, see Knecht and Kolthoff, *Inorg Chem* **1** 195 *1962*.

Although *N*-methylacetamide is commercially available it is often extensively contaminated with acetic acid, methylamine, water and an unidentified impurity. The recommended procedure is to synthesise it in the laboratory by direct reaction. The gaseous amine is passed into hot glacial acetic acid, to give a partially aqueous soln of methylammonium acetate which is heated to *ca* 130° to expel water. Chemical methods of purification such as extraction by pet ether, treatment with H_2SO_4, K_2CO_3 or CaO can be used but are more laborious.
Tests for purity include the Karl Fischer titration for water; this can be applied directly. Acetic acid and methylamine can be detected polarographically.
In addition to the above, purification of *N*-methylacetamide can be achieved by fractional freezing, including zone melting, repeated many times, or by chemical treatment with vacuum distn under reduced pressures. For details of zone melting techniques, see Knecht in *Recommended Methods for Purification of Solvents and Tests for Impurities*, Coetzee ed., Pergamon Press *1982*.

***N*-Methylacetanilide** *[579-10-2]* **M 149.2, m 102-104°.** Crystd from water, ether or light petroleum (b 80-100°).

Methyl acetate *[79-20-9]* **M 74.1, b 56.7-57.2°, d 0.934. n 1.36193, n^{25} 1.3538.** Methanol in methyl acetate can be detected by measuring solubility in water. At 20°, the solubility of methyl acetate in water is *ca* 35g per 100ml, but 1% MeOH confers miscibility. Methanol can be removed by conversion to methyl acetate, using refluxing for 6h with acetic anhydride (85ml/L), followed by fractional distn. Acidic impurities can be removed by shaking with anhydrous K_2CO_3 and distilling. An alternative treatment is with acetyl chloride, followed by washing with conc NaCl and drying with CaO or $MgSO_4$. (Solid $CaCl_2$ cannot be used because it forms a crystalline addition compound.) Distn from copper stearate destroys peroxides. Free alcohol or acid can be eliminated from methyl acetate by shaking with strong aq Na_2CO_3 or K_2CO_3 (three times), then with aq 50% $CaCl_2$ (three times), satd aq NaCl (twice), drying with K_2CO_3 and distn from P_2O_5.

***p*-Methylacetophenone** *[122-00-9]* **M 134.2, m 22-24°, b 93.5°/7mm, 110°/14mm, d 1.000, n 1.5335.** Impurities, including the *o*- and *m*-isomers, were removed by forming the semicarbazone which, after repeated crystn, was hydrolysed to the ketone. [Brown and Marino *JACS* **84** 1236 *1962*]. Also purified by distn under reduced pressure, followed by low temperature crystn from isopentane.

Methyl acrylate *[96-33-3]* **M 86.1, b 80°, d 0.9535, n 1.4040.** Washed repeatedly with aqueous NaOH until free from inhibitors (such as hydroquinone), then washed with distd water, dried ($CaCl_2$) and fractionally distd under reduced pressure in an all-glass apparatus. Sealed under nitrogen and stored at 0° in the dark. [Bamford and Han *JCSFT 1* **78** 855 *1982*].

1-Methyladamantane *[768-91-2]* **M 150.2,**
2-Methyladamantane *[700-56-1]* **M 150.2.** Purified by zone melting.

Methylal see **dimethoxymethane.**

2-Methylalanine see **α–aminoisobutyric acid.**

Methylamine (gas) *[74-89-5]* **M 31.1, b -7.55°/719mm.** Dried with sodium or BaO.

Methylamine hydrochloride *[593-51-1]* **M 67.5, m 231.8-233.4°, b 225-230°/15mm.** Crystd from *n*-butanol, absolute EtOH or MeOH/$CHCl_3$. Washed with $CHCl_3$ to remove traces of dimethylamine hydrochloride. Dried under vacuum first with H_2SO_4 then P_2O_5. Deliquescent, stored in a desiccator over P_2O_5. It has a pKa of 10.66 in water.

1-Methylaminoanthraquinone *[82-38-2]* **M 237.3, m 166.5°.** Crystd to constant melting point from butan-1-ol, then crystd from EtOH. It can be sublimed under vacuum.

***N*-Methyl-*o*-aminobenzoic acid (*N*-methylanthranilic acid)** *[119-68-6]* **M 151.2, m 178.5°.** Crystd from water or EtOH.

***p*-Methylaminophenol sulphate** *[55-55-0]* **M 344.4, m 260°(dec).** Crystd from MeOH.

6-Methylaminopurine *[443-72-1]* **M 149.2, m >300°, 312-314° (dec).** Best purified by recrystallising 2g from 50ml of H_2O and 1.2g of charcoal. It has pKa values in H_2O at 20° of 3.87 (4.18) and 10.5 (9.99) [UV: Albert and Brown *JCS* 2060 *1954*; UV: Mason *JCS* 2071 *1954*]; see also Elion et al. *JACS* **74** 411 *1952*]. The *picrate* has **m** 265°(257°) [Bredereck et al. *B* **81** 307 *1948*].

Methyl 3-aminopyrazine-2-carboxylate *[16298-03-6]* **M 153.1, m 169-172°, 172°.** Forms yellow needles from H_2O (100 parts using charcoal). If it contains the free acid then dissolve in CH_2Cl_2 wash with saturated aqueous Na_2CO_3, brine, dry over $MgSO_4$ filter, evaporate and recrystallise the residue. The *free acid* has **m** 203-204° (dec) [UV: Brown and Mason *JCS* 3443 *1956*]. The *ammonium salt* has **m** 232° (dec) (from aq Me_2CO) and the *aminde* has **m** 239.2° (from H_2O) [Ellingson et al. *JACS* **67** 1711 *1945*].

***N*-Methylaniline** *[100-61-8]* **M 107.2, b 57°/4mm, 81-82°/14mm, d 0.985, n 1.570.** Dried with KOH pellets and fractionally distd under vacuum. Acetylated and the acetyl derivative was recrystd to constant melting point (**m** 101-102°), then hydrolysed with aqueous HCl and distd from zinc dust under reduced pressure. [Hammond and Parks *JACS* **77** 340 *1955*].

o-, *m*- and ***p*-Methylaniline** see ***o*-, *m*- and *p*-toluidine.**

***N*-Methylaniline hydrochloride** *[2739-12-0]* **M 143.7, m 123.0-123.1°.** Crystd from dry benzene/$CHCl_3$ and dried under vacuum.

Methyl *p*-anisate *[121-98-2]* **M 166.2, m 48°.** Crystd from EtOH.

4-Methyl anisole *[104-93-8]* **M 122.2, b 175-176°, d_{15}^{15} 0.9757, n 1.512.** Dissolved in ethyl ether, washed with M NaOH, water, dried (Na_2CO_3), evaporated and the residue distd under vacuum.

2-Methylanthracene *[613-12-7]* **M 192.3, m 204-206°,**
4-Methylanthracene *[779-02-2]* **M 192.3, m 77-79°, b 196-197°/12mm, d 1.066.** Chromatographed on silica gel with cyclohexane as eluent and recrystd from EtOH [Werst *JACS* **109** 32 *1987*].

***N*-Methylanthranilic acid** see ***N*-methyl-*o*-aminobenzoic acid.**

2-Methylanthraquinone *[84-54-8]* **M 222.3, m 176°.** Crystd from EtOH, then sublimed.

Methylarenes (see also pentamethyl- and hexamethyl- benzenes). Recrystd from EtOH and sublimed in vacuum [Schlesener et al. *JACS* **106** 7472 *1984*].

Methyl benzoate *[93-58-3]* **M 136.2, b 104-105°/39mm, 199.5°/760mm, d 1.087, n^{15} 1.52049, n 1.51701.** Washed with dilute aqueous $NaHCO_3$, then water, dried with Na_2SO_4 and fractionally distd under reduced pressure.

***p*-Methylbenzophenone** *[134-84-9]* **M 196.3, m 57°.** Crystd from MeOH and pet ether.

Methyl-1,4-benzoquinone *[553-79-9]* **M 122.1, m 68-69°.** Crystd from heptane or EtOH, dried rapidly (vacuum over P_2O_5) and stored under vacuum.

Methyl benzoylformate *[15206-55-0]* **M 164.2, m 246-248°.** Purified by radial chromatography (ethyl ether/hexane, 1:1), and dried at 110-112° at 6mm pressure. [Meyers and Oppenlaender *JACS* **108** 1989 *1986*].

2-Methyl-3,4-benzphenanthrene *[652-04-0]* **M 242.3, m 70°.** Crystd from EtOH.

***dl*-α-Methylbenzyl alcohol** *[13323-81-4]* **M 122.2, b 60.5-61.0°/3mm.** Dried with $MgSO_4$ and distd under vacuum.

***p*-Methylbenzyl alcohol** see ***p*-tolyl carbinol.**

***R*-(+)-α-Methylbenzylamine** *[3886-69-9]* **M 121.2, b 187-188°/atm, $[\alpha]_{546}^{20}$ +35° (c 10, EtOH), $[\alpha]_D^{25}$ +39.7° (neat).** Dissolve in toluene, dry over NaOH and distd, fraction boiling at 187-188°/atm is collected. Store under N_2 to avoid forming the carbamate and urea. Similarly for the *S*-(-) **enantiomer** *[2627-86-3]*. [*Org Synth* Col. Vol II 503 *1943*].

***p*-Methylbenzyl bromide** *[104-81-4]* **M 185.1, m 35°, b 218-220°/760mm.** Crystd from pentane.

***p*-Methylbenzyl chloride** *[104-82-5]* **M 140.6, b 80°/2mm, d 1.085, n 1.543.** Dried with $CaSO_4$ and fractionally distd under vacuum.

Methyl benzylpenicillinate *[653-89-4]* **M 348.3, m 97°, $[\alpha]_D^{20}$ +328° (c 1, MeOH).** Crystd from CCl_4.

Methylbixin *[26585-94-4]* **M 408.5, m 163°.** Crystd from EtOH/$CHCl_3$.

Methyl bromide *[74-83-9]* **M 94.9, b 3.6°.** Purified by bubbling through conc H_2SO_4, followed by passage through a tube containing glass beads coated with P_2O_5. Also purified by distn from $AlBr_3$ at -80°, by passage through a tower of KOH pellets and by partial condensation.

Methyl *o*-bromobenzoate *[610-94-6]* **M 215.1, b 122°/17mm, 234-244°/760mm.** Soln in ether is washed with 10% aqueous Na_2CO_3, water, then dried and distd.

Methyl *p*-bromobenzoate *[619-42-1]* **M 215.1, m 79.5-80.5°.** Crystd from MeOH.

2-Methyl-1,3-butadiene see **isoprene.**

2-Methylbutane *[78-78-4]* **M 72.2, b 27.9°, d 0.621, n 1.35373, n^{25} 1.35088.** Stirred for several hours in the cold with conc H_2SO_4 (to remove olefinic impurities), then washed with H_2O, aqueous Na_2CO_3 and H_2O again. Dried with $MgSO_4$ and fractionally distd using a Todd column packed with glass helices. Material transparent down to 180nm was obtained by distilling from sodium wire, and passing through a column of silica gel which had previously been dried in place at 350° for 12h before use. [Potts *JPC* **20** 809 *1952*].

2-Methyl-1-butanol *[dl: 137-32-6] [l: 1565-80-6]* **M 88.2, b 128.6°, d 0.809, n^{52} 1.4082.** Refluxed with CaO, distd, refluxed with magnesium and again fractionally distd. A small sample of highly purified material was obtained by fractional crystn after conversion into a suitable ester such as the trinitrophthalate or the 3-nitrophthalate. The latter was converted to the cinchonine salt in acetone and recrystd from $CHCl_3$ by adding pentane. The salt was saponified, extracted with ether, and fractionally distd. [Terry et al. *J Chem Eng Data* **5** 403 *1960*].

2-Methyl-2-butanol see ***tert*-amyl alcohol.**

3-Methyl-1-butanol *[123-51-3]* **M 88.2, b 128°/750mm, 132°/760mm, d^{15} 0.8129, n^{15} 1.4085, n 1.4075.** Dried by heating with CaO and fractionally distilling, then heating with BaO and redistilling. Alternatively, boiled with conc KOH, washed with dilute H_3PO_4, and dried with K_2CO_3, then anhydrous $CuSO_4$, before fractionally distilling. It is separated from 2-methyl-1-butanol by fractional distn, fractional crystn and preparative gas chromatography.

3-Methyl-2-butanol *[598-75-4]* **M 88.2, b 111.5°, d 0.807, n 1.4095, n^{25} 1.4076.** Refluxed with magnesium, then fractionally distd.

3-Methyl-2-butanone *[563-80-4]* **M 86.1, b 93-94°/752mm, d 0.818, n 1.410.** Refluxed with a little $KMnO_4$. Fractionated on a spinning-band column. Dried with $CaSO_4$ and distd.

2-Methyl-2-butene *[513-35-9]* **M 70.1, f.p. -133.8°, b 38.4°/760mm, d^{15} 0.66708, d 0.6783, d^{25} 0.65694, n^{15} 1.3908.** Distd from sodium.

1-Methylbutyl- see ***sec*-amyl-.**

Methyl *n*-butyrate *[623-42-7]* **M 102.1, b 102.3°/760mm, d 0.898, n 1.389.** Treated with anhydrous $CuSO_4$, then distd under dry nitrogen.

***S*-(+)-2-Methylbutyric acid** *[1730-91-2]* **M 102.1, b 64°/2mm, 78°/15mm, 90-94°/23mm, 174-175°/atm, d_4^{20} 0.938, n_D^{20} 1.406, $[\alpha]_{546}^{20}$ +23°, $[\alpha]_D^{20}$ +19.8° (neat), $[\alpha]_D^{13}$ 18.3° (c 6,EtOH).** Purified by distn *in vacuo* [Sax and Bergmann *JACS* **77** 1910 *1955*; Doering and Aschner *JACS* **75** 393 *1953*]. The *methyl ester* is formed by addition of diazomethane and has **b** 112-115°/atm, $[\alpha]_D^{27}$ +21.1° (c 1.7, MeOH). [Kenyo and Symons *JCS* 3580 *1953*].

Methyl carbamate *[598-55-0]* **M 75.1, m 54.4-54.8°.** Crystd from benzene.

9-Methylcarbazole *1484-12-4]* **M 181.2, m 89°.** Purified by zone melting.

Methyl carbitol see **diethylene glycol monomethyl ether.**

4-Methylcatechol *[452-86-8]* **M 124.1, m 68°, b 112°/3mm, 241°/760mm.** Crystd from high-boiling pet ether and distd in a vacuum.

Methylcellosolve see **2-methoxyethanol.**

Methyl chloride *[74-87-3]* **M 50.5, b -24.1°.** Bubbled through a sintered-glass disc dipping into conc H_2SO_4, then washed with water, condensed at low temperature and fractionally distd. Has been distd from $AlCl_3$ at -80°. Alternatively, passed through towers containing $AlCl_3$, soda-lime and P_2O_5, then condensed and fractionally distd. Stored as a gas.

Methyl chloroacetate *[96-34-4]* **M 108.5, b 129-130°, d 1.230, n 1.423.** Shaken with satd aq Na_2CO_3 (three times), aq 50% $CaCl_2$ (three times), satd aq NaCl (twice), dried (Na_2SO_4) and fractionally distd.

***R*-(+) Methyl 2-chloropropionate** *[77287-29-7]* **M 122.6, b 49-50°/35mm, 78-80°/120mm, 132-134°/760mm, d_4^{20} 1.152, n_D^{20} 1.417, $[\alpha]_D^{20}$ +26° (19.0°) (neat).** Purified by repeated distillation [Walker *JCS* **67** 916 *1895*; Walden *B* **28** 1293 *1985*; see also Gless *Synthetic Commun* **16** 633 *1986*].

3-Methylcholanthrene *[56-49-5]* **M 268.4, m 179-180°.** Crystd from benzene and ethyl ether. **CARCINOGEN.**

Methyl cyanide see **acetonitrile.**

Methyl cyanoacetate *[105-34-0]* **M 99.1, f.p. -13°, b 205°, d 1.128, n 1.420.** Purified by shaking with 10% Na_2CO_3 soln, washing well with water, drying with anhydrous Na_2SO_4, and distilling.

Methyl cyanoformate *[17640-15-2]* **M 85.1, b 81°/47mm, 97°/751mm, 100-101°/760mm, d_4^{20} 1.072, n_D^{20} 1.37378.** Purified by fractionation through a 45cm glass helices packed column and with a 30cm spinning band column. [Sheppard *JOC* **27** 3756 *1962*]. It has been distd through a short Vigreux column, and further purified by recrystn from Et_2O at -40° as white crystals which melt at room temperature. NMR: δ 4.0 (XH_3) ppm, and IR: 2250 (CN) and 1750 (CO) cm^{-1}. [Childes and Weber *JOC* **41** 3486 *1976*].

Methylcyclohexane *[108-87-2]* **M 98.2, b 100.9°, d^{25} 0.7650, n 1.4231, n^{52} 1.42058.** Passage through a column of activated silica gel gives material transparent down to 220nm. Also purified by passage through a column of activated basic alumina, or by azeotropic distn with MeOH, followed by washing out the MeOH with H_2O, drying and distilling. Methylcyclohexane can be dried with $CaSO_4$, CaH_2 or sodium. Has also been purified by shaking with a mixture of conc H_2SO_4 and HNO_3 in the cold, washing with H_2O, drying with $CaSO_4$ and fractionally distilling from potassium. Percolation through a Celite column impregnated with 2,4-dinitrophenylhydrazine, phosphoric acid and H_2O (prepared by grinding 0.5g DNPH with 6ml 85% H_3PO_4, then mixing with 4ml of distilled H_2O and 10g of Celite) removes carbonyl-containing impurities.

2-Methylcyclohexanol *[583-59-5]* **M 114.2, b 65°/20mm, 167.6°/760mm, d 0.922, n 1.46085,**
***cis*- and *trans*-3-Methylcyclohexanol** *[591-23-1]* **M 114.2, b 69°/16mm, 172°/760mm, d 0.930, n 1.45757, $n^{25.5}$ 1.45444.** Dried with Na_2SO_4 and distd under vacuum.

4-Methylcyclohexanone *[589-92-4]* **M 112.2, b 165.5°/743mm, d 0.914, n 1.44506.** Dried with $CaSO_4$, then fractionally distd.

1-Methylcyclohexene *[591-49-1]* **M 107.4-108°/760mm, d 0.813, n 1.451.** Freed from hydroperoxides by passing through a column containing basic alumina or refluxing with cupric stearate, filtered and fractionally distd from sodium.

Methylcyclopentene *[96-37-7]* **M 84.2, b 71.8°, d 0.749, n 1.40970, n^{25} 1.40700.** Purification procedures include passage through columns of silica gel (prepared by heating in nitrogen to 350° prior to use) and activated basic alumina, distn from sodium-potassium alloy, and azeotropic distn with MeOH, followed by washing out the methanol with water, drying and distilling. It can be stored with CaH_2 or sodium.

3'-Methyl-1,2-cyclopentenophenanthrene *[549-38-2]* **M 232.3, m 126-127°.** Crystd from AcOH.

S-Methyl-L-cysteine *[1187-84-4]* **M 135.2, m 207-211°, $[\alpha]_D^{26}$ -32.0° (c 5,H_2O).** Likely impurities are cysteine and S-methyl-*dl*-cysteine. Crystd from water by adding 4 volumes of EtOH.

5-Methylcytosine *[554-01-8]* **M 125.1, m 270°(dec).** Crystd from water.

Methyl decanoate *[110-42-9]* **M 186.3, b 114°/15mm, 224°/760mm, d 0.874, n 1.426.** Passed through alumina before use.

Methyl 2,4-dichlorophenoxyacetate *[1928-38-7]* **M 235.1, m 43°, b 119°/11mm.** Crystd from MeOH.

***m*-Methyl-*N*,*N*-dimethylaniline** *[121-72-2]* **M 135.2, b 72-74°/5mm, 215°/760mm,**
***p*-Methyl-*N*,*N*-dimethylaniline** *[99-97-8]* **M 135.2, b 76.5, 77.5°/4mm, 211°/760mm.** Refluxed for 3h with 2gram-equivalents of acetic anhydride, then fractionally distd under reduced pressure.

2-Methyl-1,3-dithiane *[6007-26-7]* **M 134.3, b 53-54°/1.1mm, 66°/5mm, 79-80°/8-10mm, 85°/12mm, d_4^{20} 1.121, n_D^{20} 1.560.** Wash with H_2O, 2.5 M aqueous NaOH, H_2O, brine, dried over K_2CO_3 (use toluene as solvent if volume of reagent is small), filter, evaporate and distil the colourless residue. IR film: 1455, 1371 and 1060 (all medium and CH_3), 1451m, 1422s, 1412m, 1275m, 1236m, 1190m, 1171w, 918m and 866w (all dithiane) cm^{-1} [Corey and Erickson *JOC* **36** 3553 *1971*; Seebach and Corey *JOC* **40** 231 *1975*].

Methyl dodecanoate *[111-82-0]* **M 214.4, m 5°, b 141°/15mm, d 0.870, n^{50} 1.4199.** Passed through alumina before use.

***N*-Methyleneaminoacetonitrile** *[109-82-0]* **M 68.1, m 129°.** Crystd from EtOH or acetone.

Methylene-bis-acrylamide see **bis-acrylamide.**

p,p'-**Methylene-bis-(*N,N*-dimethylaniline)** *[101-61-1]* **M 254.4, m 89.5°.** Crystd from 95% EtOH (charcoal) (*ca* 12ml/g).

4,4'-Methylene bis[3-hydroxy-2-naphthalenecarboxylic acid see **embonic acid.**

Methylene Blue *[61-73-4]* **M 319.9, ε_{654} 94,000 (EtOH), ε_{664} 81,000 (H_2O).** Crystd from 0.1M HCl (16ml/g), the crystals were separated by centrifugation, washed with chilled EtOH and ethyl ether and dried under vacuum. Crystd from 50% aqueous EtOH, washed with absolute EtOH, and dried at 50-55° for 24h. Also crystd from benzene-MeOH (3:1). Salted out with NaCl from a commercial conc aqueous soln, then crystd from water, dried at 100° in an oven for 8-10h.

Methylene chloride see **dichloromethane.**

4,4'-Methylenedianiline see ***p,p'*-diaminodiphenylmethane.**

3,4-Methylenedioxyaniline *[14268-66-7]* **M 137.1, m 45-46°, b 144°/14mm.** Crystd from pet ether.

3,4-Methylenedioxycinnamic acid *[2373-80-0]* **M 192.2, m 243-244°(dec).** Crystd from glacial acetic acid.

5,5'-Methylenedisalicylic acid *[122-25-8]* **M 372.3, m 238°(dec).** Crystd from acetone and benzene.

Methylene Green *[2679-01-8]* **M 364.9.** Crystd three times from water (18ml/g).

Methylene iodide see **di-iodomethane.**

(+)- (1*S*,2*R*-) *[42151-56-4]* **and (-)- (1*R*,2*S*-)** *[552-79-4]* ***N*-Methylephedrine (2-dimethylamino-1-phenylpropanol) M 179.3, m 85-86°, 85-87°, 87-87.5°, 90°, b 115°/2mm, $[\alpha]_{546}^{20}$ ±35°, $[\alpha]_{D}^{20}$ ±30° (c 4.5, MeOH).** It has been recrystd from Et_2O, pet ether, of aq EtOH or aq MeOH and has been distilled under reduced pressure. [Smith *JCS* 2056 *1927* ; Tanaka and Sugawa *J Pharm Soc Japan 72* 1548 *1952* (*Chem Abs* **47** 8682 *1953*); Takamatsu *J Pharm Soc Japan* **76** 1227 *1956* (*Chem Abs* **51** 4304 *1957*]. The *hydrochloride* has **m** 192-193° and $[\alpha]_{D}^{20}$ +30° (c 5,H_2O). They have a pKa^{26} value of 9.22 in H_2O [Prelog and Hüfliger *HCA* **33** 2021 *1950*].

Methyl ether *[115-10-6]* **M 46.1, b -63.5°/96.5mm.** Dried by passing over alumina and then BaO, or over CaH_2, followed by fractional distn at low temperatures.

***N*-Methyl ethylamine hydrochloride** *[624-60-2]* **M 95.6, m 126-130°.** Crystd from absolute EtOH or ethyl ether.

Methyl ethyl ketone see **2-butanone.**

***N*-Methyl formamide** *[123-39-7]* **M 59.1, m -3.5°, b 100.5°/25mm, d 1.005., n^{52} 1.4306** Dried with molecular sieves for 2days, then distd under reduced pressure through a column packed with glass helices. Fractionally crystd by partial freezing and the solid portion was vac distd.

Methyl formate *[107-31-3]* **M 60.1, b 31.5°, d 0.971, n^{15} 1.34648, n 1.34332.** Washed with strong aq Na_2CO_3, dried with solid Na_2CO_3 and distd from P_2O_5. (Procedure removes free alcohol or acid.)

2-Methylfuran *[534-22-5]* **M 82.1, b 62.7-62.8°/731mm, d 0.917, n 1.436.** Washed with acidified satd ferrous sulphate soln (to remove peroxides), separated, dried with $CaSO_4$ or $CaCl_2$, and fractionally distd from KOH immediately before use. To reduce the possibility of spontaneous polymerisation, addition of about one-third of its volume of heavy mineral oil to 2-methylfuran prior to distn has been recommended.

Methyl gallate *[99-24-1]* **M 184.2, m 202°,**
***N*-Methylglucamine** *[6284-40-8]* **M 195.2, m 128-129°, $[\alpha]_{546}^{20}$ -19.5°(c 2, H_2O),**
Methyl α-D-glucosamine *[97-30-3]* **M 194.2, m 165°, $[\alpha]_D^{25}$ +157.8° (c 3.0, H_2O).** Crystd from MeOH.

α-Methylglutaric acid *[617-62-8]* **M 146.1, m 79°,**
β-Methylglutaric acid *[626-51-7]* **M 146.1, m 87°.** Crystd from distd water, then dried under vacuum over conc H_2SO_4.

Methylglyoxal *[78-98-8]* **M 72.1, b ca 72°/760mm.** Commercial 30% (w/v) aqueous soln was diluted to about 10% and distd twice, taking the fraction boiling below 50°/20mm Hg. (This treatment does not remove lactic acid).

Methyl Green *[82-94-0]* **M 458.5.** Crystd from hot water.

1-Methylguanine *[938-85-2]* **M 165.2, m >300°(dec).** Crystd from 50% aqueous acetic acid.

7-Methylguanine *[578-76-7]* **M 165.2.** Crystd from water.

2-Methylhexane *[591-76-4]* **M 100.2, b 90.1°, d 0.678, n 1.38485, n^{25} 1.38227,**
3-Methylhexane *[589-34-4]* **M 100.2, b 91.9°, d 0.687, n 1.38864, n^{25} 1.38609.** Purified by azeotropic distn with MeOH, then washed with water (to remove the MeOH), dried over type 4A molecular sieves and distd.

Methyl hexanoate *[106-70-7]* **M 130.2, b 52°/15mm, 150°/760mm, d 0.885, n 1.410.** Passed through alumina before use.

Methylhydrazine *[60-34-4]* **M 46.1, b 87°/745mm, d 0.876, n 1.436.** Dried with BaO, then vacuum distd. Stored under nitrogen.

Methyl hydrazinocarboxylate *[6294-89-9]* **M 90.1, m 70-73°.** To remove impurities, the material was melted and pumped under vacuum until the vapours were spectroscopically pure [Caminati et al. *JACS* **108** 4364 *1986*].

2-Methyl-4-hydroxyazobenzene *[1435-88-7]* **M 212.2, m 100-101°,**
3-Methyl-4-hydroxyazobenzene *[62-48-1]* **M 212.2, m 125-126°.** Crystd from hexane.

Methyl 4-hydroxybenzoate *[99-76-3]* **M 152.2, m 127.5°.** Fractionally crystd from its melt, recrystd from benzene, then from benzene/MeOH and dried over $CaCl_2$ in a vacuum desiccator.

Methyl 3-hydroxy-2-naphthoate *[883-99-8]* **M 202.2, m 73-74°.** Crystd from MeOH (charcoal) containing a little water.

***N*-Methylimidazole** *[616-47-7]* **M 82.1, b 81-84°/27mm, 197-198°/760mm, d 1.032, n 1.496.** Dried with sodium metal and then distd. Stored at 0° under dry argon.

2-Methylimidazole *[693-98-1]* **M 82.1, m 140-141°, b 267°/760mm,**
4-Methylimidazole *[822-36-6]* **M 82.1, m 47-48°, b 263°/760mm.** Recrystd from benzene or pet ether.

2-Methylindole *[95-20-5]* **M 131.2, m 61°,**
3-Methylindole *[83-34-1]* **M 131.2, m 95°.** Crystd from benzene. Purified by zone melting.

Methyl iodide *[74-88-4]* **M 141.9, b 42.8°, d 2.281, n 1.5315.** Deteriorates rapidly with liberation of iodine if exposed to light. Usually purified by shaking with dilute aqueous $Na_2S_2O_3$ or $NaHSO_3$ until

colourless, then washed with water, dilute aqueous Na_2CO_3, and more water, dried with $CaCl_2$ and distd. It is stored in a brown bottle away from sunlight in contact with a small amount of mercury, powdered silver or copper. (Prolonged exposure of mercury to methyl iodide forms methylmercuric iodide.) Methyl iodide can be dried further using $CaSO_4$ or P_2O_5. An alternative purification is by percolation through a column of silica gel or activated alumina, then distn. The soln can be degassed by using a repeated freeze-pump-thaw cycle.

Methyl isobutyl ketone see **4-methyl-2-pentanone.**

Methyl isopropyl ketone see **3-methyl-2-butanone.**

***O*-Methylisourea hydrogen sulphate (2-methylpseudourea sulphate)** *[29427-58-5]* **M 172.2, m 114-118°, 119°.** Recrystd from MeOH-Et_2O (327g of salt dissolved in 1L of MeOH and 2.5L of Et_2O is added) [Fearing and Fox *JACS* **76** 4382 *1954*]. The *picrate* has **m** 192° [Odo et al. *JOC* **23** 1319 *1958*].

***N*-Methyl maleimide** *[930-88-1]* **M 111.1, m 94-96°.** Crystd three times from ethyl ether.

3-Methylmercaptoaniline *[1783-81-9]* **M 139.2, b 101.5-102.5°/0.3mm, 163-165°/16mm, d_4^{20} 1.147, n_D^{20} 1.641.** Purified by fractional distn in an inert atmostphere. It has a pKa at 25° in H_2O of 4.05, and UV max at 226 and 300. [Bordwell and Cooper *JACS* **74** 1058*1952*]. The *N-acetyl* derivative has **m** 78-78.5° (after recrystn from aq EtOH).

4-Methylmercaptoaniline *[104-96-1]* **M 139.2, b 140°/15mm, 151[°/25mm, 155°/23mm, d_4^{20} 1.137, n_D^{20} 1.639.** Purified by fractional distn in an inert atmosphere. It has a pKa value of 4.40 at 25° in H_2O. [Lumbroso and Passerini *Bull Soc Chim France* 311 *1957*; Mangini and Passerini *JCS* 4954 *1956*].

Methyl methacrylate *[80-62-6]* **M 100.1, f.p. -50°, b 46°/100mm, d 0.937, n 1.4144.** Washed twice with aqueous 5% NaOH (to remove inhibitors such as hydroquinone) and twice with water. Dried with $CaCl_2$, Na_2CO_3, Na_2SO_4 or $MgSO_4$, then with CaH_2 under nitrogen at reduced pressure. The distillate is stored at low temperatures and redistd before use. Prior to distn, inhibitors such as ß-naphthylamine (0.2%) or di-β-naphthol are sometimes added. Also purified by boiling foueous H_3PO_4 soln and finally with saturated NaCl soln. It was dried for 24h over anhydrous $CaSO_4$, distd at 0.1mm Hg at room temperature and stored at -30° [Albeck et al. *JCSFT 1* **1** 1488 *1978*].

α-Methylmethionine *[562-48-1]* **M 163.0, m 283-284°.** Crystd from aqueous EtOH.

S-Methyl-L-methionine chloride *[1115-84-0]* **M 199.5, $[\alpha]_D^{23}$ +33° (0.2M HCl).** Likely impurities are methionine, methionine sulphoxide and methionine sulphone. Crystd from water by adding a large excess of EtOH. Stored in a cool, dry place, protected from light.

Methylmevalonic acid *[516-05-2]* **M 118.1, m 135°(dec).** Crystallises as the hydrate from water.

***N*-Methylmorpholine** *[109-02-4]* **M 101.2, b 116-117°/764mm, d 0.919, n 1.436.** Dried by refluxing with BaO or sodium, then fractionally distd through a helices-packed column.

4-Methylmorpholine-4-oxide monohydrate *[7529-22-8]* **M 135.2, m 71-73°.** When dried for 2-3h at high vacuum it dehydrates. Add MeOH to the oxide and distil off the solvent under vacuum until the temp is *ca* 95°. Then add Me_2CO at reflux then cool to 20°. The crystals are filtered off washed with Me_2CO and dry. The degree of hydration may vary and may be important for the desired reactions. [van Rheenan et al. *TET LETT* 1973 1076; Schneider and Hanze US Pat 2 769 823; see also Sharpless et al. *TET LETT* 2503 *1976*].

1-Methylnaphthalene *[90-12-0]* **M 142.2, f.p. -30°, b 244.6°, d 1.021, n 1.6108.** Dried for several days with $CaCl_2$ or by prolonged refluxing with BaO. Fractionally distd through a glass helices-packed column from sodium. Purified further by soln in MeOH and pptn of its picrate complex by adding to a saturated soln of picric acid in MeOH. The picrate, after crystn to constant melting point (**m** 140-141°) from MeOH., was dissolved in benzene and extracted with aqueous 10% LiOH until the extract was colourless. Evaporation of

the benzene under vacuum gave 1-methylnaphthalene [Kloetzel and Herzog *JACS* **72** 1991 *1950*]. However, neither the picrate nor the styphnate complexes satisfactorily separates 1- and 2- methylnaphthalenes. To achieve this, 2-methylnaphthalene (10.7g) in 95% EtOH (50ml) has been ppted with 1,3,5-trinitrobenzene (7.8g) and the complex has been crystd from MeOH to **m** 153-153.5° (**m** of the 2-methyl isomer is 124°). [Alternatively, 2,4,7-trinitrofluorenone in hot glacial acetic acid could be used, and the derivative (**m** 163-164°) recrystd from glacial acetic acid]. The 1-methylnaphthalene was regenerated by passing a soln of the complex in dry benzene through a 15-in column of activated alumina and washing with benzene/pet ether (b 35-60°) until the coloured band of the nitro compound had moved down near the end of the column. The complex can also be decomposed using tin and acetic-hydrochloric acids, followed by extraction with ethyl ether and benzene; the extracts were washed successively with dilute HCl, strongly alkaline sodium hypophosphite, water, dilute HCl and water. [Soffer and Stewart *JACS* **74** 567 *1952*]. It can be purified from anthracene by zone melting.

2-Methylnaphthalene *[91-57-6]* **M 142.2, m 34.7-34.9°, b 129-130°/25mm.** Fractionally crystd repeatedly from its melt, then fractionally distd under reduced pressure. Crystd from benzene and dried under vacuum in an Abderhalden pistol. Purified *via* its picrate (**m** 114-115°) as described for 1-methylnaphthalene.

6-Methyl-2-naphthol *[17579-79-2]* **M 158.2, m 128-129°,**
7-Methyl-2-naphthol *[26593-50-0]* **M 158.2, m 118°.** Crystd from EtOH or ligroin. Sublimed *in vacuo*.

2-Methyl-1,4-naphthoquinone see **vitamin K_3** (see entry in Chapter 5).

Methyl 1-naphthyl ether *[2216-69-5]* **M 158.2, b 90-91°/2mm, d 1.095, n^{26} 1.6210.** Steam distd from alkali. The distillate was extracted with ethyl ether. After drying the extract and evaporating the ethyl ether, the methyl naphthyl ether was distd under reduced pressure.

Methyl 1-naphthyl ketone see **1-acetylnaphthalene.**

Methyl 2-naphthyl ketone see **2-acetylnaphthalene.**

Methyl nitrate *[598-58-3]* **M 77.0, b 65°/760mm, d^5 1.2322, d^{15} 1.2167, d^{25} 1.2032.** Distd at -80°. The middle fraction was subjected to several freeze-pump-thaw cycles. **VAPOUR EXPLODES ON HEATING.**

Methyl nitrite *[624-91-9]* **M 61.0, b -12°, d^{15} (liq) 0.991.** Condensed in a liquid nitrogen trap. Distd under vacuum, first trap containing dry Na_2CO_3 to free it from acid impurities then into further Na_2CO_3 traps before collection.

***N*-Methyl-4-nitroaniline** *[100-15-2]* **M 152.2, m 152.2°.** Crystd from aqueous EtOH.

2-Methyl-5-nitroaniline *[99-55-8]* **M 152.2, m 109°.** Acetylated, and the acetyl derivative crystd to constant melting point, then hydrolysed with 70% H_2SO_4 and the free base regenerated by treatment with ammonia [Bevan, Fayiga and Hirst *JCS* 4284 *1956*].

4-Methyl-3-nitroaniline *[119-32-4]* **M 152.2, m 81.5°.** Crystd from hot water (charcoal), then ethanol and dried in a vacuum desiccator.

Methyl 3-nitrobenzoate *[618-95-1]* **M 181.2, m 78°.** Crystd from MeOH (1g/ml).

Methyl 4-nitrobenzoate *[619-50-1]* **M 181.2, m 95-95.5°.** Dissolved in ethyl ether, then washed with aqueous alkali, the ether was evaporated and the ester was recrystd from EtOH.

2-Methyl-2-nitro-1,3-propanediol *[77-49-6]* **M 135.1, m 145°.** Crystd from *n*-butanol.

2-Methyl-2-nitro-1-propanol *[76-39-1]* **M 119.1, m 87-88°.** Crystd from pet ether.

***N*-Methyl-4-nitrosoaniline** *[10595-51-4]* **M 136.2, m 118°.** Crystd from benzene.

***N*-Methyl-*N*-nitroso-*p*-toluenesulphonamide (diazald)** *[80-11-5]* **M 214.2, m 62°.** Crystd from benzene by addition of pet ether.

Methylnorbornene-2,3-dicarboxylic anhydride (5-methylnorborn-5-ene-2-endo-3-endo-dicarboxylic anhydride *[25134-21-8]* **M 178.2, m 88.5-89°.** Purified by thin layer chromatography on Al_2O_3 (previously boiled in EtOAc) and eluted with hexane-C_6H_6 (1:2) then recrystd from C_6H_6-hexane. The free acid has **m** 118.5-119.5°. [Miranov et al. *TET* **19** 1939 *1963*].

3-Methyloctane *[2216-33-3]* **M 128.3, b 142-144°/760mm, d 0.719, n 1.407.** Passed through a column of silica gel [Klassen and Ross *JPC* **91** 3668 *1987*].

Methyl octanoate (methyl caprylate) *[111-11-5]* **M 158.2, b 83°/15mm, 193-194°/760mm, d 0.877, n 1.419.** Passed through alumina before use.

Methyl oleate *[112-62-9]* **M 296.5, f.p. -19.9°, b 217°/16mm, d 0.874, n 1.4522.** Purified by fractional distn under reduced pressure, and by low temperature crystn from acetone.

Methyl Orange *[547-58-0]* **M 327.3.** Crystd twice from hot water, then washed with a little EtOH followed by ethyl ether.

3-Methyl-2-oxazolidone *[19836-78-3]* **M 101.1, m 15°, b 88-91°/1mm, d 1.172, n 1.455.** Purified by successive fractional freezing, then dried in a dry-box over Linde type 4A molecular sieves for 2days.

3-Methyl-3-oxetanemethanol (3-hydroxymethyl-3-methyloxetane) *[3143-02-0]* **M 102.1, b 80°/4mm, 92-93°/12mm, d_4^{20} 1.033, n_D^{25} 1.4449.** Purified by fractionation through a glass column [Pattison *JACS* **79** 3455 *1957*].

Methylpentane (mixture of isomers). Passage through a long column of activated silica gel (or alumina) gave material transparent down to 200nm.

2-Methylpentane *[107-83-5]* **M 86.2, b 60.3°, d 0.655, n 1.37145, n^{25} 1.36873.** Purified by azeotropic distn with MeOH, followed by washing out the MeOH with water, drying ($CaCl_2$, then sodium), and distn. [Forziati et al. *J Res Nat Bur Stand* **36** 129 *1946*].

3-Methylpentane *[96-14-0]* **M 86.2, b 63.3°, d 0.664, n 1.37652, n^{25} 1.37384.** Purified by azeotropic distn with MeOH, as for 2-methylpentane. Purified for ultraviolet spectroscopy by passage through columns of silica gel or alumina activated by heating for 8h at 210° under a stream of nitrogen. Has also been treated with conc (or fuming) H_2SO_4, then washed with water, aqueous 5% NaOH, water again, then dried ($CaCl_2$, then sodium), and distd through a long, glass helices-packed column.

2-Methyl-2,4-pentanediol *[107-41-5]* **M 118.2, b 107.5-108.5°/25mm, d 0.922, n^{25} 1.4265.** Dried with Na_2SO_4, then CaH_2 and fractionally distd under reduced pressure through a packed column, taking precautions to avoid absorption of water.

2-Methyl-1-pentanol *[105-30-6]* **M 102.2, b 65-66°/60mm, 146-147°/760mm, d 0.827, n 1.420.** Dried with Na_2SO_4 and distd.

4-Methyl-2-pentanol *[108-11-2]* **M 102.2, b 131-132°, d 0.810, n 1.413.** Washed with aqueous $NaHCO_3$, dried and distd. Further purified by conversion to the phthalate ester by adding 120ml of dry pyridine and 67g of phthalic anhydride per mole of alcohol, purifying the ester and steam distilling it in the presence of NaOH. The distillate was extracted with ether, and the extract was dried and fractionally distd. [Levine and Walti *JBC* **94** 367 *1931*].

3-Methyl-3-pentanol carbamate (Emylcamate) *[78-28-4]* **M 145.2, m 56-58.5°.** Crystd from 30% EtOH.

4-Methyl-2-pentanone *[108-10-1]* **M 100.2, b 115.7°, d 0.801, n 1.3958, n^{25} 1.3938.** Refluxed with a little $KMnO_4$, washed with aqueous $NaHCO_3$, dried with $CaSO_4$ and distd. Acidic impurities were removed by passage through a small column of activated alumina.

2-Methyl-1-pentene *[763-29-1]* **M 84.2, b 61.5-62°, d 0.680, n 1.395.** Water was removed, and peroxide formation prevented by several vacuum distns from sodium, followed by storage with sodium-potassium alloy.

***cis*-4-Methyl-2-pentene** *[691-38-3]* **M 84.2, m -134.4°, b 57.7-58.5°, d 0.672, n 1.388,** ***trans*-4-Methyl-2-pentene** *[674-76-0]* **M 84.2, m -140.8°, b 58.5°, d 0.669, n 1.389.** Dried with CaH_2, and distd.

5-Methyl-1,10-phenanthroline *[3002-78-6]* **M 194.2, m 113°(anhydr).** Crystd from benzene/pet ether.

***N*-Methylphenazonium methosulphate** *[299-11-6]* **M 306.3, m 155-157°.** Crystd from EtOH.

***N*-Methylphenothiazine** *[1207-72-3]* **M 213.2, a-form m 99.3° and b 360-365°, ß-form m 78-79°.** Recrystn (three times) from EtOH gave a-form (prisms). Recrystn from EtOH/benzene gave the ß-form (needles). Also purified by vacuum sublimation and carefully dried in a vacuum line. Also crystd from toluene and stored in the dark [Guarr et al. *JACS* **107** 5104 *1985;* Olmsted et al. *JACS* **109** 3297 *1987*].

4-Methylphenylacetic acid *[622-47-9]* **M 150.2, m 94°.** Crystd from heptane.

1-Methyl-1-phenylhydrazine sulphate *[33008-18-3]* **M 218.2.** Crystd from hot H_2O by addition of hot EtOH.

3-Methyl-1-phenyl-5-pyrazolone *[89-25-8]* **M 174.2, m 127°.** Crystd from hot H_2O, or EtOH/water (1:1).

***N*-Methyl-2-phenylsuccinimide** see **phensuximide.**

***N*-Methylphthalimide** *[550-44-7]* **M 161.1, m 133.8°.** Recrystd from absolute EtOH.

2-Methylpiperazine *[109-07-9]* **M 100.2, m 66°.** Purified by zone melting.

3-Methylpiperidine *[626-56-2]* **M 99.2, b 125°/763mm, d 0.846, n^{25} 1.4448.** Purified *via* the *hydrochloride* (**m** 172°). [Chapman, Isaacs and Parker *JCS* 1925 *1959*].

4-Methylpiperidine *[626-58-4]* **M 99.2, b 124.4°/755mm, d 0.839, n^{25} 1.4430.** Purified *via* the *hydrochloride* (**m** 189°). Freed from 3-methylpyridine by zone melting.

1-Methyl-4-piperidone *[1445-73-4]* **M 113.2, b 53-56°/0.5mm, 54-56°/9mm, 68-71°/17mm, 85-87°/45mm, d_4^{20} 0.972, n_D^{25} 1.4588.** It is best purified by fractional distn. It has a pKa of 7.9 at 25° in H_2O. The *hydrochloride* of the hydrate (4-diol) has **m** 94.7-95.5°, but the anhydrous *hydrochloride* which crystallises from $CHCl_3$-Et_2O and has **m** 165-168° (164-167°) and can also be obtained by sublimation at 120°/2mm.. The *oxime* has **m** 130-132° (from Me_2CO). The *methiodide* crystallises from MeOH and the crystals with 1MeOH has **m** 189-190°, and the solvent-free *iodide* has **m** 202-204° dec. [Lyle et al. *JOC* **24** 342 *1959*; Bowden and Greeen *JCS* 1164 *1952*; Tomita *J Pharm Soc Japan* **71** 1053 *1951*].

2-Methylpropane-1,2-diamine *[811-93-8]* **M 88.2, b 47-48°/17mm.** Dried with sodium for 2days, then distd under reduced pressure from sodium.

2-Methylpropane-1-thiol *[513-44-0]* **M 90.2, b 41.2°/142mm, n^{25} 1.43582.** Dissolved in EtOH, and added to 0.25M $Pb(OAc)_2$ in 50% aqueous EtOH. The ppted lead mercaptide was filtered off, washed with a little EtOH, and impurities were removed from the molten salt by steam distn. After cooling, dilute HCl was added dropwise to the residue, and the mercaptan was distd directly from the flask. Water was separated from the distillate, and the mercaptan was dried (Na_2CO_3) and distd under nitrogen. [Mathias *JACS* **72** 1897 *1950*].

2-Methylpropane-2-thiol *[75-66-1]* **M 90.2, b 61.6°/701mm, d^{25} 0.79426, n^{25} 1.41984.** Dried for several days with CaO, then distd from CaO. Purified as for *2-methylpropane-1-thiol.*

2-Methyl-1-propanol *[78-83-1]* **M 74.1, b 107.9°, d 0.804, n^{15} 1.39768, n^{25} 1.3939.** Dried by refluxing with CaO and BaO for several hours, followed by treatment with calcium or aluminium amalgam, then fractional distn from sulphanilic or tartaric acids. More exhaustive purifications involve formation of phthalate or borate esters. Heating with phthalic anhydride gives the *acid phthalate* which, after crystn to constant melting point (**m** 65°) from pet ether, is hydrolysed with aqueous 15% KOH. The alcohol is distd as the water azeotrope and dried with K_2CO_3, then anhydrous $CuSO_4$, and finally magnesium turnings, followed by fractional distn. [Hückel and Ackermann *J prakt Chem* **136** 15 *1933*]. The borate ester is formed by heating the dried alcohol for 6h in an autoclave at 160-175° with a quarter of its weight of boric acid. After several fractional distns under vacuum the ester is hydrolysed by heating for a short time with aq alkali and the alcohol is dried with CaO and distd. [Michael, Scharf and Voigt *JACS* **38** 653 *1916*].

2-Methyl-2-propanol see *tert*-**butyl alcohol.**

***N*-Methylpropionamide** *[1187-58-2]* **M 87.1, f.p. -30.9°, b 103°/12-13mm, d 0.934, n^{25} 1.4356.** A colourless, odourless, neutral liquid at room temperature with a high dielectric constant. The amount of water present can be determined directly by Karl Fischer titration; GLC and NMR have been used to detect unreacted propionic acid. Commercial material of high quality is available, probably from the condensation of anhydrous methylamine with 50% excess of propionic acid. Rapid heating to 120-140° with stirring favours the reaction by removing water either directly or as the ternary xylene azeotrope. The quality of the distillate improves during the distn.
The propionamide can be dried over CaO. H_2O and unreacted propionic acid were removed as their xylene azeotropes. It was vacuum dried. Material used as an electrolyte solvent (specific conductance less than 10^{-6} ohm^{-1} cm^{-1}) was obtained by fractional distn under reduced pressure, and stored over BaO or molecular sieves because it readily absorbs moisture from the atmosphere on prolonged storage. [Hoover *PAC* **37** 581 *1974*; *Recommended Methods for Purification of Solvents and Tests for Impurities,* Coetzee ed, Pergamon Press, *1982*].

Methyl propionate *[554-12-1]* **M 88.1, b 79.7°.** Washed with satd aq NaCl, then dried with Na_2CO_3 and distd from P_2O_5. (This removes any free acid and alcohol.) It has also been dried with anhydrous $CuSO_4$.

Methyl *n*-propyl ether *[557-17-5]* **M 74.1, b 39°, d 0.736, n^{14} 1.3602.** Dried with $CaSO_4$, then passed through a column of alumina (to remove peroxides) and fractionally distd.

Methyl *n*-propyl ketone *[107-87-9]* **M 86.1, b 102.4°, d 0.807, n 1.3903.** Refluxed with a little $KMnO_4$, dried with $CaSO_4$ and distd. It was converted to its bisulphite addition compound by shaking with excess saturated aqueous $NaHSO_3$ at room temperature, cooling to 0°, filtering, washing with ethyl ether and drying. Steam distillation gave a distillate from which the ketone was recovered, washed with aq $NaHCO_3$ and distd water, dried (K_2CO_3) and fractionally distd. [Waring and Garik *JACS* **78** 5198 *1956*].

3-Methyl-1-propyn-3-ol carbamate *[302-66-9]* **M 141.2, m 55.8-57°.** Crystd from ether/pet ether or cyclohexane.

2-Methylpyrazine *[109-08-0]* **M 94.1, b 136-137°, d 1.025, n 1.505.** Purified *via* the picrate. [Wiggins and Wise *JCS* 4780 *1956*].

2-Methylpyridine (2-picoline) *[109-06-8]* **M 93.1, b 129.4°, d 0.9444, n 1.50102.** Biddiscombe and Handley [*JCS* 1957 *1954*] steam distd a boiling soln of the base in 1,2 equivalents of 20% H_2SO_4 until about 10% of the base had been carried over, along with non-basic impurities. Excess aqueous NaOH was then added to the residue, the free base was separated, dried with solid NaOH and fractionally distd. 2-Methylpyridine can also be dried with BaO, CaO, CaH_2, $LiAlH_4$, sodium or Linde type 5A molecular sieves. An alternative purification is *via* the $ZnCl_2$ adduct, which is formed by adding 2-methylpyridine (90ml) to a soln of anhydrous $ZnCl_2$ (168g) and 42ml conc HCl in absolute EtOH (200ml). Crystals of the complex are filtered off, recrystd twice from absolute EtOH (to give **m** 118.5-119.5°), and the free base is liberated by addition of excess aqueous NaOH. It is steam distd, and solid NaOH added to the distillate to form two layers, the upper one of which is then dried with KOH pellets, stored for several days with BaO and fractionally distd. Instead of $ZnCl_2$, $HgCl_2$ (430g in 2.4L of hot water) can be used. The complex, which separates on cooling, can be dried at 110° and recrystd from 1% HCl (to **m** 156-157°).

3-Methylpyridine (3-picoline) *[108-99-6]* **M 93.1, m -18.5°, b 144°/767mm, d 0.957, n 1.5069.** In general, the same methods of purification that are described for *2-methylpyridine* can be used. However, 3-methylpyridine often contains 4-methylpyridine and 2,6-lutidine, neither of which can be removed satisfactorily by drying and fractionation, or by using the $ZnCl_2$ complex. Biddiscombe and Handley [*JCS* 1957 *1954*], after steam distn as for *2-methylpyridine*, treated the residue with urea to remove 2,6-lutidine, then azeotropically distd with acetic acid (the azeotrope had **b** 114.5°/712mm), and recovered the base by adding excess of aqueous 30% NaOH, drying with solid NaOH and carefully fractionally distilling. The distillate was then fractionally crystd by slow partial freezing. An alternative treatment [Reithof et al. *IECAE* **18** 458 *1946*] is to reflux the crude base (500ml) for 20-24h with a mixture of acetic anhydride (125g) and phthalic anhydride (125g) followed by distn until phthalic anhydride begins to pass over. The distillate was treated with NaOH (250g in 1.5L of water) and then steam distd. Addition of solid NaOH (250g) to this distillate (*ca* 2L) led to the separation of 3-methylpyridine which was removed, dried (K_2CO_3, then BaO) and fractionally distd. (Subsequent fractional freezing would probably be advantageous.)

4-Methylpyridine (4-picoline) *[108-89-4]* **M 93.1, m 4.25°, b 145.0°/765mm, d 0.955, n 1.5058.** Can be purified as for *2-methylpyridine*. Biddescombe and Handley's method for 3-methylpyridine is also applicable. Lidstone [*JCS* 242 *1940*] purified *via* the *oxalate* (**m** 137-138°) by heating 100ml of 4-methylpyridine to 80° and adding slowly 110g of anhydrous oxalic acid, followed by 150ml of boiling EtOH. After cooling and filtering, the ppte was washed with a little EtOH, then recrystd from EtOH, dissolved in the minimum quantity of water and distd with excess 50% KOH. The distillate was dried with solid KOH and again distd. Hydrocarbons can be removed from 4-methylpyridine by converting the latter to its hydrochloride, crystallising from EtOH/ethyl ether, regenerating the free base by adding alkali and distilling. As a final purification step, 4-methylpyridine can be fractionally crystd by partial freezing to effect a separation from 3-methylpyridine. Contamination by 2,6-lutidine is detected by its strong absorption at 270nm.

4-Methylpyridine 1-oxide *[1003-67-4]* **M 109.1, m 184°.** Crystd from acetone/ether.

***N*-Methylpyrrole** *[96-54-8]* **M 81.1, b 115-116°/756mm, d 0.908, n 1.487.** Dried with $CaSO_4$, then fractionally distd from KOH immediately before use.

1-Methyl-2-pyrrolidinone *[872-50-4]* **M 99.1, f.p. -24.4, b 65-76°/1mm, 78-79°/12mm, 94-96°/20mm, 202°/760mm, d_4^{20} 1.0328, n_D^{20} 1.4678.** Dried by removing water as benzene azeotrope. Fractionally distd at 10 torr through a 100-cm column packed with glass helices. It has a pKa^{25} of 0.2 in H_2O [Adelman *JOC* **29** 1837 *1964*; McElvain and Vozza *JACS* **71** 896 *1949*]. The *hydrochloride* has **m** 86-88° (from EtOH or Me_2CO-EtOH) [Reppe et al. *A* **596** 1 *1955*].

2-Methylquinoline (quinaldine) *[91-63-4]* **M 143.2, b 86-87°/1mm, 155°/14mm, 246-247°/760mm, d 1.058, n 1.6126.** Dried with Na_2SO_4 or by refluxing with BaO, then fractionally distd under reduced pressure. Redistd from zinc dust. Purified by conversion to its *phosphate* (**m** 220°) or *picrate* (**m** 192°) from which after recrystn, the free base was regenerated. [Packer, Vaughan and Wong *JACS* **80** 905 *1958*]. Its $ZnCl_2$ complex can be used for the same purpose.

4-Methylquinoline (lepidine) *[491-35-0]* **M 143.2, b 265.5°, d 1.084, n 1.61995.** Refluxed with BaO, then fractionally distd. Purified *via* its recrystd *dichromate salt* (**m** 138°). [Cumper, Redford and Vogel *JCS* 1176 *1962*].

6-Methylquinoline *[91-62-3]* **M 143.2, b 258.6°, d 1.067, n 1.61606.** Refluxed with BaO, then fractionally distd. Purified *via* its recrystd $ZnCl_2$ *complex* (**m** 190°). [Cumper, Redford and Vogel *JCS* 1176 *1962*].

7-Methylquinoline *[612-60-2]* **M 143.2, M 143.2, m 38°, b 255-260°, d 1.052, n 1.61481.** Purified *via* its *dichromate complex* (**m** 149°, after five recrystns from water). [Cumper, Redford and Vogel *JCS* 1176 *1962*].

8-Methylquinoline *[611-321-5]* **M 143.2, b 122.5°/16mm, 247.8°/760mm, d 1.703, n 1.61631.** Purified as for 2-methylquinoline. The *phosphate* and *picrate* have **m** 158° and **m** 201° respectively.

Methyl Red *[493-52-7]* **M 269.3, m 181-182°.** Extracted with boiling toluene in a Soxhlet flask. The crystals which separated on slow cooling to room temperature are filtered off, washed with a little toluene and recrystd from glacial acetic acid, benzene or toluene followed by pyridine/water. Alternatively, dissolved in aq 5% $NaHCO_3$ soln, and ppted from hot soln by dropwise addition of aq HCl. Repeated until the extinction coefficients did not increase.

Methyl salicylate (methyl 2-hydroxybenzoate) *[119-36-8]* **M 152.2, m -8.6°, m 79°/6mm, 104-105°/14mm, 223.3°/atm, d_4^{20} 1.1149, n_D^{20} 1.5380.** Dilute with Et_2O, wash with conc $NaHCO_3$ (may effervesce due to the presence of free acid), brine, dry $MgSO_4$, filter, evaporate and distil. Its solubility is 1g/1500 of H_2O. The *benzoyl* derivative has **m** 92° (b 270-280°/120mm), and the *3,5-dinitrobenzoate* has **m** 107.5°, and the *3,5-dinitrocarbamoyl* derivative has **m** 180-181°. [Hallas *JCS* 5770 *1965*].

Methyl salicylsalicylate *[580-02-9]* **M 194.2, m 51-52°.** Crystd from pet ether.

α-Methylstyrene (monomer) *[98-83-9]* **M 118.2, b 57°/15mm, d 0.910, n 1.5368.** Washed three times with aqueous 10% NaOH (to remove inhibitors such as quinol), then six times with distd water, dried with $CaCl_2$ and distd under vacuum. The distillate is kept under nitrogen, in the cold, and redistd if kept for more than 48h before use. It can also be dried with CaH_2.

***trans*-ß-Methylstyrene** *[873-66-5]* **M 118.2, b 176°/760mm, d 0.910, n 1.5496.** Distd under nitrogen from powdered NaOH through a Vigreux column, and passed through activated neutral alumina before use [Wong et al. *JACS* **109** 3428 *1987*].

4-Methylstyrene *[622-97-9]* **M 118.2, b 60°/12mm, 106°/10mm, d_4^{20} 0.9173, n_D^{20} 1.542.** Purified as the above styrenes and add a small amount of antioxidant if it is to be stored, UV in EtOH λmax 285nm (log ε 3.07), and in EtOH + HCl 295nm (log ε 2.84) and 252nm (log ε 4.23). [Schwartzman and Carson *JACS* **78** 322 *1956*; Joy and Orchin *JACS* **81** 305 *1959*; Buck et al. *JCS* 2377*1949*].

Methylsuccinic acid *[498-21-5]* **M 132.1, m 115.0°.** Crystd from water.

(±)-3-Methylsulpholane (3-methyl-tetrahydrothiophene-1,1-dioxide) *[872-93-5]* **M 134.2, m 0.5°, b 101°.2mm, 125-130°/12mm, 278-282°/763.5mm, d_4^{20} 1.1885, n_D^{20} 1.4770.** Distil under vacuum and recryst from Et_2O at -60° to -70°. IR film has strong bands at 570 and 500 cm^{-1}. [Eigenberger *J Prakt Chem [2]* **131** 289 *1931*; Freaheller and Katon *Spectrochim Acta* **20** 1099*1964*].

Methyl tetradecanoate (methyl myristate) *[134-10-7]* **M 382.7, m 18.5°, b 155-157°/7mm.** Passed through alumina before use.

2-Methyltetrahydrofuran *[96-47-9]* **M 86.1, b 80.0°, d_4^{20} 0.856, n_D^{20} 1.4053.** Likely impurities are 2-methylfuran, methyldihydrofurans and hydroquinone (stabiliser, which is removed by distn under reduced pressures). It was washed with 10% aqueous NaOH, dried, vacuum distd from CaH_2, passed through freshly activated alumina under nitrogen, and refluxed over sodium metal under vacuum. Stored over sodium. [Ling and Kevan *JPC* **80** 592 *1976*]. Vacuum distd from sodium, and stored with sodium-potassium alloy. (Treatment removes water and prevents the formation of peroxides.) Alternatively, it can be freed from peroxides by treatment with ferrous sulphate and sodium bisulphate, then solid KOH, followed by drying with, and distilling from, sodium, or type 4A molecular sieves under argon. It may be difficult to remove benzene if it is present as an impurity (can be readily detected by its ultraviolet absorption in the 249-268nm region). [Ichikawa and Yoshida *JPC* **88** 3199 *1984*]. It has also been purifed by percolating through Al_2O_3 and fractionated collecting fraction **b** 79.5-80°. After degassing, the material was distd onto degassed molecular sieves, then distd onto anthracene and a sodium mirror. The solvent was distd from the green soln onto potassium mirror or sodium-potassium alloy, from which it was distilled again. [Mohammad and Kosower *JACS* **93** 2713 *1971*]. It should be stored in the presence of 0.1% of hydroquinone as stabiliser. **Harmful vapours.**

***N*-Methylthioacetamide** *[5310-10-1]* **M 89.1, m 59°.** Recrystd from benzene.

3-(Methylthio)aniline see **3-methylmercaptoaniline.**

3-Methylthiophene *[616-44-4]* **M 98.2, b 111-113°, d 1.024, n 1.531.** Dried with Na_2SO_4, then distd from sodium.

6-Methyl-2-thiouracil *[56-04-2]* **M 142.2, m 330°(dec), 299-303° (dec), 323-324° (dec).** Crystd from a large volume of H_2O. Purified by dissolving in base adding charcoal, filtering and acidifying with AcOH. Suspend the wet solid (*ca* 100g) in boiling H_2O (1L), stir and add AcOH (20ml), stir and refrigerate. Collect the product, wash with cold H_2O (4 x 200ml), drain for several hours then place in an oven at 70° to constant weight. [IR: Short and Thompson *JCS* 168 *1952*; Foster and Snyder *Org Synth* Coll Vol IV 638 *1063*].

Methyl 4-toluenesulphonate *[80-48-8]* **M 186.2, m 25-28°, 28°, b 144.6-145.2°/5mm, 168-170°/13mm, d_4^{20} 1.23.** It is purified by distn *in vacuo* and could be crystd from pet ether or Et_2O-pet ether at low temperature. It is a powerful methylating agent and is **TOXIC** and a **skin irritant**, so it is better to purify by repeated distn. [IR: Schreiber *AC* **21** 1168 *1949*; Buehler et al. *JOC* **2** 167 *1937*; Roos et al. *Org Synth* Coll Vol I 145 *1948*].

17α-Methyltostesterone *[58-18-4]* **M 302.5, m 164-165°, $[\alpha]_{546}^{20}$ +87° (c 1, dioxane).** Crystd from hexane/benzene.

Methyltricaprylylammonium chloride see **aliquat 336.**

2-Methyltricycloquinazoline *[2642-52-6]* **M 334.4.** Purified by vac sublimation. **CARCINOGEN.**

Methyl trifluoromethanesulphonate (methyl triflate) *[333-27-7]* **M 164.1, b. 97-97.5°/736mm, 99°/atm, 100-102°/atm, d_4^{20} 1.496, n_D^{25} 1.3238.** Purified by fractional distn at atmospheric pressure in the absence of moisture. It is **POWERFUL ALKYLATING AGENT** and a strong **irritant.** [IR: Gramstad and Haszeldine *JCS* 173 *1956*, 4069 *1957*].

***N*-Methyltryptophan (L-abrine)** *[526-31-8]* **M 218.3, m 295°(dec), $[\alpha]_D^{21}$ +44.4° (c 2.8, 0.5M HCl).** Crystd from water.

***dl*-5-Methyltryptophan** *[951-55-3]* **M 218.3, m 275°(dec).** Crystd from aqueous EtOH.

6-Methyluracil *[626-48-2]* **M 126.1, m 270-280°(dec), λ_{max} 260$_{nm}$ logε 3.97.** Crystd from EtOH or acetic acid.

3-Methyluric acid *[39717-48-1]* **M 182.1, m >350°,**
7-Methyluric acid *[30409-21-3]* **M 182.1, m >380°,**
9-Methyluric acid *[30345-24-5]* **M 182.1, m >400°.** Crystd from water.

Methyl vinyl ketone *[78-94-4]* **M 70.1, b 62-68°/400mm, 79-80°/760mm, d 0.845, n 1.413.** Forms an 85% azeotrope with water. After drying with K_2CO_3 and $CaCl_2$ (with cooling), the ketone is distd at low pressures.

Methyl vinyl sulphone *[3680-02-2]* **M 106.1, b 116-118°/20mm, d 1.215, n 1.461.** Passed through a column of alumina, then degassed and distd on a vacuum line and stored at -190° until required.

Methyl Violet *[8004-87-3]* **M 394.0.** Crystd from absolute EtOH by pptn with ethyl ether during cooling in an ice-bath. Filtered off and dried at 105°.

Methyl Viologen Dichloride see ***N,N'*-dimethyl-4,4'-bipyridyl dichloride (paraquat dichloride).**

1-Methylxanthine *[6136-37-4]* **M 166.1, m >360°,**
3-Methylxanthine *[1076-22-5]* **M 166.1, m >360°,**
7-Methylxanthine *[552-62-5]* **M 166.1, m >380°(dec),**
8-Methylxanthine *[17338-96-4]* **M 166.1, m 292-293°(dec),**
9-Methylxanthine *[1198-33-0]* **M 166.1, m 384°(dec).** Crystd from water.

Metrazole *[56-95-5]* **M 138.2, m 61°.** Crystd from ethyl ether. Dried under vacuum over P_2O_5.

Mevalonic acid lactone,
Mevalonic acid 5-phosphate,
Mevalonic acid 5-pyrophosphate see Chapter 5.

Michler's ketone *[90-94-8]* **M 268.4, m 179°.** Dissolved in dilute HCl, filtered and ppted by adding ammonia (to remove water-insoluble impurities such as benzophenone). Then crystd from EtOH or pet ether. [Suppan *JCSFT1* **71** 539 *1975*]. It was also purified by dissolving in benzene, then washed with water until the aqueous phase was colourless. The benzene was evaporated off and the residue recrystd three times from benzene and EtOH [Hoshino and Kogure *JPC* **72** 417 *1988*].

Milling Red SWB *[6459-94-5]* **M 832.8,**
Milling Yellow G *[51569-18-7].* Salted out three times with sodium acetate, then repeatedly extracted with EtOH. [McGrew and Schneider *JACS* **72** 2547 *1950*]. See entry under Chlorazol Sky Blue FF.

Monensin *[17090-79-8]* **M 670.9.** Purified by chromatography.

Monobutyl urea *[592-31-4]* **M 116.2, m 96-98°,**
Monoethyl urea *[625-52-5]* **M 88.1, m 92-95°,**
Monomethyl urea *[598-50-5]* **M 74.1, m 93-95°.** Crystd from EtOH/water, then dried under vacuum at room temperature.

Monopropyl urea *[627-06-5]* **M 102.1, m 110°.** Crystd from EtOH.

Morin (hydrate) *[480-16-0]* **M 302.2, m 289-292°.** Stirred at room temperature with ten times its weight of absolute EtOH, then left overnight to settle. Filtered, and evaporated under a heat lamp to one-tenth its volume. An equal volume of water was added, and the ppted morin was filtered off, dissolved in the minimum amount of EtOH and again ppted with an equal volume of water. The ppte was filtered, washed with water and dried at 110° for 1h. (Yield *ca* 2.5%.) [Perkins and Kalkwarf *AC* **28** 1989 *1956*].

Morphine (H_2O) *[57-27-2]* **M 302.2, m 230°(dec), $[\alpha]_D^{23}$ -130.9° (MeOH).** Crystd from MeOH.

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Morpholine *[110-91-8]* **M 87.1, f.p. -4.9°, b 128.9°, d 1.0007, n 1.4540, n^{25} 1.4533.** Dried with KOH, fractionally distd, then refluxed with Na, and again fractionally distd. Dermer and Dermer [*JACS* **59** 1148 *1937*] ppted as the oxalate by adding slowly to slightly more than 1 molar equivalent of oxalic acid in EtOH. The ppte was filtered and recrystd twice from 60% EtOH. Addition of the oxalate to conc aq NaOH regenerated the base, which was separated and dried with solid KOH, then sodium, before being fractionally distd.

2-(*N*-Morpholino)ethanesulphonic acid (MES) *[4432-31-9]* **M 213.3, m >300°(dec).** Crystd from hot EtOH containing a little water. It has a basic pKa of 6.95.

Mucic acid see **galactaric acid.**

Mucochloric acid *[87-56-9]* **M 169.0, m 124-126°.** Crystd twice from water (charcoal).

***trans,trans*-Muconic acid** *[3588-17-8]* **M 142.1, m 300°,**
Muramic acid (H_2O) *[1114-41-6]* **M 251.2, m 152-154°(dec), $[\alpha]_D^{20}$ +155° to +110° (in H_2O).** Crystd from water.

Murexide *[3051-09-0]* **M 284.2, m >300°, λ_{max} 520nm (ε 12,000).** The sample may be grossly contaminated with uramil, alloxanthine, etc. Difficult to purify. It is better to synthesise it from pure alloxanthine [Davidson *JACS* **58** 1821 *1936*]. Crystd from water.

Myristic acid *[544-63-8]* **M 228.4, m 58°.** Purified *via* the *methyl ester* (**b** 153-154°/10mm, n^{25} 1.4350), as for capric acid. [Trachtman and Miller *JACS* **84** 4828 *1962*]. Also purified by zone melting. Crystd from pet ether.

Naphthacene (benz[b]anthracene, 2,3-benzanthracene, rubene) *[92-24-0]* M 228.3, m >300°, 341° (open capillary), 349°, 357°.

Crystd from EtOH or benzene. Dissolved in sodium-dried benzene and passed through a column of alumina. The benzene was evaporated under vacuum, and the chromatography was repeated using fresh benzene. Finally, the naphthacene was sublimed under vacuum. [Martin and Ubblehode *JCS* 4948 *1961*]. Also recrysts in orange needles from xylene and sublimes *in vacuo* at 186°. [UV: *B* **65** 517 *1932*, **69** 607 *1936*; IR: *Spectrochim Acta* **4** 373 *1951*].

2-Naphthaldehyde *[66-99-9]* **M 156.2, m 59°, b 260°/19mm.** Distilled with steam and crystd from water or EtOH.

Naphthalene *[91-20-3]* **M 128.2, m 80.3°, b 87.5°/10mm, 218.0°, d 1.0253, d^{100} 0.9625, n^{85} 1.5590.** Crystd one or more times from the following solvents: EtOH, MeOH, CCl_4, benzene, glacial acetic acid, acetone or ethyl ether, followed by drying at 60° in an Abderhalden drying apparatus. Also purified by vacuum sublimation and by fractional crystn from its melt. Other purification procedures include refluxing in EtOH over Raney Ni, and chromatography of a CCl_4 soln on alumina with benzene as eluting solvent. Baly and Tuck [*JCS* 1902 *1908*] purified naphthalene for spectroscopy by heating with conc H_2SO_4 and MnO_2, followed by steam distn (repeating the process), and formation of the picrate which, after recrystallisation, was decomposed and the naphthalene was steam distd. It was then crystd from dilute EtOH. It can be dried over P_2O_5 under vacuum. Also purified by sublimation and subsequent crystn from cyclohexane. Alternatively, it has been washed at 85° with 10% NaOH to remove phenols, with 50% NaOH to remove nitriles, with 10% H_2SO_4 to remove organic bases, and with 0.8g $AlCl_3$ to remove thianaphthalenes and various alkyl derivatives. Then it was treated with 20% H_2SO_4, 15% Na_2CO_3 and finally distd. [Gorman et al. *JACS* **107** 4404 *1985*].

Zone refining purified naphthalene from anthracene, 2,4-dinitrophenylhydrazine, methyl violet, benzoic acid, methyl red, chrysene, pentacene and indoline.

Naphthalene-2,5-disulphonic acid *[92-41-1]* **M 288.2.** Crystd from conc HCl.

Naphthalene Scarlet Red 4R *[2611-82-7]* **M 623.5.** Dissolved in the minimum quantity of boiling water, filtered and enough EtOH was added to ppte *ca* 80% of the dye. This process was repeated until a soln of the dye in aqueous 20% pyridine had a constant extinction coefficient.

Naphthalene-1-sulphonic acid *[85-47-2]* **M 208.2, m ($2H_2O$) 90°, (anhydrous) 139-140°.** Crystd from conc HCl and twice from water.

Naphthalene-2-sulphonic acid *[120-18-3]* **M 208.2, m 91°.** Crystd from conc HCl.

Naphthalene-1-sulphonyl chloride *[85-46-1]* **M 226.7, m 64-67°, 68°, b 147.5°/0.9mm, 147.5°/13mm.** If the IR indicates the presence of OH then treat with an equal weight of PCl_5 and heat at *ca* 100° for 3h, cool and pour into ice + H_2O, stir well and filter off the solid. Wash the solid with cold H_2O and dry the solid in a vacuum desiccator over P_2O_5 + solid KOH. Extract the solid with pet ether (b 40-60°) filter off any insoluble solid and cool. Collect the crystalline sulphonyl chloride and recryst from pet ether or C_6H_6 pet ether. If large quantities are available then it can be distd under high vacuum. [Fierz-Davaid and Weissenbach *HCA* **3** 2312 *1920*]. The *sulphonamide* has **m** 150° (from EtOH or H_2O).

Naphthalene-2-sulphonyl chloride *[93-11-8]* **M 226.7, m 74-76°, 78°, 79°, b 148°/0.6mm, 201°/13mm.** Crystd (twice) from benzene/pet ether (1:1 v/v). Purified as the 2-sulphonyl chloride. [Fierz-Davaid and Weissenbach *HCA* **3** 2312 *1920*]. The *sulphonamide* has **m** 217° (from EtOH).

Naphthalene-2-thiol *[91-60-1]* **M 160.2, m 81-82°.** Crystd from EtOH.

1,8-Naphthalic anhydride *[81-84-5]* **M 198.2, m 274°.** Extracted with cold aqueous Na_2CO_3 to remove free acid, then crystd from acetic anhydride.

Naphthamide *[2243-82-5]* **M 171.2, m 195°.** Crystd from EtOH.

Naphthazarin (5,8-dihydroxy-1,4-naphthoquinone) *[475-38-7]* **M 190.2, m ~ 220-230°(dec), m 225-230°.** Red-brown needles with a green reflex from EtOH. Also recrystd from hexane and purified by vacuum sublimation. [Huppert et al. *JPC* **89** 5811 *1985*]. It is sparingly soluble in H_2O but soluble in alkalis. It sublimes at 2-10mm. The *diacetate* forms golden yellow prisms from $CHCl_3$, **m** 192-193° and the *5,8-dimethoxy* derivative has **m** 157° (155°) (from pet ether) [Bruce and Thompson *JCS* 1089 *1955*; IR: Schmand and Boldt *JACS* **97** 447 *1975*; NMR: Brockmann and Zeeck *B* **101** 4221 *1968*]. The *monothiosemicarbazone* has **m** 168°(dec) from EtOH [Gardner et al. *JACS* 74 2106 *1952*].

Naphthionic acid (4-aminonaphthalene-1-sulphonic acid) *[84-86-6]* **M 223.3, m > 300°(dec).** It crystallises from H_2O as needles of the 0.5 hydrate . Salt solns fluoresce strongly blue. It has a pKa^{25} of 2.68 in H_2O.

α-Naphthoic acid *[86-55-5]* **M 172.2, m 162.5-163.0°.** Crystd from toluene (3ml/g) (charcoal), pet ether (b 80-100°), or aqueous 50% EtOH.

β-Naphthoic acid *[93-09-4]* **M 172.2, m 184-185°.** Crystd from EtOH (4ml/g), or aqueous 50% EtOH. Dried at 100°.

α–Naphthol *[90-15-3]* **M 144.2, m 95.5-96°.** Sublimed, then crystd from aqueous MeOH (charcoal), aq 25% or 50% EtOH, benzene, cyclohexane, heptane, CCl_4 or boiling water. Dried over P_2O_5 under vacuum. [Shizuka et al. *JACS* **107** 7816 *1985*].

β-Naphthol *[135-19-3]* **M 144.2, m 122.5-123.5°.** Crystd from aqueous 25% EtOH (charcoal), water, benzene, toluene or CCl_4, e.g. by repeated extraction with small amounts of EtOH, followed by dissolution in a minimum amount of EtOH and pptn with distilled water, then drying over P_2O_5 under vacuum. Has also been dissolved in aqueous NaOH, and ppted by adding acid (repeated several times), then ppted from benzene by addition of heptane. Final purification can be by zone melting or sublimation *in vacuo*. [Bardez et al. *JPC* **89** 5031 *1985*; Kikuchi et al. *JPC* **91** 574 *1987*].

Naphthol AS-D (3-hydroxy-2-naphthoic-*o*-toluide) *[135-61-5]* **M 277.3, m 1196-198°.** Purified by recrystn from xylene. Gives yellow-green fluorescent solutions at pH 8.2-9.5, [IR: Schnopper et al. *AC* **31** 1542 *1959*]. With AcCl *naphthol AS-D acetate* is obtained **m** 168-169°, and with chloroacetyl chloride *naphthol AS-D-chloroacetate* is obtained [Moloney et al. *J Histochem Cytochem* **8** 200 *1960*; Burstone *Arch Pathology* **63** 164 *1957*].

α-Naphtholbenzein *[6948-88-5]* **M 392.5, m 122-125°.** Crystd from EtOH, aqueous EtOH or glacial acetic acid.

1-Naphthol-2-carboxylic acid *[86-48-6]* **M 188.2, m 203-204°.** Successively crystd from EtOH/water, ethyl ether and acetonitrile, with filtration through a column of charcoal and Celite. [Tong and Glesmann *JACS* **79** 583 *1957*].

2-Naphthol-3-carboxylic acid *[92-70-6]* **M 188.2, m 222-223°.** Crystd from water or acetic acid.

Naphthol Yellow S (citronin A, flavianic acid sodium salt, 8-hydroxy-5,7-dinitro-2-naphthalene sulphonic acid disodium salt) *[846-70-8]* **M 358.2, dec on heating.** Greenish yellow powder soluble in H_2O. The *free sulphonic acid* can be recrystd from dil HCl (**m** 150°) or AcOH-EtOAc (**m** 148-149.5°). The disodium salt is then obtained by dissolving the acid in two equivalentss of aqueous NaOH and evaporating to dryness and drying the residue in a vacuum desiccator. The sodium salt can be recrystd from the minimum volume of H_2O or from EtOH [Dermer and Dermer *JACS* **61** 3302 *1939*].

1,2-Naphthoquinone *[524-42-5]* **M 158.2, m 140-142°(dec).** Crystd from ether (red needles) or benzene (orange leaflets).

1,4-Naphthoquinone *[130-15-4]* **M 158.2, m 125-125.5°.** Crystd from ethyl ether (charcoal). Steam distd. Crystd from benzene or aqueous EtOH. Sublimed in a vacuum.

1,2-Naphthoquinone-4-sulphonic acid sodium salt see **3,4-dihydro-3,4-dioxo-1-naphthlene sulphonic acid sodium salt.**

β-Naphthoxyacetic acid *[120-23-0]* **M 202.2, m 156°.** Crystd from hot water or benzene.

β-Naphthoyltrifluoroacetone *[893-33-4]* **M 254.1.** Crystd from EtOH.

Naphthvalene *[34305-47-0]* **M 104.1.** Purified by chromatography on alumina and eluting with pentane [Abelt et al. *JACS* **107** 4148 *1985*].

1-Naphthyl acetate *[830-81-9]* **M 186.2, m 45-46°.** Chromatographed on silica gel.

2-Naphthyl acetate *[1523-11-1]* **M 186.2, m 71°.** Crystd from pet ether (b 60-80°) or dilute aq EtOH.

1-Naphthylacetic acid *[86-87-3]* **M 186.2, m 132°.** Crystd from EtOH or water.

2-Naphthylacetic acid *[581-96-4]* **M 186.2, m 143.1-143.4°.** Crystd from water or benzene.

α-Naphthylamine *[134-32-7]* **M 143.2, m 50.8-51.2°, b 160°.** Sublimed at 120° in a stream of nitrogen, then crystd from pet ether (b 60-80°), or abs EtOH then ethyl ether. Dried under vacuum in an

Abderhalden pistol. Has also been purified by crystn of its hydrochloride from water, followed by liberation of the free base and distn; finally purified by zone melting. **CARCINOGEN.**

β-Naphthylamine *[91-59-8]* **M 143.2, m 113°.** Sublimed at 180° in a stream of nitrogen. Crystd from hot water or benzene. Dried under vacuum in an Abderhalden pistol. **CARCINOGEN.**

α-Naphthylamine hydrochloride *[552-46-5]* **M 179.7.** Crystd from water (charcoal).

1-Naphthylamine-4-sulphonic acid *[84-86-6]* **M 223.3, m >300°(dec),**
1-Naphthylamine-5-sulphonic acid *[84-89-9]* **M 223.3,**
2-Naphthylamine-1-sulphonic acid *[81-16-3]* **M 223.3.** Crystd under nitrogen from boiling water and dried in a steam oven.

2-Naphthylamine-6-sulphonic acid *[93-00-5]* **M 223.3.** Crystd from a large volume of hot water.

***R*-(+)-** *[42177-25-3]* **and *S*-(-)-** *[15914-84]* **1-(1-Naphthyl) ethanol M, 172.2, m 46°, 45-47.5°, 48°, $[\alpha]_{546}^{20}$ ±94°, $[\alpha]_{D}^{20}$±78° (c 1, MeOH).** Purified by recrystn from Et_2O-pet ether, Et_2O, hexane [Balfe et al. *JCS* 797 *1946*; IR, NMR: Theisen and Heathcock *JOC* 53 2374 *1988*; see also Fredga et al. *Acta Chem Scand* **11** 1609 *1957*]. The *RS-alcohol [57605-95-5]* has **m** 63-65,°, 65-66° from hexane.

***R*-(+)-** *[3886-70-2]* **and *S*-(-)-** *[10420-89-0]* **1-(1-Naphthyl)ethylamine, M 171.2, b 153°/11mm, d_4^{20} 1.067, n_D^{20} 1.624, $[\alpha]_{546}^{20}$ ±65°, $[\alpha]_{D}^{20}$±55° (c 2, MeOH); $[\alpha]_{D}^{17}$±82.8° (neat).** Purified by distn in a good vacuum. [Mori et al. *TET* **37** 1343 *1981*; cf Wilson in *Topics in Stereochemistry* (Allinger and Eliel eds) **vol 6** 135 *1971*; Fredga et al. *Acta Chem Scand* **11** 1609 *1957*]. The *hydrochlorides* crystallises from H_2O $[\alpha]_{D}^{18}$±3.9° (c 3, H_2O) and the *sulphates* recrystallises from H_2O as *tetrahydrates* **m** 230-232°. The *RS-amine* has **b** 153°/11mm, 156°/15mm, 183.5°/41mm [Blicke and Maxwell *JACS* **61** 1780 *1939*].

2-Naphthylethylene *[827-54-3]* **M 154.2, m 66°, b 95-96°/2.1mm, 135-137°/18mm.** Crystd from aqueous EtOH.

***N*-(α-Naphthyl)ethylenediamine dihydrochloride** *[1465-25-4]* **M 291.2, m 188-190°.** Crystd from water.

1-Naphthyl isocyanate *[30135-65-0]* **M 169.2, m 3-5°, b 269-270°/atm., d_4^{20} 1.18.** Distd at atmospheric pressure or in a vacuum. Can be crystd from pet ether (b 60-70°) at low temperature. *It has a pungent odour, is* **TOXIC** *and is absorbed through the skin.*

1-Naphthyl isothiocyanate *[551-06-4]* **M 185.3, m 58-59°.** Crystd from hexane (1g in 9 ml). White needles soluble in most organic solvents but is insoluble in H_2O. *It is absorbed through the skin and may cause dermatitis.* [*Org Synth* Col.Vol. IV 700 *1963*].

β-Naphthyl lactate *[93-43-6]* **M 216.2.** Crystd from EtOH.

Naphthyl methyl ether see **methoxynaphthalene.**

2-(ß-Naphthyloxy)ethanol *[93-20-9]* **M 188.2, m 76.7°.** Crystd from benzene/pet ether.

***N*-1-Naphthylphthalamic acid** *[132-66-1]* **M 291.3, m 203°.** Crystd from EtOH.

β-Naphthyl salicyclate *[613-78-5]* **M 264.3, m 95°,**
α-Naphthyl thiourea *[86-88-4]* **M 202.2.** Crystd from EtOH.

1-Naphthyl urea *[6950-84-1]* **M 186.2, m 215-220°,**
2-Naphthyl urea *[13114-62-0]* **M 186.2, m 219-220°.** Crystd from EtOH.

1,5-Naphthyridine *[254-79-5]* **M 130.1, m 75°, b 112°/15mm.** Purified by repeated sublimation.

Narcein *[131-28-2]* **M 445.4, m 176-177° (145° anhydrous).** Crystd from water (as trihydrate).

Narigenine *[480-41-1]* **M 272.3, m 251°.** Crystd from aqueous EtOH.

Naringin *[10236047-2]* **M 580.5, m 171° ($2H_2O$), $[a]_D^{19}$ -90° (c 1, EtOH), $[a]_{546}^{20}$ -107° (c 1, EtOH).** Crystd from water. Dried at 110°(to give the dihydrate).

Neopentane (2,2-dimethylpropane) *[463-82-1]* **M 72.2, b 79.3°, d 0.6737, n 1.38273.** Purified from isobutene by passage over conc H_2SO_4 or P_2O_5, and through silica gel.

Neopentyl glycol see **2,2-dimethyl-1,3-propanol.**

D(+)-Neopterin see entry in Chapter 5.

Neostigmine bromide *[114-80-7]* **M 303.2, m 176°(dec).** Crystd from EtOH/ethyl ether. (*Highly* **TOXIC**).

Neostigmine methyl sulphate *[51-60-5]* **M 334.4, m 142-145°.** Crystd from EtOH. (*Highly* **TOXIC**].

Nerolidol *[142-50-7]* **M 222.4, m of semicarbazide 134-135°.** Purified by thin layer chromatography on plates of kieselguhr G [McSweeney *JC* **17** 183 *1965*] or silica gel plates impregnated with $AgNO_3$, using 1,2-dichloromethane/$CHCl_3$/ethyl acetate/propanol (10:10:1:1) as solvent system. Also by gas/liquid chromatography on butanediol succinate (20%) on Chromosorb W. Stored in a cool place, in an inert atmosphere, in the dark.

Neutral Red (Basic Red 5, CI 50040) *[553-24-2]* **M 288.8, m 290°(dec).** Crystd from benzene/MeOH (1:1).

New Methylene Blue N (CI 927) *[6586-05-6]* **M 416.1.** Crystd from benzene/MeOH (3:1).

Nicotinaldehyde thiosemicarbazone *[3608-75-1]* **M 180.2, m 222-223°.** Crystd from water.

Nicotinamide *[98-92-0]* **M 122.1, m 128-131°.** Crystd from benzene.

Nicotinic acid (niacin) *[59-67-6]* **M 123.1, m 232-234°.** Crystd from benzene.

Nicotinic acid hydrazide *[553-53-7]* **M 137.1, m 158-159°.** Crystd from aqueous EtOH or benzene.

Nile Blue A *[3625-57-8]* **M 415.5, m 138°(dec).** Crystd from pet ether.

Ninhydrin *[485-47-2]* **M 178.1, m 241-243°(dec).** Crystd from hot water (charcoal). Dried under vacuum and stored in a sealed brown container.

Nioxime see **cyclohexanedione dioxime.**

Nitrioltriacetatic acid *[139-13-9]* **M 191.1, m 247°(dec).** Crystd from water. Dried at 110°.

2,2',2"-Nitrilotriethanol hydrochloride see **triethanolamine hydrochloride.**

2-Nitroacetanilide *[552-32-9]* **M 180.2, m 93-94°.** Crystd from water.

4-Nitroacetanilide *[104-04-1]* **M 180.2, m 217°.** Ppted from 80% H_2SO_4 by adding ice, then washed with water, and crystd from EtOH. Dried in air.

3-Nitroacetophenone *[121-89-1]* **M 165.2, m 81°, b 167°/18mm, 202°/760mm.** Distilled in steam and crystd from EtOH.

4-Nitroacetophenone *[100-19-6]* **M 165.2, m 80-81°, b 145-152°/760mm.** Crystd from EtOH or aqueous EtOH.

3-Nitroalizarin *[568-93-4]* **M 285.2, m 244°(dec).** Crystd from acetic acid.

o-**Nitroaniline** *[88-74-4]* **M 138.1, m 72.5-73.0°.** Crystd from hot water (charcoal), then crystd from water, aqueous 50% EtOH, or EtOH, and dried in a vacuum desiccator. Has also been chromatographed on alumina, then recrystd from benzene.

m-**Nitroaniline** *[99-09-2]* **M 138.1, m 114°.** Purified as for *o*-nitroaniline. **Warning: it is absorbed through the skin.**

p-**Nitroaniline** *[100-01-6]* **M 138.1, m 148-148.5°.** Purified as for *o*-nitroaniline. Also crystd from acetone. Freed from *o*- and *m*-isomers by zone melting and sublimation.

o-**Nitroanisole** *[91-23-6]* **M 153.1, f.p. 9.4°, b 265°/737mm, d 1.251, n 1.563.** Purified by repeated vacuum distn in the absence of oxygen.

p-**Nitroanisole** *[100-17-4]* **M 153.1, m 54°.** Crystd from pet ether or hexane and dried *in vacuo*.

9-Nitroanthracene *[602-60-8]* **M 223.2, m 142-143°.** Purified by recrystn from EtOH or MeOH. Further purified by sublimation or TLC.

5-Nitrobarbituric acid *[480-68-2]* **M 173.1, m 176°.** Crystd from water.

o-**Nitrobenzaldehyde** *[552-89-6]* **M 151.1, m 44-45°, b 120-144°/3-6mm.** Crystd from toluene (2-2.5ml/g) by addition of pet ether (b 40-60°)(7ml/ml of soln). Can also be distd at reduced pressures.

m-**Nitrobenzaldehyde** *[99-61-6]* **M 151.1, m 58°,**
p-**Nitrobenzaldehyde** *[555-16-8]* **M 151.1, m 106°.** Crystd from water or EtOH/water, then sublimed twice at 2mm pressure at a temperature slightly above its melting point.

Nitrobenzene *[98-95-3]* **M 123.1, f.p. 5.8°, b 84-86.5°/6.5-8mm, 210.8°/760mm, d 1.206, n^{15} 1.55457, n 1.55257.** Common impurities include nitrotoluene, dinitrothiophene, dinitrobenzene and aniline. Most impurities can be removed by steam distn in the presence of dilute H_2SO_4, followed by drying with $CaCl_2$, and shaking with, then distilling at low pressure from BaO, P_2O_5, $AlCl_3$ or activated alumina. It can also be purified by fractional crystn from absolute EtOH (by refrigeration). Another purification process includes extraction with aqueous 2M NaOH, then water, dilute HCl, and water, followed by drying ($CaCl_2$, $MgSO_4$ or $CaSO_4$) and fractional distn under reduced pressure. The pure material is stored in a brown bottle, in contact with silica gel or CaH_2. It is very *hygroscopic*.

4-Nitrobenzene-azo-resorcinol (magneson II) *[74-39-5]* **M 259.2, m 199-200°.** Crystd from EtOH.

4-Nitrobenzhydrazide *[606-26-8]* **M 181.1, m 213-214°.** Crystd from EtOH.

4'-Nitrobenzo-15-crown-5 *[6083569-0]* **M 313.3, m 84-85°, 93-95°.** Recrystd from EtOH, MeOH or C_6H_6-hexane as for the 18-crown-6 compound below. It complexes with Na^+, K^+, NH_4^+, Ca^{2+}, Mg^{2+} and Cd^{2+}. NMR ($CDCl_3$) has δ: 3.6-4.4 (m $16CH_2$), 6.8 (d 1H arom), 7.65 (d 1H arom), 7,80 (dd 1H arom J_{ab}

9Hz and J_{bc} 3Hz) ppm [Shmid et al. *JACS* **98** 5198 *1976*; Kikukawa et al. *Bull Chem Soc Japan* **50** 2207 *1977*; Toke et al. *A* **349** 349, 761 *1988*; Lindner et al. *Z Anal Chem* **322** 157 *1985*].

4'-Nitrobenzo-18-crown-6 *[53408-96-1]* **M 357.4, m 83-84°, 83-84°.** If impure and discoloured then chromatograph on Al_2O_3 and eluting with C_6H_6 (1:1) with 1% MeOH added. The fractions are followed by TLC on Al_2O_3 (using detection with Gragendorff's reagent R_F 0.6 in the above solvent system). Recrystallise the residues from the fractions containing the product from C_6H_6-hexane to give yellowish leaflets. It complexes with Na or K ions with $\log K_{Na}$ 3.95 and $\log K_K$ 4.71. [Petranek and Ryba *Coll Chem Czech Chem Commun* **39** 2033 *1974*].

2-Nitrobenzoic acid *[552-16-9]* **M 167.1, m 146-148°.** Crystd from benzene (twice), *n*-butyl ether (twice), then water (twice). Dried and stored in a vacuum desiccator. [Le Noble and Wheland *JACS* **80 5397** *1958*]. Has also been crystd from EtOH/water.

3-Nitrobenzoic acid *[121-92-6]* **M 167.1, m 143-143.5°,**
4-Nitrobenzoic acid *[62-23-7]* **M 167.1, m 241-242°.** Crystd from benzene, water, EtOH (charcoal), glacial acetic acid or MeOH/water. Dried and stored in a vacuum desiccator.

4-Nitrobenzoyl chloride *[122-04-3]* **M 185.6, m 75°. b 155°/20mm.** Crystd from dry pet ether (b 60-80°) or CCl_4. Distilled under vacuum. **Irritant.**

4-Nitrobenzyl alcohol *[619-73-8]* **M 153.1, m 93°.** Crystd from EtOH and sublimed in a vacuum. Purity should be at least 99.5%. Sublimed samples should be stored in the dark over anhydrous $CaSO_4$ (Drierite). It the IR contains OH bands then the sample should be resublimed before use. {Mohammed and Kosower *JACS* **93** 2709 *1979*].

4-Nitrobenzyl bromide *[100-11-8]* **M 216.0, m 98.5-99.0°.** Recrystd four times from abs EtOH, then twice from cyclohexane/hexane/benzene (1:1:1), followed by vac sublimation at 0.1mm and a final recrystn from the same solvent mixture. [Lichtin and Rao *JACS* **83** 2417 *1961*]. Has also been crystd from pet ether (b 80-100°, 10ml/g, charcoal). It slowly decomposes even when stored in a desiccator in the dark. **Irritant.**

m-**Nitrobenzyl chloride** *[619-23-8]* **M 171.6, m 45°.** Crystd from pet ether (b 90-120°). **Irritant**.

p-**Nitrobenzyl chloride** *[100-14-1]* **M 171.6, m 72.5-73°.** Crystd from CCl_4, dry ethyl ether, 95% EtOH or *n*-heptane, and dried under vacuum. **Irritant**.

p-**Nitrobenzyl cyanide** *[555-21-5]* **M 162.2, m 117°.** Crystd from EtOH. **TOXIC**.

4-(4-Nitrobenzyl)pyridine *[1083-48-3]* **M 214.2, m 70-71°.** Crystd from cyclohexane.

2-Nitrobiphenyl *[86-00-0]* **M 199.2, m 36.7°.** Crystd from EtOH (seeding required). Sublimed under vacuum.

3-Nitrocinnamic acid *[555-68-0]* **M 193.2, m 200-201°.** Crystd from benzene or EtOH.

4-Nitrocinnamic acid *[619-89-6]* **M 193.2, m 143° (*cis*), 286°(*trans*).** Crystd from water.

N-**Nitrosodiethanolamine** *[1116-54-7]* **M 134.4.** Purified by dissolving the amine (0.5g) in 1-propanol (10ml) and 5g of anhydrous Na_2SO_4 added with stirring. After standing for 1-2h, it was filtered and passed through a chromatographic column packed with AG 50W x 8 (H^+form, a strongly acidic cation exchanger). The eluent and washings were combined and evapd to dryness at 35°. [Fukuda et al. *AC* **53** 2000 *1981*]. *Possible* **CARCINOGEN.**

4-Nitrodiphenylamine *[836-30-6]* **M 214.2, m 133-134°.** Crystd from EtOH.

2-Nitrodiphenyl ether *[2216-12-8]* **M 215.2, b 106-108°/0.01mm, 137-138°/0.5mm, 161-162°/4mm, 188-189°/12mm, 195-200°/25mm, d_4^{20} 1.241, n_D^{25} 1.600.** Purified by fractional distn. UV (EtOH): 255, 315mm (ε 6200 and 2800); IR (CS_2): 1350 (NO_2) and 1245, 1265 (COC) cm^{-1} [UV, IR: Dahlgard and Brewster *JACS* **80** 5861 *1958*; Tomita and Takase *J Pharm Soc Japan* **75** 1077 *1955*; Fox and Turner *JCS* 1115 *1930*, Henley *JCS* 1222 *1930*].

Nitrodurene *[38899-21-7]* **M 179.2, m 53-55°, b 143-144°/10mm.** Crystd from EtOH, MeOH, acetic acid, pet ether or chloroform.

Nitroethane *[79-24-3]* **M 75.1, b 115°, d 1.049, n 1.3920, n^{25} 1.39015.** Purified as described for *nitromethane*. A spectroscopic impurity has been removed by shaking with activated alumina, decanting and rapidly distilling.

2-Nitrofluorene *[607-57-8]* **M 211.2, m 156°.** Crystd from aqueous acetic acid.

Nitroguanine *[556-88-7]* **M 104.1, m 232°(dec).** Crystd from water (20ml/g).

5-Nitroindole *[6146-52-7]* **M 162.1, m 141-142°.** Decolorised (charcoal) and recrystd twice from aqueous EtOH.

Nitromesitylene *[603-71-4]* **M 165.2, m 44°, b 255°.** Crystd from EtOH.

Nitromethane *[75-52-5]* **M 61.0, f.p. -28.5°, b 101.3°, d 1.13749, d^{30} 1.12398, n 1.3819, n^{30} 1.37730.** Nitromethane is generally manufactured by gas-phase nitration of methane. The usual impurities include aldehydes, nitroethane, water and small amounts of alcohols. Most of these can be removed by drying with $CaCl_2$ or by distn to remove the water/nitromethane azeotrope, followed by drying with $CaSO_4$. Phosphorus pentoxide is not suitable as a drying agent. [Wright et al. *JCS* 199 *1936*]. The purified material should be stored by dark bottles, away from strong light, in a cool place. Purifications using extraction are commonly used. For example, Van Looy and Hammett [*JACS* **81** 3872 *1959*] mixed about 150ml of conc H_2SO_4 with 1L of nitromethane and allowed it to stand for 1 or 2days. The solvent was washed with water, aqueous Na_2CO_3, and again with water, then dried for several days with $MgSO_4$, filtered again with $CaSO_4$. It was fractionally distd before use. Smith, Fainberg and Winstein [*JACS* **83** 618 *1961*] washed successively with aqueous $NaHCO_3$, aqueous $NaHSO_3$, water, 5% H_2SO_4, water and dilute $NaHCO_3$. The solvent was dried with $CaSO_4$, then percolated through a column of Linde type 4A molecular sieves, followed by distn from some of this material (in powdered form). Buffagni and Dunn [*JCS* 5105 *1961*] refluxed for 24h with activated charcoal while bubbling a stream of nitrogen through the liquid. The suspension was filtered, dried (Na_2SO_4) and distd, then passed through an alumina column and redistd. It has also been refluxed over CaH_2, distd and kept under argon over 4A molecular sieves.
Can be purified by zone melting or by distn under vacuum at 0°, subjecting the middle fraction to several freeze-pump-thaw cycles. An impure sample containing higher nitroalkanes and traces of cyanoalkanes was purified (on the basis of its NMR spectrum) by crystn from ethyl ether at -60° (cooling in Dry-ice)[Parrett and Sun *J Chem Educ* **54** 448 *1977*].
Fractional crystn was more effective than fractional distn from Drierite in purifying nitromethane for conductivity measurements. [Coetzee and Cunningham *JACS* **87** 2529 *1965*]. Specific conductivities around 5 x 10^{-9} $ohm^{-1}cm^{-1}$ were obtained.

Nitron *[487-88-7]* **M 312.4, m 189°(dec).** Crystd from EtOH or chloroform.

1-Nitronaphthalene *[86-57-7]* **M 173.2, m 57.3-58.3°, b 30-40°/0.01mm.** Fractionally distd under reduced pressure, then crystd from EtOH, aqueous EtOH or heptane. Chromatographed on alumina from benzene/pet ether. Sublimes *in vacuo*.

2-Nitronaphthalene *[581-89-5]* **M 173.2, m 79°, b 165°/15mm.** Crystd from aqueous EtOH and sublimed in a vacuum.

1-Nitro-2-naphthol *[550-60-7]* **M 189.2, m 103°.** Crystd (repeatedly) from benzene/pet ether (b 60-80°)(1:1).

2-Nitro-1-naphthol *[607-24-9]* **M 189.2, m 127-128°.** Crystd (repeatedly) from EtOH.

5-Nitro-1,10-phenanthroline *[4199-88-6]* **M 225.2, m 197-198°.** Crystd from benzene/pet ether, until anhydrous.

2-Nitrophenol *[88-75-5]* **M 139.1, m 44.5-45.5°.** Crystd from EtOH/water, water, EtOH, benzene or MeOH/pet ether (b 70-90°). Can be steam distd. Petrucci and Weygandt [*AC* **33** 275 *1961*] crystd from hot water (twice), then EtOH (twice), followed by fractional crystn from the melt (twice), drying over $CaCl_2$ in a vacuum desiccator and then in an Abderhalden drying pistol.

3-Nitrophenol *[554-84-7]* **M 139.1, m 96°, b 160-165°/12mm.** Crystd from water, $CHCl_3$, CS_2, EtOH or pet ether (b 80-100°), and dried under vacuum over P_2O_5 at room temperature. Can also be distd at low pressure.

4-Nitrophenol *[100-02-7]* **M 139.1, m 113-114°.** Crystd from water (which may be acidified, e.g. *N* H_2SO_4 or 0.5*N* HCl), EtOH, aqueous MeOH, $CHCl_3$, benzene or pet ether, then dried under vacuum over P_2O_5 at room temperature. Can be sublimed at 60°/10^{-4}mm.

2-Nitrophenoxyacetic acid *[1878-87-1]* **M 197.2, m 150-159°.** Crystd from water.

p-**Nitrophenyl acetate** *[830-03-5]* **M 181.2.** Recrystd from absolute EtOH [Moss et al. *JACS* **108** 5520 *1986*].

3-Nitrophenylacetic acid *[3740-52-1]* **M 181.2, m 120°.** Crystd from EtOH/water.

4-Nitrophenylacetic acid *[104-03-0]* **M 181.2, m 80.5°.** Crystd from EtOH/water (1:1), then from sodium-dried ethyl ether and dried over P_2O_5 under vacuum.

4-Nitrophenylacetonitrile *[555-21-5]* **M 162.2, m 116-117°.** Crystd from EtOH.

4-(4-Nitrophenylazo)resorcinol see **4-nitrobenzene-azo-resorcinol.**

4-Nitro-1,2-phenylenediamine *[99-56-9]* **M 153.1, m 201°.** Crystd from water.

***R*-(+)-** *[57233-86-0]* **and *S*-(-)-** *[132873-57-5]* **1-(4-Nitrophenyl)ethylamine hydrochloride M 202.6. m 225°, 240-242° (dec), 243-245° (dec), 248-250°, $[\alpha]_D^{20}$ ±72° (c 1, 0.05 M NaOH), ± 0.3° (H_2O).** To ensure dryness the hydrochloride (*ca* 175 g) is extracted with EtOH (3 X 100ml) and evaporated to dryness (any residual H_2O increases the solubility in EtOH and lowers the yield). The hydrochloride residue is triturated with absolute EtOH and dried *in vacuo*. The product is further purified by refluxing with absolute EtOH (200 ml for 83g) for 1h, cool to 10° to give 76.6g of hydrochloride **m** 243-245° (dec). The *free base* is prepd by dissolving in N NaOH, extract with CH_2Cl_2 (3 x 500ml), dry (Na_2CO_3), filter, evaporate and distil, **b** 119-120°/0.5mm (105-107°/0.5mm, 157-159°/9mm, d_4^{20} 1.1764, n_D^{20} 1.5688, $[\alpha]_D^{24}$ ±17.7° (neat)[Perry et al. *S* 492 *1977*; ORD: Nerdel and Liebig *A* **621** 142 *1959*].

4-Nitrophenylhydrazine *[100-16-3]* **M 153.1, m 158°(dec).** Crystd from EtOH.

3-Nitrophenyl isocyanate *[3320-87-4]* **M 164.1, m 52-54°,**
4-Nitrophenyl isocyanate *[100-28-7]* **M 164.1, m 53°.** Crystd from pet ether (b 28-38°).

4-Nitrophenyl trifluoroacetate *[4195-17-9]* **M 223.2, m 93-95°.** Recrystd from $CHCl_3$/hexane [Margolis et al. *JBC* **253** 7891 *1078*].

2-Nitrophenylpropiolic acid *[16619-65-1]* **M 191.1, m 157°(dec).** Crystd from water.

4-Nitrophenyl urea *[556-10-5]* **M 181.2, m 238°.** Crystd from EtOH and hot water.

3-Nitrophthalic acid *[603-11-2]* **M 211.1, m 216-218°.** Crystd from hot water (1.5ml/g). Air dried.

4-Nitrophthalic acid *[610-27-5]* **M 211.1, m 165°.** Crystd from ether or ethyl acetate.

3-Nitrophthalic anhydride *[641-70-3]* **M 193.1, m 164°.** Crystd from benzene, benzene/pet ether, acetic actic or acetone. Dried at 100°.

1-Nitropropane *[108-03-2]* **M 89.1, b 131.4°, d 1.004, n 1.40161, n^{25} 1.39936,**
2-Nitropropane *[79-46-9]* **M 89.1, b 120.3°, d 0.989, n 1.3949, n^{25} 1.39206.** Purified as *nitromethane.*

5-Nitro-2-*n*-propoxyaniline *[553-79-7]* **M 196.2, m 47.5-48.5°.** Crystd from *n*-propyl alcohol/pet ether.

5-Nitroquinoline *[607-34-1]* **M 174.2, m 70°.** Crystd from pentane, then from benzene.

8-Nitroquinoline *[706-35-2]* **M 174.2, m 88-89°.** Crystd from hot water, MeOH, EtOH or EtOH/ethyl ether (3:1).

4-Nitroquinoline 1-oxide *[56-57-5]* **M 190.2, m 157°.** Recrystd from aqueous acetone [Seki et al. *JPC* **91** 126 *1987*].

2-Nitroresorcinol *[601-89-8]* **M 155.1, m 81-81°.** Crystd from aqueous EtOH.

4-Nitrosalicylic acid *[619-19-1]* **M 183.1, m 277-288°.** Crystd from water.

5-Nitrosalicylic acid *[96-97-9]* **M 183.1, m 233°.** Crystd from acetone (charcoal), then twice more from acetone alone.

***N*-Nitrosodiphenylamine** *[156-10-5]* **M 198.2, m 144-145°(dec).** Crystd from benzene.

1-Nitroso-2-naphthol *[131-91-9]* **M 173.2, m 110.4-110.8°.** Crystd from pet ether (b 60-80°, 7.5ml/g).

2-Nitroso-1-naphthol *[132-53-6]* **M 173.2, m 158°(dec).** Purified by recrystn from pet ether (b 60-80°) or by dissolving in hot EtOH, followed by successive addition of small volumes of water.

4-Nitroso-1-naphthol *[605-60-7]* **M 173.2, m 198°.** Crystd from benzene.

2-Nitroso-1-naphthol-4-sulphonic acid ($3H_2O$) *[3682-32-4]* **M 316.3, m 142-146°(dec).** Crystd from dilute HCl soln. Crystals were dried over $CaCl_2$ in a vacuum desiccator. Also purified by dissolution in aqueous alkali and pptn by addition of water.

4-Nitrosophenol *[104-91-6]* **M 123.1, m >124°(dec).** Crystd from xylene.

***N*-Nitroso-*N*-phenylbenzylamine** *[612-98-6]* **M 212.2, m 58°.** Crystd from absolute EtOH and dried in air.

β-Nitrostyrene *[102-96-5]* **M 149.2, m 60°.** Crystd from absolute EtOH, or three times from benzene/pet ether (b 60-80°) (1:1).

4-Nitrostyrene *[100-13-0]* **M 149.2, m 20.5-21°.** Crystd from $CHCl_3$/hexane. Purified by addition of MeOH to ppte the polymer, then crystd at -40° from MeOH. Also crystd from EtOH. [Bernasconi et al. *JACS* **108** 4541 *1986*].

2-Nitro-4-sulphobenzoic acid *[552-23-8]* **M 247.1, m 111°.** Crystd from dilute HCl.

2-Nitrotoluene *[88-72-2]* **M 137.1, m -9.55° (α-form), -3.85° (β-form), b 118°/16mm, d 1.163, 222.3°/760mm, n 1.545.** Crystd (repeatedly) from absolute EtOH by cooling in a Dry-ice/alcohol mixture, Further purified by passage of an alcoholic soln through a column of alumina.

3-Nitrotoluene *[99-08-1]* **M 137.1, m 16°, b 113-114°/15mm, 232.6°, d 1.156, n 1.544.** Dried with P_2O_5 for 24h, then fractionally distd under reduced pressure. [*Org. Synth* Vol I 416 *1948*].

4-Nitrotoluene *[99-89-0]* **M 137.1, m 52°.** Crystd from EtOH, MeOH/water, EtOH/water (1:1) or MeOH. Air dried, then dried in a vac desiccator over H_2SO_4. [Wright and Grilliom *JACS* **108** 2340 *1986*].

5-Nitrouracil (2,4-dihydroxy-5-nitropyrimidine) *[611-08-5]* **M 157.1, m 280-285°**, >300°. Recrystallises as prisms from boiling H_2O as the monohydrate and loses H_2O on drying *in vacuo*. It has pKa^{20} values of 0.03, 5.55 and 11.3 in H_2O [UV: Brown *JCS* 3647 *1959*; Brown *J Appl Chem* **2** 239 *1952*; Johnson *JACS* **63** 263 *1941*].

Nitrourea *[556-89-8]* **M 105.1, m 158.4-158.8°(dec).** Crystd from EtOH/pet ether.

5-Nitrovanillin (nitroveratric aldehyde) *[6635-20-7]* **M 197.2, m 172-175°, 176°, 178°.** Forms yellow plates from AcOH, and needles from EtOH [Slotta and Szyszke *B* **68** 184 *1935*]. With diazomethane, 5-nitro-3,4-dimethoxyacetophenone is formed [Brady and Manjunath *JCS* **125** ***1067*** **1924**]. The *methyl ether* crystallises from EtOAc or AcOH, **m** 88°, 90-91°, and the *phenylhydrazone* has **m** 108-110° (from aqueous EtOH). [Finger and Schott *J Prakt Chem* [2] **115** 288 *1927*]. For *oxime* **m** 216° (from EtOH or AcOH) and the *oxime -acetate* has **m** 147° (from aq EtOH) [Vogel *M* **20** 384 *1899*; Brady and Dunn *JCS* **107** 1861 *1915*].

Nonactin *[6833-84-7]* **M 737.0, m 147-148°, $[\alpha]_D^{20}$ 0 ±2° (c 1.2, $CHCl_3$).** Crystd from MeOH as colourless needles, and dries at 90°/20h/high vacuum. [*HCA* **38** 1445 *1955*, **55** 1371 *1972*; *TET LETT* 3391 *1975*].

***n*-Nonane** *[111-84-2]* **M 126.3, b 150.8°, d 0.719, n 1.40542, n^{25} 1.40311.** Fractionally distd, then stirred with successive volumes of conc H_2SO_4 for 12h each until no further colouration was observed in the acid layer. Then washed with water, dried with $MgSO_4$ and fractionally distd. Alternatively, it was purified by azeotropic distn with 2-ethoxyethanol, followed by washing out the alcohol with water, drying and distilling. [Forziati et al. *J Res Nat Bur Stand* **36** 129 *1946*].

Nonanoic acid see **pelargonic acid.**

2,5-Norbornadiene *[121-46-0]* **M 92.1, b 89°, d 0.854, n 1.4707.** Purified by distn from activated alumina [Landis and Halpern *JACS* **109** 1746 *1987*].

***cis-endo*-5-Norbornene-2,3-dicarboxylic anhydride (carbic anhydride, 3aα,4,7,7,αα-tetrahydro-4α−7α-methanoisobenzofuran-1,3-dione)** *[129-64-6]* **M 164.2, m 164.1°, 164-165°, 164-167°, d 1.417.** Forms crystals from pet ether, hexane or cyclohexane. It is hydrolysed by H_2O to form the acid [Diels and Alder *A* **460** 98 *1928*; Maitte *Bull Soc Chim France* 499 *1959*]. The *exo-exo-isomer* has **m** 142-143° (from C_6H_6-pet ether) [Alder and Stein *A* **504** 216 *1933*].

Norbornylene *[498-66-8]* **M 94.2, m 44-46°, b 96°.** Refluxed over Na, and distd [Gilliom and Grubbs *JACS* **108** 733 *1986*]. Also purified by sublimation *in vacuo* onto an ice-cold finger [Woon et al. *JACS* **108** 7990 *1986*].

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Norcamphor (bicyclo[2.2.1]heptan-2-one) *[497-38-1]* **M 110.2, m 94-95°.** Crystd from water.

Norcholanic acid *[511-18-2]* **M 346.5, m 177°, 186°, $[\alpha]_D^{20}$ +32° (EtOH).** Crystd from acetic acid.

Norcodeine *[467-15-2]* **M 285.3, m 185°, 186°.** Crystd from acetone or ethyl acetate.

Nordihydroguaiaretic acid *[500-38-9]* **M 302.4, m 184-185°.** Crystd from dilute acetic acid.

Norleucine *[R: 327-56-0] [S: 327-57-1]* **M 117.2, m 301° $[\alpha]_{546}^{20}$ ±28° (c 5, 5M HCl);** *[RS: 616-06-8]* **m 297-300°.** Crystd from water.

Norvaline *[R: 2031-12-9] [S: 6600-40-4]* **M 117.2, m 305°(dec), $[\alpha]_{546}^{20}$ ±25° (c 10, 5M HCl).** Crystd from aqueous EtOH or water.

Novobiocin *[303-81-1]* **M 612.6, two forms m 152-156° and m 174-178°, λ_{max}.330nm (acid EtOH), 305nm (alk EtOH), $[\alpha]_D^{20}$ -47° (c 1, EtOH).** Crystd from EtOH and stored in the dark. The sodium salt can be crystd from MeOH, then dried at 60°/0.5mm. [Sensi, Gallo and Chiesa *AC* **29 1611** *1957*].

Nuclear Fast Red *[6409-77-4]* **M 357.3, m >290°(dec). λ_{max} 518nm.** A soln of 5g of the dye in 250ml of warm 50% EtOH was cooled to 15° for 36h, then filtered on a Büchner funnel, washed with EtOH until the washings were colourless, then with 100ml of ethyl ether and dried over P_2O_5. [Kingsley and Robnett *AC* **33** 552 *1961*].

Nylon powder. Pellets were dissolved in ethylene glycol under reflux. Then ppted as a white powder on addition of EtOH at room temperature. This was washed with EtOH and dried at 100° under vacuum.

n-Octacosane *[630-02-4]* M 394.8, m 62.5°.

Purified by forming its adduct with urea, washing and crystallising from acetone/water. [McCubbin *TFS* **58** 2307 *1962*]. Crystd from hot, filtered isopropyl ether soln (10ml/g).

***n*-Octadecane** *[593-45-3]* **M 254.5, m 28.1°, b 173.5°/10mm, 316.1°/760mm, d_4^{20} 0.7768, n 1.4390.** Crystd from acetone and distd under reduced pressure from sodium.

***n*-Octadecanoic acid** *[124-07-2]* **M 144.2, m 16.7-17°, b 144-145°/27mm, d_4^{20} 0.911, n 1.428.** Fractionally crystd by partial freezing. Dried with Linde type 4A molecular sieves and fractionally distd under reduced pressure.

1-Octadecanol see ***n*-octadecyl alcohol.**

Octadecyl acetate *[822-23-1]* **M 312.5, m 32.6°.** Distd under vac, then crystd from ethyl ether/MeOH.

***n*-Octadecyl alcohol** *[112-92-5]* **M 270.5, m 61°, b 153-154°/0.3mm.** Crystd from MeOH, or dry ethyl ether and benzene, then fractionally distd under reduced pressure. Purified by column chromatography. Freed from cetyl alcohol by zone melting.

Octadecyl ether *[6297-03-6]* **M 523.0, m 59.4°.** Vacuum distd, then crystd from MeOH/benzene.

Octadecyltrimethylammonium bromide *[1120-02-1]* **M 392.5.** Recrystd from EtOH. Dried in a vacuum desiccator.

2,3,7,8,12,13,17,18-Octaethylporphin *[2683-82-1]* **M 534.8.** Chromatographed on SiO_2 using $CHCl_3$ as eluent.

Octafluoropropane (profluorane) *[76-19-7]* **M 188.0, b -38°.** Purified for pyrolysis studies by passage through a copper vessel containing CoF_3 at about 270°, then fractionally distd. [Steunenberg and Cady *JACS* **74** 4165 *1952*].

1,2,3,4,6,7,8,9-Octahydroanthracene *[1079-71-6]* **M 186.3, m 78°.** Crystd from EtOH, then zone refined.

Octamethylcyclotetrasiloxane *[556-67-2]* **M 296.6, m 17.3°, b 175-176°, d_4^{20} 0.957, n 1.396.** Purified by zone melting.

Octan-1,8-diol *[629-41-4]* **M 146.2, m 59-61°, b 172°/0.2mm.** Recrystd from EtOH.

Octan-4,5-diol see **dipropylene glycol.**

***n*-Octane** *[111-65-9]* **M 114.2, b 126.5°, d_4^{20} 0.704, n 1.39743, n^{25} 1.39505.** Extracted repeatedly with conc H_2SO_4 or chlorosulphonic acid, then washed with water, dried and distd. Also purified by azeotropic distn with EtOH, followed by washing with water to remove the EtOH, drying and distilling. For further details, see n-*heptane*. Also purified by zone melting.

1-Octanethiol *[111-88-6]* **M 146.3, b 86°/15mm, 197-200°/760mm, d_4^{20} 0.8433, n 1.4540.** Passed through a column of alumina [Battacharyya et al. *JCSFT1* **82** 135 *1986*].

Octaphenylcyclotetrasiloxane *[546-56-5]* **M 793.2, m 201-202°, b 330-34°/760mm.** Crystd from benzene/EtOH or glacial acetic acid.

1-Octene *[111-66-0]* **M 112.2, b 121°/742mm, d_4^{20} 0.716, n 1.4087,**
(*trans*)-2-Octene *[13389-42-9]* **M 112.2, b 124-124.5°/760mm, d_4^{20} 0.722, n 1.4132.** Distd under nitrogen from sodium. [Removes water and peroxides]. Peroxides can also be removed by percolation through dried, acid washed alumina. Stored under nitrogen in the dark. [Strukul and Michelin *JACS* **107** 7563 *1985*].

***n*-Octyl alcohol** *[111-87-5]* **M 130.2, b 98°/19mm, 195.3°/760mm, d 0.828, n 1.43018.** Fractionally distd under reduced pressure. Dried with sodium and again fractionally distd or refluxed with boric anhydride and distd (**b** 195-205°/5mm), the distillate being neutralised with NaOH and again fractionally distd. Also purified by distn from Raney nickel and by preparative GLC.

***n*-Octylammonium 9-anthanilate** *[88020-99-9]* **M 351.5, m 134-135°.** Recrystd several times from ethyl acetate.

***n*-Octylammonium hexadecanoate** *[88020-97-7]* **M 385.7, m 52-53°.** Purified by several recrystns from *n*-hexane or ethyl acetate. The solid was then washed with cold anhydrous ethyl ether, and dried *in vacuo* over P_2O_5.

***n*-Octylammonium octadecanoate** *[32580-92-0]* **M 413.7, m 56-57°.** Purified as for the *hexadecanoate* above.

***n*-Octylammonium tetradecanoate** *[544-61-8]* **M 358.6, m 46-48°.** Purified as for the *hexadecanoate* above.

4-Octylbenzoic acid *[3575-31-3]* **M 234.3, m 99-100°.** Crystd from EtOH has **m** 139°; crystd from aq EtOH has **m** 99-100°.

***n*-Octyl bromide** *[111-83-1]* **M 193.1, b 201.5°, d_4^{20} 1.118, n^{25} 1.4503.** Shaken with H_2SO_4, washed with water, dried with K_2CO_3 and fractionally distd.

4-(*tert*-Octyl)phenol *[140-66-9]* **M 206.3, m 85-86°.** Crystd from *n*-hexane.

1-Octyne *[629-05-0]* **M 110.2, b 126.2°/760mm, d_4^{20} 0.717, n^{25} 1.4159.** Distd from $NaBH_4$ to remove peroxides.

β-Oestradiol *[50-28-2]* **M272.4, m 179°, $[\alpha]_D^{20}$ +80° (c 1, dioxane),**
β-Oestradiol-3-benzoate *[50-50-0]* **M 376.5, m 194-195°, $[\alpha]_{546}^{20}$ +70° (c 2, dioxane),** Crystd from EtOH

Oleic acid *[112-80-1]* **M 282.5, m 16°, b 360°(dec), d_4^{20} 0.891, n^{30} 1.4571.** Purified by fractional crystn from its melt, followed by molecular distn at 10^{-3}mm, or by conversion to its methyl ester, the free acid can be crystd from acetone at -40° to -45° (12ml/g). For purification by the use of lead and lithium salts, see Keffler and McLean [*JCS Ind (London)* **54** 176T *1935*]. Purification based on direct crystn from acetone is described by Brown and Shinowara [*JACS* **59** 6 *1937*].

Oleyl alcohol *[142-28-2]* **M 268.5, b 182-184°/1.5mm, d_4^{20} 0.847, $n^{27.5}$ 1.4582.** Purified by fractional crystn at -40° from acetone, then distd under vacuum.

Opianic acid (2-formyl-4,5-dimethylbenzoic acid) *[519-05-1]* **M 210.2, m 150°.** Crystd from water.

Orcinol *[504-15-4]* **M 124.2, m 107.5°, (H_2O) m 59-61°.** Crystd from $CHCl_3$/benzene (2:3).

L-Ornithine *[70-26-8]* **M 132.2, m 140°, $[\alpha]_D^{25}$ +16° (c 0.5, H_2O).** Crystd from water containing 1mM EDTA (to remove metal ions).

L-Ornithine monohydrochloride *[3184-13-2]* **M 168.6, $[\alpha]_D^{25}$ +28.3° (5M HCl).** Likely impurities are citrulline, arginine and D-ornithine. Crystd from water by adding 4 volumes of EtOH.

Orotic acid (H_2O) *[50887-69-9]* **M 174.1, m 235-346°(dec).** Crystd from water.

Orthanilic acid (2-aminobenzenesulphonic acid) *[88-21-1]* **M 173.2, m >300°(dec).** Crystd from aqueous soln, containing 20ml of conc HCl per L, then crystd from distilled water.

Ouabain *[630-60-4]* **M 728.8, m 180°(dec), $[\alpha]_{546}^{20}$ -30° (c 1, H_2O).** Crystd from water. Dried at 130°. Stored in the dark.

Oxalic acid ($2H_2O$) *[630-60-4]* **M 90.0, m 101.5°;** ***[anhydrous** 144-62 -7]* **m 189.5°.** Crystd from distilled water. Dried in vacuum over H_2SO_4. The anhydrous acid can be obtained by drying at 100° overnight.

Oxaloacetic acid *[328-42-7]* **M 132.1, m 160°(decarboxylates).** Crystd from boiling ethyl acetate, or from hot acetone by addition of hot benzene.

2-Oxaloglutaric acid *[328-50-7]* **M 146.1, m 114°.** Crystd repeatedly from acetone/benzene.

Oxamide *[471-46-5]* **M 88.1, m >320°(dec).** Crystd from water, ground and dried in an oven at 150°.

Oxamycin see ***R*-4-amino-3-isoxazolidone.**

2-Oxazolidinone *[497-25-6]* **M 87.1, m 89-90°, 91°.** Crystd from benzene.

2-Oxohexamethyleneimine see **ε-caprolactam.**

Oxalylindigo *[2533-00-8]* **M 316.3.** Recrystd twice from nitrobenzene and dried by heating *in vacuo* for several hours. [Sehanze et al. *JACS* **108** 2646 *1986*].

Oxetane (1.3-trimethylene oxide) *[503-30-0]* **M 58.1, b 45-46°/736mm, 47-49°/atm, 48°/760mm, d_4^{20} 0.892, n_D^{20}1.395.** Distd from sodium metal. Also purified by preparative gas chromatography using a 2m silica gel column. Alternatively add KOH pellets (50g for 100g of oxetane) and distil through a column packed with 1/4in Berl Saddles and the main portion boiling at 45-50° is collected and redistd over fused KOH. [Noller *Org Synth* Coll Vol III 835 *1955*; Dittmer et al. *JACS* **79** 4431 *1957*].

Oxine Blue *[3733-85-5]* **M 369.4, m 134-135°.** Recrystd from EtOH. Dried over H_2SO_4.

2,2'-Oxydiethanol see **diethylene glycol.**

Palmitic acid

(hexadecanoic acid) *[57-10-3]* **M 256.4, m 63-64°.** Crystd from EtOH. Purified *via* the *methyl ester* (**b** 193-194°/12mm, n^{35} 1.4359) as for *capric acid*, or by zone melting.

***R*-Pantothenic acid** *[867-81-2]* **M 241.2, m 122-124°, $[\alpha]_D^{25}$ +27° (c 5, H_2O).** Crystd from EtOH.

Papain see Chapter 5.

[2.2]-Paracyclophane (tricyclo[8.2.2.$2^{4,7}$]hexadeca-4,6,10,12,13,15-hexaene) *[1633-22-3]* **M 208.3, m 284°, 285-287°, 286-288°, 288-290°.** Purified by recrystn from AcOH. ^{1}H-NMR δ: 1.62 (Ar-H) and -1.71 (CH_2) ppm [Waugh and Fessenden *JACS* **79** 846 *1957*; IR and UV: Cram et al. *JACS* **76** 6132 *1954*, Cram and Steinberg *JACS* **73** 5691 *1951*; complex with unsaturated compounds: Cram and Bauer *JACS* **81** 5971 *1959*; Syntheses: Brink *S* 807 *1975*, Givens et al. *JOC* **44 16087** *1979*, Kaplan et al. *TET LETT* 3665 *1976*].

Paraffin (oil) *[8012-95-1]* **d 0.880, n 1.482.** Treated with fuming H_2SO_4, then washed with water and dilute aqueous NaOH, then percolated through activated silica gel.

Paraffin Wax. Melted in the presence of NaOH, washed with water until all of the base had been removed. The paraffin was allowed to solidify after each wash. Finally, 5g of paraffin was melted by heating on a water-bath, then shaken for 20-30min with 100ml of boiling water and fractionally crystd.

Parafuchsin (4,4',4"-triaminotrityllium [triphenylmethane] carbonium ion, pararosaniline, paramagenta) *[467-62-9]* **M 305.4.** Dissolve in EtOH (1.16g in 30ml), filter and add aqueous NH_3 till neutral and ppte by adding H_2O giving 0.8g **m** 247° dec (sintering At 230°). Dissolve in EtOH neutralise with NH_3 add 0.1g of charcoal filter, and repeat, then add H_2O (100ml) to ppte the colourless *carbinol* dry, **m** *257°* dec (sintering at 232°). [Weissberger and Theile *JCS* 148 *1934*]. The *carbinol* (pseudo-base) was said to have **m** 232° (186° dec), and is slightly sol in H_2O but sol in acids and EtOH, and has a pKa of 7.57 whereas the free base has pKa > 13 [Goldacre and Phillips *JCS* 172 *1949*]. The *perchlorate* (dark red with a green reflex) has **m** 300° and explodes at 317° [Dilthey and Diaklage *J Prakt Chem* [2] 129 *1931*].

Paraldehyde *[30525-89-4]* **M 132.2, m 12.5°, 124°, d 0.995, n 1.407.** Washed with water and fractionally distd.

Patulin *[149-29-1]* **M 154.1, m 110°.** Crystd from ethyl ether or chloroform. (*Highly* **TOXIC**).

Pavatrine hydrochloride *[548-65-2]* **M 333.7, m 143-144°.** Recrystd from isopropanol, and dried over P_2O_5 under vacuum.

Pectic acid,
Pectin see Chapter 5.

Pelargonic acid (nonanoic acid) *[112-05-0]* **M 158, m 15°, b 98.9°/1mm, 225°/760mm.** Esterified with ethylene glycol and distd. (This removes dibasic acids as undistillable residues.) The acid was regenerated by hydrolysing the ester.

Penicillic acid *[90-65-3]* **M 158.2, m 58-64° (H_2O), 83-84° (anhydrous).** Crystd from water as the monohydrate, or from pet ether.

Pentaacetyl-α-D-glucopyranose *[604-68-2]* **M 390.4, m 112°, $[\alpha]_{546}^{20}$+119° (c 5, $CHCl_3$),**
Pentaacetyl-β-D-glucopyranose *[604-69-3]* **M 390.4, m 131°, $[\alpha]_{546}^{20}$+5°(c 5, $CHCl_3$).** Crystd from EtOH.

Pentabromoacetone *[79-49-2]* **M 452.6, m 76°.** Crystd from ethyl ether or EtOH.

Pentabromophenol *[608-71-9]* **M 488.7, m 229°.** Purified by crystn (charcoal) from toluene then from CCl_4. Dried for 2 weeks at *ca* 75°.

1-Pentacene *[13360-61-7]* **M 278.4, m 300°**. Crystd from benzene.

Pentachloroethane (pentalin) *[76-01-7]* **M 202.3, b 69°/37mm, 152.2°/64mm, 162.0°, d 1.678, n^{15} 1.50542.** Usual impurities include trichloroethylene. Partially decomposes if distd at atmospheric pressure. Drying with CaO, KOH or sodium is unsatisfactory because HCl is split off. It can be purified by steam distn, or by washing with conc H_2SO_4, water, and then aqueous K_2CO_3, drying with solid K_2CO_3 or $CaSO_4$, and fractionally distd under reduced pressure.

Pentachloronitrobenzene *[82-68-8]* **M 295.3, m 146°.** Crystd from EtOH.

Pentachlorophenol *[87-86-5]* **M 266.3, m 190-191°.** Twice crystd from toluene/EtOH. Sublimed *in vacuo.*

Pentachloropyridine *[2176.62-7]* **M 251.3, m 122-124°, 123°, 124°, 124-125°, 125-126°, b 279-280°/atm.** Purified by recryst from EtOH or aqueous EtOH. It sublimes at 150°/3mm. [den Hertog et al. *Rec Trav Chim Pays Bas* **69** 673 *1950*; Schikh et al. *B* **69** 2604 *1936*].

Pentachlorothiophenol *[133-49-3]* **M 282.4, m between 228° and 235°.** Crystd from benzene.

Pentachrome Azure Blue B. Crystd from MeOH.

Pentadecafluoro octanoic acid (perfluorocaprylic acid) *[335-67-1]* **M 414.1, m 54.9-55.6°, b 189°/736mm.** Recrystd from CCl_4 and toluene, and can be distd. It forms micelles in H_2O and the solubility is 1% in H_2O. [Bernett and Zisman *JPC* **63** 1911 **1959**; IR: Bro and Sperati *J Polymer Sci* **38** 289 *1959*].

Pentadecanoic acid *[1002-84-2]* **M 242.4, m 51-53°, b 158°/1mm, 257°/760mm, d^{80} 0.8424.** Purification as for hexadecanoic acid.

Pentadecanolide (1-oxacyclohexadecan-2-one, pentadecanoic-ω-lactone, 15-hydroxypentadecanoic lactone, exaltolide, Tibetolide) *[106-02-5]* **M 240.4, m 34-36°, 37-37.5°, 37-38°, b 102-103°/0.03mm, 112-114°/0.2mm, 137°/2mm, 169°/10-11mm, d_4^{40} 0.9401.** It has been recrystd from MeOH (4 parts) at -15°. [Hundiecker and Erlbach *B* **80** 135 *1947*; Galli and Mandolini *Org Synth* **58** 100 *1978*; Demole and Enggist *HCA* **11** 2318 *1978*].

Penta-1,3-diene *[cis: 1574-41-0], [trans: 2004-70-8]* **M 68.1, b 42°, d 0.680, n 1.4316,**

Penta-1,4-diene *[591-93-5]* **M 68.1, b 25.8-26.2°/756mm, d 0.645, n 1.3890.** Distd from $NaBH_4$. Purified by preparative gas chromatography. [Reimann et al. *JACS* **108** 5527 *1986*].

Penta-2,4-dione see **acetylacetone.**

Pentaerythritol *[115-77-5]* **M 136.2, m 260.5°.** Refluxed with an equal volume of MeOH, then cooled and the ppte dried at 90°. Crystd from dil aq HCl. Sublimed under vacuum at 200°.

Pentaerythritol tetraacetate *[597-71-7]* **M 304.3, m 78-79°.** Crystd from hot water, then leached with cold water until the odour of acetic acid was no longer detectable.

Pentaerythrityl laurate *[13057-50-6]* **M 864.6, m 50°.** Crystd from pet ether.

Pentaerythrityl tetranitrate. *[78-11-5]* **M 316.2, m 140.1°.** Crystd from acetone or acetone/EtOH. **EXPLOSIVE.**

Pentaethylenehexamine *[4067-16-7]* **M 232.4.** Fractionally distd twice at 10-20mm, the fraction boiling at 220-250° being collected. Its soln in MeOH (40ml in 250ml) was cooled in an ice-bath and conc HCl was added dropwise with stirring. About 50ml was added, and the ppted hydrochloride was filtered off, washed with acetone and ethyl ether, then dried in a vacuum desiccator. [Jonassen et al. *JACS* **79** 4279 *1957*].

Pentafluorobenzene *[363-72-4]* **M 168.1, b 85°/atm, 85-86°/atm, 88-89°/atm, d_4^{20} 1.524, n_D^{20} 1.3931.** Purified by distn and by gas chromatography. IR film: 1535 and 1512 cm^{-1} (benzene ring). [UV: Stephen and Tatlow *Chemistry and Industry (London)* 821 *1957* ; Nield et al. *JCS* 166 *1959*].

2,3,4,5,6-Pentafluorobenzoic acid *[602-94-8]* **M 212.1, m 101-103°, 103-104°, 104-105°, 106-107°.** Dissolve in Et_2O, treat with charcoal, filter, dry ($CaSO_4$), filter, evaporate and recrystallise residue from pet ether (b 90-100°) after adding a little toluene to give large colourless plates. UV (H_2O): λmax 265nm (ε 761). The *S-benzylisothiuronium salt* has **m** 187° after recrystn from H_2O. [McBee and Rapkin *JACS* **73** 1366 *1951*; Nield et al. *JCS* 166, 170 *1959*].

***O*-(2,3,4,5,6-Pentafluorobenzyl)hydroxylamine hydrochloride (PFBOA)** *[57981-02-9]* **M 249.6, m 215, 215-216.** Recrystd from EtOH to form colourless leaflets. Drying the compound at high vacuum and elevated temperature will result in losses by sublimation. [Youngdale *J Pharm Sci* **65** 625 *1976*; Wehner and Handke *J Chromatography* **177** 237 *1979*; Nambara et al. give incorrect **m** as 115-116° *J Chromatography* **114** 81 *1975*].

2,3,4,5,6-Pentafluorophenol *[771-61-9]* **M 184.1, m 33-35°, 38.5-39.5°, b 72-74°/48mm, 142-144°/atm, 143°/atm, n_D^{20}1.4270 (liquid prep).** A *hygroscopic* low melting solid not freely soluble in H_2O. Purified by distn, preferably in a vacuum. It has pKa^{17} of 5.53 in H_2O [Forbes et al. *JCS* 2019 *1959*; IR and pKa: Birchall and Haszeldine *JCS* 13 *1959*]. IR film: 3600 (OH) and 1575 (fluoroaromatic breathing) cm^{-1}. The *benzoyl* derivative has **m** 74-75°, *3,4-dinitrobenzoyl* derivative has **m** 107°, the *tosylate* has **m** 64-65° (from EtOH) and the *K salt* crystallises from Me_2CO, **m** 242° dec, with $1H_2O$ *salt* the **m** is 248° dec and the $2H_2O$ *salt* has **m** 245° dec.

***R*-(+)-** *[104371-21-3]* ***S*-(-)-** *[104371-20-2]* **1-(Pentafluorophenyl)ethanol M 212.1, m 41-42°,42°, 42.5-43°, $[\alpha]_{546}^{20}$ ±9°, $[\alpha]_D^{20}$±7.5° (c 1, *n*-pentane).** Recrystd from *n*-pentane at -40° and vacuum sublimed at room temp at 0.3mm (use ice cooled cold finger). It has also been purified by column chromatography through Kieselgel 60 (0.063-0.2mm mesh, Merck), eluted with EtOAc-*n*-hexane (1:5), then recrystd from *n*-pentane and vacuum sublimed. It has R_F on Kieselgel 60 F_{254} TLC foil and eluting with EtOAc-*n*-hexane (1:5). [Meese *A* 2004 *1986*]. The *racemate [75853-08-6]* has **m** 32-34°, **b** 77-79°/8mm, 80-82°/37mm, n_D^{20} 1.4426 and the *3,4-dinitrobenzoate* has **m** 83° [Nield et al. *JCS* 166 *1959*].

2,2,3,3,3-Pentafluoropropan-1-ol *[422-05-9]* **M 150.1, b 80°, d 1.507, n 1.288.** Shaken with alumina for 24h, dried with anhydrous K_2CO_3, and distd, collecting the middle fraction (**b** 80-81°) and redistilling.

Pentafluoropyridine *[700-16-3]* **M 169.1, m -41.5°, b 83.5°, 83.5°, 83-85°, d_4^{20} 1.609, n_D^{20} 1.3818.** Distd through a concentric tube column; has λ max in cyclohexane at 256.8nm. [Chambers et al. *JCS* 3573 *1964*]; ^{19}F NMR: Bell et al. *J Fluorine Chem* **1** 51 *1971*]. The *hexafluoroantimonate* has **m** 98-102° dec.

2',3,4',5,7-Pentahydroxyflavone see **Morin.**

Pentamethylbenzene *[700-12-9]* **M 148.3, m 53.5-55.1°.** Successively crystd from absolute EtOH, toluene and MeOH, and dried under vacuum. [Rader and Smith *JACS* **84** 1443 *1962*]. It has also been crystd from benzene or aqueous EtOH, and sublimed.

1,5-Pentamethylenetetrazole *[54-95-5]* **M 138.2, m 60-61°, b 194°/12mm.** Crystd from ethyl ether.

***n*-Pentane** *[109-66-0]* **M 72.2, b 36.1°, d 0.626, n 1.35748, n^{25} 1.35472.** Stirred with successive portions of conc H_2SO_4 until there was no further coloration during 12h, then with 0.5N $KMnO_4$ in 3M H_2SO_4 for 12h, washed with water and aqueous $NaHCO_3$. Dried with $MgSO_4$ or Na_2SO_4, then P_2O_5 and fractionally distd through a column packed with glass helices. It was also purified by passage through a column of silica gel, followed by distn and storage with sodium hydride. An alternative purification is by azeotropic distn with MeOH, which is subsequently washed out from the distillate (using water), followed by drying and distn. For removal of carbonyl-containing impurities, see n-*heptane*.
Also purified by fractional freezing (*ca* 40%) on a copper coil through which cold air was passed, then washed with conc H_2SO_4 and fractionally distd.

2,4-Pentanedione see **acetylacetone.**

Pentane-1-thiol *[110-66-7]* **M 104.2, b 122.9°/697.5mm, d^{25} 0.8375.** Dissolved in aqueous 20% NaOH, then extracted with a small amount of ethyl ether. The soln was acidified slightly with 15% H_2SO_4, and the thiol was distd out, dried with $CaSO_4$ or $CaCl_2$, and fractionally distd under nitrogen. [Ellis and Reid *JACS* **54** 1674 *1932*].

Pentan-1-ol see ***n*-amyl alcohol.**

Pentan-2-ol *[6032-29-7]* **M 88.2, b 119.9°, d 0.810, n 1.41787, n^{25} 1.4052.**
Pentan-3-ol *[684-02-1]* **M 88.2, b 116.2°, d 0.819, n^{25} 1.4072.** Refluxed with CaO, distd, refluxed with magnesium and again fractionally distd.

Pentan-3-one *[96-22-0]* **M 86.1, b 101.7°, d 0.813, n 1.3924, n^{25} 1.3900.** Refluxed with $CaCl_2$ for 2h, then left overnight with fresh $CaCl_2$, filtered and distd.

Pentaquine monophosphate *[5428-64-8]* **M 395.6, m 189-190°.** Crystd from 95% EtOH.

Pent-2-ene (mixed isomers) *[109-68-2]* **M 70.1, b 36.4°, d 0.650, n 1.38003, n^{25} 1.3839.** Refluxed with sodium wire, then fractionally distd twice through a Fenske column.

***cis*-Pent-2-ene** *[627-20-3]* **M 70.1, b 37.1°, d 0.657, n 1.3830, n^{25} 1.3798.** Dried with sodium wire and fractionally distd, or purified by azeotropic distn with MeOH, followed by washing out the MeOH with water, drying and distilling. Also purified by chromatography through silica gel and alumina [Klassen and Ross *JPC* **91** 3668 *1987*].

***trans*-Pent-2-ene** *[646-04-8]* **M 70.1, b 36.5°, d 0.6482, n 1.3793.** It was treated as above and washed with water, dried over anhydrous Na_2CO_3, and fractionally distd. The middle cut was purified by two passes of fractional melting.

Pentobarbital (5-ethyl-5-1'-methylbutyl barbituric acid, Nembutal) *[76-74-4]* **M 226.4, m ~127°(dec).** Soln of the sodium salt in 10% HCl was prepared and the acid was extracted by addition of ether. Then purified by repeated crystn from $CHCl_3$. [Bucket and Sandorfy *JPC* **88** 3274 *1984*].

Pentyl acetate (*n*-amyl acetate) *[628-63-7]* **M 130.2, b 147-149°/atm, 149.55°, 149.2°/atm, d_4^{20} 0.8753, n_D^{20} 1.4028.** Purified by repeated fractional distn through an efficient column or spinning band column. [Timmermann and Hennant-Roland *J Chimie Phys* **52** 223 *1955*; Mumford and Phillips *JCS* 75 *1950*; ^{1}H NMR: Crawford and Foster *Canad J Physics* **34** 653 *1956*].

Pentyl- see ***tert*-butyl.**

***tert*-Pentyl** *see* ***tert*-amyl.**

***neo*-Pentyl alcohol** see **2,2-dimethyl-1-propanol.**

Pent-2-yne *[627-21-4]* **M 68.1, b 26°/2.4mm, d 0.710, n^{25} 1.4005.** Stood with, then distd at low pressure from, sodium or $NaBH_4$.

Pepsin see Chapter 5.

Perbenzoic acid *[93-59-4]* **M 138.1, m 41-43°.** Crystd from benzene. Readily sublimed.

Perchlorobutadiene *[87-68-3]* **M 260.8, b 144.1°/100mm, 210-212°/760mm, d 1.683, n 1.5556.** Washed with four or five 1/10th volumes of MeOH (or until the yellow colour has been extracted), then stirred for 2h with H_2SO_4, washed with distilled water until neutral and filtered through a column of P_2O_5. Distd under reduced pressure through a packed column. [Rytner and Bauer *JACS* **82** 298 *1960*].

Perfluorobutyric acid *[375-22-4]* **M 214.0, m -17.5°, b 120°/735mm, d 1.651, n^{16} 1.295.** Fractionally distd twice in an Oldershaw column with an automatic vapour-dividing head, the first distn in the presence of conc H_2SO_4 as a drying agent.

Perfluorocyclobutane *[115-25-3]* **M 200.0, m -40°, b -5°, d^{-20} 1.654, d^{o} 1.72.** Purified by trap-to-trap distn, retaining the middle portion.

Perfluorocyclohexane *[355-68-0]* **M 300.1, m 51° (sublimes), b 52°.** Extracted repeatedly with MeOH, then passed through a column of silica gel (previously activated by heating at 250°).

Perfluoro-1,3-dimethylcyclohexane *[335-27-3]* **M 400.1, b 101°, d 1.829, n 1.300.** Fractionally distd, then 35ml was sealed with about 7g KOH pellets in a borosilicate glass ampoule and heated at 135° for 48h. The ampoule was cooled and opened, and the liquid was resealed with fresh KOH in another ampoule and heated as before. This process was continued until no further decomposition was observed. The substance was then washed with distilled water, dried ($CaSO_4$) and distd. [Grafstein *AC* **26** 523 *1954*].

Perfluoroheptane *[335-57-9]* **M 388.1, b 99-101°, d^{25} 1.7200.** Purified as for *perfluorodimethylhexane*. Other procedures include shaking with H_2SO_4, washing with water, drying with P_2O_5 for 48h and fractionally distilling. Alternatively, it has been refluxed for 24h with saturated acid $KMnO_4$ (to oxidise and remove hydrocarbons), then neutralised, steam distd, dried with P_2O_5, and passed slowly through a column of dry silica gel. It has been purified by fractional crystn, using partial freezing.

Perfluoro-*n*-hexane *[355-42-0]* **M 338.1, m -4°, b 58-60°, d 1.684.** Purified by fractional freezing. The methods described for *perfluoroheptane* should be applicable here.

Perfluoro(methylcyclohexane) *[355-02-2]* **M 350.1, b 76.3°, d^{25} 1.7878.** Refluxed for 24h with saturated acid $KMnO_4$ (to oxidise and remove hydrocarbons), then neutralised, steam distd, dried with P_2O_5 and passed slowly through a column of dry silica gel. [Glew and Reeves *JPC* **60** 615 *1956*]. Also purified by percolation through a 1m neutral activated alumina column, and ^1H-impurities checked by NMR.

Perfluorononane *[375-96-2]* **M 488.1.** Purified as for *perfluorodimethylcyclohexane.*

Perfluoropropane *[76-19-7]* **M 188.0.** Purified by several trap-to-trap distns.

Perfluorotripropylamine *[338-83-0]* **M 521.1.** Purified as for *perfluorodimethylcyclopropane.*

Pericyazine *[2622-26-6]* **M 365.4.** Recrystd from a saturated soln in cyclohexane.

Perylene *[198-55-0]* **M 252.3, m 273-274°.** Purified by silica-gel chromatography of its recrystd picrate. [Ware *JACS* **83** 4374 *1961*]. Crystd from benzene, toluene or EtOH and sublimed in a flow of oxygen-free nitrogen. [Gorman et al. *JACS* **107** 4404 *1985;* Johansson et al. *JACS* **109** 7374 *1987*].

Petroleum ether *[8032-32-4]* **b 35-60°, d 0.640, n 1.363.** Shaken several times with conc H_2SO_4, then 10% H_2SO_4 and conc $KMnO_4$ (to remove unsatd, including aromatic, hydrocarbons) until the permanganate colour persists. Washed with water, aqueous Na_2CO_3 and again with water. Dried with $CaCl_2$ or Na_2SO_4, and distd. It can be dried further using CaH_2 or sodium wire. Passage through a column of activated alumina, or treatment with CaH_2 or sodium, removes peroxides. For the elimination of carbonyl-containing impurities without using permanganate, see *n-heptane*. These procedures could be used for all fractions of pet ethers.

***R*(-)-α-Phellandrene** *[4221-98-1]* **M 136.2, b 61°/11mm, 175-176°/760mm, d 0.838, n 1.471.** Purified by gas chromatography on an Apiezon column.

Phenacetin see ***p*-acetophenetidine.**

Phenacylamine hydrochloride *[5468-37-1]* **M 171.6, m 194°(dec).** Recrystd from 2-propanol [Castro *JACS* **108** 4179 *1986*].

Phenacyl bromide see **2-bromoacetophenone.**

Phenanthrene *[85-01-8]* **M 178.2, m 98°.** Likely contaminants include, anthracene, carbazole, fluorene and other polycyclic hydrocarbons. Purified by distn from sodium, boiling with maleic anhydride in xylene, crystn from acetic acid, sublimation and zone melting. Has also been recrystd repeatedly from EtOH, benzene or pet ether (b 60-70°), with subsequent drying under vacuum over P_2O_5 in an Abderhalden pistol. Feldman, Pantages and Orchin [*JACS* **73** 4341 *1951*] separated from most of the anthracene impurity by refluxing phenanthrene (671g) with maleic anhydride (194g) in xylene (1.25L) under nitrogen for 22h, then filtered. The filtrate was extracted with aqueous 10% NaOH, the organic phase was separated, and the solvent was evaporated. The residue, after stirring for 2h with 7g of sodium, was vacuum distd, then recrystd twice from 30% benzene in EtOH, then dissolved in hot glacial acetic acid (2,2ml/g), slowly adding an aqueous soln of CrO_3 (60g in 72ml H_2O added to 2.2L of acetic acid), followed by slow addition of conc H_2SO_4 (30ml). The mixture was refluxed for 15min, diluted with an equal volume of water and cooled. The ppte was filtered off, washed with water, dried and distd, then recrystd twice from EtOH. Further purification is possible by chromatography from $CHCl_3$ soln on activated alumina, with benzene as eluent, and by zone refining.

Phenanthrene-9-aldehyde *[4707-71-5]* **M 206.3, m 102.2-103°/12mm.** Crystd from EtOH and sublimed at 95-98°/0.07mm.

9,10-Phenanthrenequinone *[84-11-7]* **M 208.2, m 208°.** Crystd from dioxane or 95% EtOH and dried under vacuum.

Phenanthridine *[229-87-8]* **M 179.2, m 106.5°.** Purified *via* the $HgCl_2$ addition compound formed when phenanthridine (20g) in 1:1 HCl (100ml) was added to aqueous $HgCl_2$ (60g in 3L), and the mixture was heated to boiling. Conc HCl was then added until all of the solid had dissolved. The compound separated on cooling, and was decomposed with strong aqueous NaOH (*ca* 5M). Phenanthridine was extracted with ethyl ether and crystd from pet ether (b 80-100°) or ethyl acetate. [Cumper, Ginman and Vogel *JCS* 45218 *1962*]. Also purified by zone melting.

1,10-Phenanthroline (*o*-phenanthroline) *[66-71-7]* **M 198.2, m 88-101°, 108-110° (H_2O), 118° (anhydrous), b >300°.** Crystd as its *picrate* (**m** 191°) from EtOH, then the free base was liberated, dried at 78°/8mm over P_2O_5 and crystd from pet ether (b 80-100°). [Cumper, Ginman and Vogel *JCS* 1188 *1962*]. It can be purified by zone melting. Also crystd from hexane, benzene/pet ether (b 40-60°) or sodium-dried benzene, dried and stored over H_2SO_4. The monohydrate is obtained by crystn from aqueous EtOH or ethyl acetate. It has been crystd from H_2O (300 parts) to give the *monohydrate* **m** 102-103° and sublimes at 10^{-3}mm [Fielding and LeFevre *JCS* 1811 *1951*]. The *anhydrous* compound has **m** 118° (after drying at high vacuum at 80°), also after recrystn from pet ether or C_6H_6 (70 parts) and drying at 78°/8mm. [UV: Badger et al. *JCS* 3199 *1951*]. It has a pKa in H_2O of 4.857 (25°) or 5.02 (20°) and 4.27 in 50% aq EtOH (20°) [Albert et al. *JCS* 2240*1948*].

1,10-Phenanthroline hydrochloride (*o*-phenanthroline hydrochloride) *[3829-86-5]* **M 243.7, m 212-219°.** It crystallises from 95% EtOH, **m** 212-219° as the *monohydrate*, the *half hydrate* has **m** 217°. The *3HCl* has **m** 143-145° (sinters at 128°) [Thevenet et al. *Acta Cryst* **Sect B 33** 2526 *1977*].

4,7-Phenanthroline-5,6-dione *[84-12-8]* **M 210.2, m 295°(dec).** Crystd from MeOH.

Phenazine *[92-82-0]* **M 180.2, m 171°.** Crystd from EtOH, $CHCl_3$ or ethyl acetate, after pre-treatment with activated charcoal. It can be sublimed *in vacuo*, and zone refined.

Phenazine monosulphate *[299-11-6]* **M 306.3, m 155-157° (or 198° dec on rapid heating).** Crystd from EtOH (charcoal).

Phenethylamine *[64-04-0]* **M 121.2, b 87°/13mm, d 0.962, n 1.535.** Distd from CaH_2, under reduced pressure, just before use.

Phenethyl bromide *[103-63-9]* **M 185.1, b 92°/11mm, d 1.368, n 1.557**. Washed with conc H_2SO_4, water, aq 10% Na_2CO_3 and water again, then dried with $CaCl_2$ and fractionally distd just before use.

Phenethyl urea *[2158-04-5]* **M 164.2, m 173-174°.** Crystd from water.

Phenetole *[103-73-1]* **M 122.2, b 60°/9mm, 77.5°/31mm, 170.0°/760mm, d 0.967, n 1.50735, n^{25} 1.50485.** Small quantities of phenol can be removed by shaking with NaOH, but this is not a very likely contaminant of commercial material. Fractional distn from sodium, at low pressures, probably gives adequate purification. It can be dissolved in ethyl ether and washed with 10% NaOH (to remove phenols), then water. The ethereal soln was evaporated and the phenetole fractionally distd under vacuum.

Phenocoll hydrochloride (*p*-phenetidine HCl) *[536-10-6]* **M 230.7, m 234°.** Crystd from water. Sublimes *in vacuo*.

Phenol *[108-95-2]* **M 94.1, m 40.9°, b 85.5-86.0°/20mm, 180.8°/760mm, d 1.06, n^{41} 1.54178, n^{46} 1.53957.** Steam was passed through a boiling soln containing 1mole of phenol and 1.5-2.0moles of NaOH in 5L of H_2O until all non-acidic naterial had distd. The residue was cooled, acidified with 20% (v/v) H_2SO_4, and the phenol was separated, dried with $CaSO_4$ and fractionally distd under reduced pressure. It was then fractionally crystd several times from its melt, [Andon et al. *JCS* 5246 *1960*]. Purification *via* the benzoate has been used by Berliner, Berliner and Nelidow [*JACS* **76** 507 *1954*]. The benzoate was crystd from 95% EtOH, then hydrolysed to the free phenol by refluxing with two equivalents of KOH in aq EtOH until the soln became homogeneous. It was acidified with HCl and extracted with ethyl ether. The ether layer was freed

from benzoic acid by thorough extraction with aqueous $NaHCO_3$, and, after drying and removing the ether, the phenol was distd.
Phenol has also been crystd from a 75% w/w soln in water by cooling to 11° and seeding with a crystal of the hydrate. The crystals were centrifuged off, rinsed with cold water (0-2°) satd with phenol, and dried. It can be crystd from pet ether [Berasconi and Paschalis *JACS* **108** 2969 *1986*].
Draper and Pollard [*Science* **109** 448 *1949*] added 12% water, 0.1% aluminium (can also use zinc), and 0.05% $NaHCO_3$ to phenol, and distd at atmospheric pressure until the azeotrope was removed, The phenol was then distd at 25mm. Phenol has also been dried by distn from the benzene soln to remove the water-benzene azeotrope and the excess benzene, followed by distn of the phenol at reduced pressure under nitrogen. Processes such as this are probably adequate for analytical grade phenol which has as its main impurity water. Phenol has also been crystd from pet ether/benzene or pet ether (b 40-60°). Purified material is stored in a vacuum desiccator over P_2O_5 or $CaSO_4$.

Phenol-2,4-disulphonic acid *[96-77-5]* **M 254.2.** Crystd from EtOH/ethyl ether.

Phenolphthalein *[787-09-8]* **M 319.2, m 263°.** Dissolved in EtOH (7ml/g), then diluted with eight volumes of cold water. Filtered. Heated on a water-bath to remove most of the alcohol and the pptd phenolphthalein was filtered off and dried under vacuum.

Phenolphthalol *[81-92-5]* **M 306.3, m 201-202°.** Crystd from aqueous EtOH.

Phenosafranine *[81-93-6]* **M 322.8, λ_{max} 530nm (H_2O).** Crystd from dilute HCl.

Phenothiazine *[92-84-2]* **M 199.3, m 184-185°.** Crystd from benzene or toluene (charcoal) after boiling for 10min under reflux. Filtered on a suction filter. Dried in an oven at 100°, then in a vacuum desiccator over paraffin chips. Also twice recrystd from water and dried in an oven at 100° for 8-10h.

Phenoxazine *[135-67-1]* **M 199.2, m 156°, 156-158°, 158-159°, b 215°/4mm.** Crystd from EtOH and sublimed *in vacuo*. If too impure then extract in a Soxhlet using toluene. Evaporate the solvent and dissolve residue (*ca* 100g) in C_6H_6 (1L) **CARCINOGEN**, use a good fumecupboard) and chromatograph through an Al_2O_3 column (50 x 450 mm). The eluent (*ca* 3L) is evaporated to *ca* 150ml and cooled when *ca* 103g of phenoxazine **m** 149-153° is obtained. Sublimation yields platelets **m** 158-159°. It forms a green *picrate* **m** 141.5-142°. [Gilman and Moore *JACS* **79** 3485 *1957*; Müller et al. *JOC* **24** 37 *1959*].

Phenoxyacetic acid *[122-59-8]* **M 152.2, m 98-99°.** Crystd from water or aqueous EtOH.

Phenoxyacetyl chloride *[701-99-5]* **M 170.6, b 112°/10mm, 102°/16mm, 225-226°/atm, d_4^{20} 1.235, n_D^{20} 1.534.** If it has no OH band in the IR then distil in a vacuum, taking precutions for the moisture-sensitive copound. If it contains free acid (due to hydrolysis, OH bands in the IR) then add an equal volume of redistilled $SOCl_2$, reflux for 2-3h, evaporate and distil the residue is a vacuum as before. The *amide* has **m** 101°. [McElvain and Carney *JACS* **68** 2592 *1946*].

4-Phenoxyaniline *[139-59-3]* **M 185.2, m 95°.** Crystd from water.

Phenoxybenzamine *[59-96-1]* **M 303.5, hydrochloride** *[63-92-3]* **M 340.0, m 137.5-140°.** Crystd from EtOH/ethyl ether.

2-Phenoxybenzoic acid *[2243-42-7]* **M 214.2, m 113°, b 355°/760mm,**
3-Phenoxybenzoic acid *[3739-38-6]* **M 214.2, m 145°.** Crystd from aqueous EtOH.

Phenoxybutyric acid *[6303-58-8]* **M 180.2, m 63-65°, 64°, 65-66°, b 180-185°/12mm.** It has been purified by recrystn from pet ether, C_6H_6, Et_2O-pet ether, EtOH and from H_2O. It can be distd in a good vac. [UV: Ramart-Lucas and Hoch *Bull Soc Chim France* [4] **51** 824 *1932*; Dann and Arndt *A* **587** 38 *1954*]. The *acid chloride* has **b** 154-156°/20mm [Hamford and Adams *JACS* **57** 921 *1935*]; and the *amide* crystallises from C_6H_6 as needles **m** 113°.

2-Phenoxypropionic acid *[940-31-8]* **M 166.2, m 115-116°, b 105-106°/5mm, 265-266°/758mm.** Crystd from water.

Phensuximide *[86-34-0]* **M 189.2, m 71-73°.** Crystd from hot 95% EtOH.

Phenylacetamide *[103-81-1]* **M 135.2, m 158.5°.** Crystd repeatedly from absolute EtOH. Dried under vacuum over P_2O_5.

Phenyl acetate *[122-79-2]* **M 136.2, b 78°/10mm, d 1.079, n^{22} 1.5039.** Freed from phenol and acetic acid by washing (either directly or as a soln in pentane) with aqueous 5% Na_2CO_3, then with saturated aqueous $CaCl_2$, drying with $CaSO_4$ or Na_2SO_4, and fractional distn at reduced pressure.

Phenylacetic acid *[103-82-2]* **M 136.2, m 76-77°, b 140-150°/20mm.** Crystd from pet ether (b 40-60°), isopropyl alcohol, aq 50% EtOH or hot water. Dried under vac. It can be distd under reduced pressure.

Phenylacetone *[103-79-9]* **M 134.2, b 69-71°/3mm, d 1.00, n 1.516.** Converted to the semicarbazone and crystd three times from EtOH (**m** 186-187°). The semicarbazone was hydrolysed with 10% phosphoric acid and the ketone was distd. [Kumler, Strait and Alpen *JACS* **72** 1463 *1950*].

Phenylacetonitrile see **benzyl cyanide.**

4'-Phenylacetophenone *[92-91-1]* **M 196.3, m 120.3-121.2°, b 196-210°/18mm.** Crystd from EtOH. Can also be distd under reduced pressure.

Phenylacetylene *[536-74-3]* **M 102.1, b 75°/80mm, d 0.930, n^{25} 1.5463.** Distd through a spinning band column. Should be filtered through a short column of alumina before use [Collman et al. *JACS* **108** 2988 *1986*].

***dl*-Phenylalanine** *[150-30-1]* **M 165.2, m 162°.** Crystd from water and dried under vacuum over P_2O_5.

L-Phenylalanine *[63-91-2]* **M 165.2, m 280°(dec), $[\alpha]_D^{25}$ -34.0° (c 2, H_2O).** Likely impurities are leucine, valine, methionine and tyrosine. Crystd from water by adding 4 volumes of EtOH. Dried under vac over P_2O_5. Also crystd from satd refluxing aq solns at neutral pH, or 1:1 (v/v) EtOH/water soln, or conc HCl.

***R*-(+)-** *[5267-64-1]* ***S*-(-)-** *[3182-95-4]* **Phenylalaninol (2-amino-3-phenylpropan-1-ol) M 151.2, m 91-92°, 91.5°, 92-94°, b 80°/11mm (Kugelrohr), $[\alpha]_{546}^{20}$ ±28°, $[\alpha]_D^{20-25}$ ±23-28.7° (c 1-5, EtOH).** It can be recrystd from Et_2O or C_6H_6-pet ether (b 40-60°) and distd in a vacuum. Has been purified by dissolving in Et_2O, drying over K_2CO_3, filtering, evaporating to a small volume , cooling in ice and collecting the plates. Store in the presence of KOH (i.e. CO_2—free atm). [Karrer and Ehrhardt *HCA* **34** 3203 *1951*; Oeda *Bull Chem Soc Japan* **13** 465 *1938*]. The *picrate* has **m** 141-141.5° (from EtOH-pet ether). The *hydrogen oxalate* has **m** 177°, 161-162° [Hunt and McHale *JCS* 2073 *1957*]. The *racemate* has **m** 87-88° from C_6H_6-pet ether (75-77° from Et_2O) , and the *hydrochloride* has **m** 139-141° [Fodor et al. *JCS* 1858 *1951*].

3-Phenylallyl chloride (cinnamyl chloride) *[E: 18685-01-3][Z: 18684-06-1]* **M 152.6, b 92-93°/3mm.** Distd under vacuum three times from K_2CO_3.

Phenyl 4-aminosalicylate *[133-11-9]* **M 229.2, m 153°.** Crystd from isopropanol.

4-Phenylanisole *[361-37-6]* **M 184.2, m 89.9-90.1°.** Crystd from benzene/pet ether. Dried under vacuum in an Abderhalden pistol.

9-Phenylanthracene *[602-55-1]* **M 254.3, 153-154°.** Chromatographed on alumina in benzene and crystd from acetic acid.

***N*-Phenylanthranilic acid** *[91-40-7]* **M 213.2, 182-183°.** Crystd from EtOH (5ml/g) or acetic acid (2ml/g) by adding hot water (1ml/g).

2-Phenyl-1-azaindolizine *[56983-95-0]* **M 194.2, m 140°.** Crystd from EtOH or benzene/pet ether.

***p*-Phenylazoaniline** see ***p*-aminoazobenzene,**

***p*-Phenylazobenzoyl chloride** *[104-24-5]* **M 244.7, m 93°.** Crystd from pet ether (b 60-80°).

4-Phenylazodiphenylamine see **benzeneazodiphenylamine.**

1-Phenylazo-2-naphthol (Sudan I) *[842-07-9]* **M 248.3, m 131°.** Crystd from EtOH.

4-Phenylazo-α-naphthylamine *[131-22-6]* **M 247.3.** Crystd from cyclohexane.

1-Phenylazo-2-napthylamine *[85-84-7]* **M 247.3, m 99-100°.** Crystd from absolute EtOH or glacial acetic acid.

4-Phenylazophenacyl bromide M 317.3, m 103-104°. Purified on a column of silica gel, using pet ether/ethyl ether (9:1 v/v) as solvent.

4-Phenylazophenol *[1689-82-3]* **M 198.2, m 155°.** Crystd from benzene or 95% EtOH.

Phenyl benzoate *[93-99-2]* **M 198.2, m 69.5°, b 198-199°.** Crystd from EtOH using *ca* twice the volume needed for complete soln at 69°.

Phenyl-1,4-benzoquinone *[363-03-1]* **M 184.2, m 114-115°.** Crystd from heptane or pet ether (b 60-70°) and sublimed *in vacuo*. [Carlson and Miller *JACS* **107** 479 *1985*].

***N*-Phenylbenzylamine** see **benzylaniline.**

1-Phenylbiguanide *[102-02-3]* **M 177.2, m 144-146°.** Crystd from water or toluene.

Phenyl boric acid (benzeneboronic acid) see Chapter 4.

1-Phenyl-1,3-butanedione see **benzoylacetone.**

***S*-(-)-1-Phenylbutanol** *[22135-49-5]* **M 150.2, m 46-47°, 46-48°, 49°, b 90-92°/2mm.** $[\alpha]_D^{18}$ **-51.4° (c 5, $CHCl_3$),** -44.7° **(c 5.13, C_6H_6).** Purified by distn and crystallises on cooling. The *hydrochloride* has $[\alpha]_D^{20}$ +45.1° (c 4.8, C_6H_6). The (-)-*hydroperoxide* has **b** 58°/0.005mm, n_D^{20} 1.5123, α_D^{18} -2.14°, (l = 0.5, neat). [Holding and Ross *JCVS* 145 *1954*; Davies and Feld *JCS* 4637 *1958*]. The (±)-*racemate* has **b** 73°/0.05mm, and its *4-nitrophenylhydrazone* has **m** 58°.

1-Phenylbutan-2-one see **benzyl ethyl ketone.**

Phenylbutazone *[50-33-9]* **M 308.4, m 105°.** Crystd from EtOH.

***trans*-4-Phenyl-3-buten-2-one** see **benzalacetone.**

2-Phenylbutyramide *[90-26-6]* **M 163.2, m 86°.** Crystd from water.

***R*-(-)-** *[937-79-4]* **and *S*-(+)-** *[4286-15-1]* **2-Phenylbutyric acid M 164.2, b 102-104°/atm,** d_4^{20} **1.056,** n_D^{20} **1.521,** $[\alpha]_D^{20} \pm 96°$ **(c 2.5, C_6H_6),** $[\alpha]_D^{23} \pm 95.8$ **(neat).** Purified by distn at atmospheric pressure using an efficient column. The *acid chlorides* have **b** 106-107°/20mm, $[\alpha]_D^{18} \pm 108°$ (c 2,

C_6H_6). [Levene et al. *JBC* **100** 589 *1933*, Gold and Aubert *HCA* **41** 1512 *1958*; ORD in heptane: Rothen and Levene *JCP* **7** 975 *1939*].

***R*-(-)- *[772-14-5]* and *S*-(+)- *[772-15-6]* 3-Phenylbutyric acid M 164.2, b 94-95°/3mm, 134°/4mm, d_4^{26} 1.066, n_D^{25} 1.5167, $[\alpha]_D^{20} \pm 57°$ (c 1, C_6H_6).** Purified as the 2-isomer above, i.e. by distn, but under a good vacuum. [Prelog and Scherrer *HCA* **42** 2227 *1959*; Levene and Marker *JBC* **93** 761 *1932*, **100** 685 *1933*; Cram *JACS* **74** 2137 *1952*]. The *R-amide* crystallises from H_2O, **m** 101.5-102°, $[\alpha]_D^{20}$ -16.5° (c 1.2, EtOH). The *racemic acid* has **m** 39-40°, **b** 134-136°/6mm, 158°/12mm [Marvel et al. *JACS* **62** 3499 *1940*].

4-Phenylbutyric acid *[1821-12-1]* **M 164.2, m 50°.** Crystd from pet ether (b 40-60°).

***o*-(Phenylcarbamoyl)-1-scopolamine methobromide M 518.4, m 200.5-201.5°(dec).** Crystd from 95% EtOH.

9-Phenylcarbazole *[1150-62-5]* **M 243.3, m 94-95°.** Crystd from EtOH or isopropanol and sublimed *in vacuo*.

***O*-Phenyl chlorothionoformate** *[1005-56-7]* **M 172.6, b 81-83°/6mm, 91°/10mm, d_4^{20} 1.276, n_D^{20} 1.585.** Purified by dissolving in $CHCl_3$, washing with H_2O, drying ($CaCl_3$), filtering, evaporating and distilling twice under vacuum to give a clear yellow liquid. **It is reactive and POISONOUS - work in a fumecopboard.** Store in sealed ampoules under N_2. Possible impurity is *O,O'-diphenyl thiocarbonate* which has **m** 106° which remains behind in the distilling flask. [Bögemann et al. in *Methoden Der Organischen Chemie (Houben-Weyl)* 4th edn (E.Müller ed.) **Vol 9** *Schwefel-Selen-Tellur Verbindungen* pp807-808 *1955*; Rivier and Schalch *HCA* **6** 612 *1932*; Kalson *B* **20**, 2384 *1987*; Rivier and Richard *HCA* **8** 490 *1925*; Schönberg and Varga *A* **483** 176 *1930*; *B* **64** 1390 *1931*].

Phenyl cinnamate *[2757-04-2]* **M 224.3, m 75-76°, b 205-207°/15mm.** Crystd from EtOH (2ml/g). It can also be distd under reduced pressure.

α-Phenylcinnamic acid *[91-48-5]* **M 224.3, m 174°(*cis*), m 138-139°(*trans*).** Crystd from ether/pet ether.

α-Phenyl-*p*-cresol see ***p*-benzylphenol.**

***o*-Phenylenediamine** *[95-54-5]* **M 108.1, m 100-101°.** Crystd from aqueous 1% sodium hydrosulphite (charcoal), washed with ice-water and dried in a vacuum desiccator, or sublimed *in vacuo*. It has been purified by recrystn from toluene and zone refined [Anson et al. *JACS* **108** 6593 *1986*]. Purification by refluxing a CH_2Cl_2 solution containing charcoal was also carried out followed by evaporation and recrystn [Koola and Kochi *JOC* **52** 4545 *1987*], protect from light.

***m*-Phenylenediamine** *[108-45-2]* **M 108.1, m 61-63°, 62-63°, 62.85°, 63-64°, b 146°/22mm, 282-284°/760mm, 284-287°/atm, d_{10}^{10} 1.1422, $n_D^{57.7}$ 1.6340.** Purified by distn under vac followed by recryst from EtOH (rhombs) and if necessary redistn. It should be protected from light otherwise it darkens rapidly. [Neilson et al. *JCS* 371 *1962*; IR: Katritzky and Jones *JCS* 3674, 2058 *1959*; UV: Forbes and Leckie *Canad J Chem* **36** 1371 *1958*]. The *hydrochloride* has **m** 277-278°, and the *bis-4-chlorobenzenesulphonyl* derivative has **m** 220-221° from H_2O (214-215°, from MeOH-H_2O) [Runge and Pfeiffer *B* **90** 1737 *1957*].

***p*-Phenylenediamine** *[106-50-3]* **M 108.1, m 140°.** Crystd from EtOH or benzene, and sublimed *in vacuo*, protect from light.

***o*-Phenylenediamine dihydrochloride** *[615-28-1]* **M 181.1, m 180°.** Crystd from dilute HCl (60ml conc HCl, 40ml water, with 2g stannous chloride), after treatment of the hot soln with charcoal by adding an equal volume of conc HCl and cooling in an ice-salt mixture. The crystals were washed with a small amount of conc HCl and dried in a vacuum desiccator over NaOH.

2-Phenyl-1,3-diaza-azulene *[2161-31-1]* **M 187.5.** Recrystd three times from de-aerated cyclohexane in the dark.

1,4-Phenylene diisothiocyanate (bitoscanate) *[4044-65-9]* **M 192.3, m 129-131°, 130-131°, 132°.** Purified by recrystn from AcOH, pet ether (b 40-60°), Me_2CO or aq Me_2CO. [van der Kerk et al. *Rec Trav Chim Pays Bas* **74** 1262 *1955*; Leiber and Slutkin *JOC* **27** 2214 *1962*].

***R*-(-)-** *[16355-00-3]* **and *S*-(+)-** *[25779-13-9]* **1-Phenyl-1,2-ethanediol M 138.2, m 64-67°, 65-66°, $[\alpha]_D^{24}$ ±40.5° (c 2.8, H_2O), $[\alpha]_D^{20}$ ±39° (c 3, EtOH).** Purified by recryst from C_6H_6-ligroin and sublimed at 1-2mm. [Arpesella et al. *Gazetta* **85** 1354 *1955;* Prelog et al. *HCA* **37** 221 *1954*].

***R*-(+)-** *[33375-06-3]* **and *S*(-)-** *[14649-03-7]* **1-Penylethyl isocyanate M 147.2, b 82-83°/12-14mm, d_4^{20} 1.045, n_D^{20} 1.513, $[\alpha]_D^{24}$ ±-2° (c 3.5, C_6H_6), ±10.5° (neat).** Purified by fractional distn under vacuum. With ammonia it gives the *ureido* derivative which crystallises from H_2O, **m** 121-122°, $[\alpha]_D^{25}$ ±48.8°. [Cairns *JACS* **63** 870 *1941*]. The *racemate* has **b** 90-94°/3mm, 96°/18mm [Seiftan *A* **562** 75 *1949*].

Phenyl disulphide see **diphenyl disulphide.**

***dl*-1-Phenylethanol** *[13323-81-4]* **M 122, b 106-107°/22-23mm, d 1.01, n^{25} 1.5254.** Purified *via* its hydrogen phthalate. [See Houssa and Kenyon *JCS* 2260 *1930*]. Shaken with a soln of ferrous sulphate, and the alcohol layer was washed with distilled water and fractionally distd.

2-Phenylethanol *[60-12-8]* **M 122.1, b 215-217°, d 1.020.** Purified by shaking with a soln of ferrous sulphate, and the alcohol layer was washed with distd water and fractionally distd.

Phenyl ether *[101-84-8]* **M 170.2, m 27.0°, d 1.074, $n^{30.7}$ 1.57596.** Crystd from 90% EtOH. Melted, washed with 3M NaOH and water, dried with $CaCl_2$ and fractionally distd under reduced pressure. Fractionally crystd from its melt and stored over P_2O_5.

***p*-α-Phenylethylphenol** *[1988-89-2]* **M 198.3, m 56.0-56.3°.** Crystd from pet ether.

5-(α-Phenylethyl)semioxamazide *[93-95-8]* **M 207.1, m 167-168° (*l*-), 157° (*dl*-).** Crystd from EtOH.

9-Phenyl-3-fluorone *[975-17-7]* **M 320.3, m >300°(dec), λ_{max} 462nm (ε 4.06 x 10^4, in 1M HCl aq EtOH).** Recrystd from warm, acidified EtOH by addition of ammonia. The crude material (1g) can be extracted with EtOH (50ml) in a Soxhlet apparatus for 10hr to remove impurities. Impurities can be detected by paper electrophoresis. [Petrova et al. *Anal Lett* **5** 695 *1972*].

L-α-Phenylglycine *[2935-35-5]* **M 151.2, m 305-310°, $[\alpha]_{546}$ +185° (c 1, M HCl).** Crystd from EtOH.

Phenylglycine-*o*-carboxylic acid *[612-42-0]* **M 195.2, m 208°.** Crystd from hot water (charcoal).

Phenylglyoxaldoxime see **isonitrosoacetophenone.**

Phenylhydrazine *[100-63-0]* **M 108.1, m 23°, b 137-138°/18mm, 241-242°/760mm, d 1.10, n 1.607.** Purified by chromatography, then crystd from pet ether (b 60-80°)/benzene. [Shaw and Stratton *JCS* 5004 *1962*].

Phenylhydrazine hydrochloride *[59-88-1]* **M 144.5, m 244°.** One litre of boiling EtOH was added to 100g of phenylhydrazine hydrochloride dissolved during 1-3h (without heating) in 200ml of warm water (60-70°). The soln was filtered off, while still hot, through Whatman No 2 filter paper and cooled in a refrigerator. The ppte was collected on a medium sintered-glass filter and recrystd twice this way, then washed with cold

EtOH, dried thoroughly and stored in a stoppered brown bottle. [Peterson, Karrer and Guerra *AC* **29** 144 *1957*]. Hough, Powell and Woods [*JCS* 4799 *1956*] boiled the hydrochloride with three times its weight of water, filtered hot (charcoal), added one-third volume of conc HCl and cooled to 0°. The crystals were washed with acetone, and dried over P_2O_5 under vacuum. The salt has also been crystd from 95% EtOH.

Phenylhydroxylamine *[100-65-2]* **M 109.1, m 82°.** Crystd from water.

2-Phenyl-1,3-indandione *[83-12-5]* **M 222.2, m 149-151°,**
2-Phenylindolizine *[25379-20-8]* **M 193.2, m 214°(dec).** Crystd from EtOH.

Phenylisocyanate *[103-71-9]* **M 119.1, b 45-47°/10mm, d 1.093, n 1.536.** Distd under reduced pressure from P_2O_5.

Phenylisothiocyanate (phenyl mustard oil) *[103-72-0]* **M 135.2, m -21°, b 95°/12mm, 117.1°/33mm, 221°/760mm,** d_4^{25} **1.1288,** $n_D^{23.4}$ **1.64918.** It is insol in H_2O, but sol in Et_2O and EtOH. If impure (due to formation of thiourea) then steam dist into a receiver containing 5-10ml of N H_2SO_4. Separate the oil, dry over $CaCl_2$ and distil under vacuum. [Dains et al. *Org Synth* Coll Vol I 447 *1941*].

3-Phenyllactic acid see **2-hydroxy-3-phenylpropionic acid.**

1-Phenyl-5-mercaptotetrazole *[86-93-1]* **M 178.2, m 150° (dec), 155° (dec), 157-158°.** Purified by recryst from EtOH or $CHCl_3$ (**m** 152°), and has a pKa^{25} of 3.65 in 5% aqueous EtOH. [Tautomerism: Kauer and Sheppard *JOC* **32** *3580 1967*; UV: Leiber et al. *Canad J Chem* **37** *563 1959*]. The *ammonium salt* crystallises from EtOH and dec at 176°, and the *sodium salt* crystallises from EtOH-C_6H_6, melts at 96° and dec at 145° [Stollé *J Prakt Chem* [2] **133** 60 *1932*].

Phenyl methanesulphonate *[16156-59-5]* **M 172.1, m 61-62°.** Crystd from MeOH.

2-Phenylnaphthalene *[612-94-2]* **M 204.3, m 103-104°.** Chromatographed on alumina in benzene and crystd from aqueous EtOH.

***N*-Phenyl-1-naphthylamine** *[90-30-2]* **M 219.3, m 63.7-64.0°.** Crystd from EtOH, pet ether or benzene/EtOH. Dried under vacuum in an Abderhalden pistol.

***N*-Phenyl-2-naphthylamine** *[135-88-6]* **M 219.3, m 107.5-108.5°.** Crystd from EtOH, MeOH, glacial acetic acid or benzene/hexane.

4-Phenylphenacyl bromide *[135-73-9]* **M 275.2, m 126°.** Crystd (charcoal) from EtOH (15ml/g), or ethyl acetate/pet ether (b 90-100°.

4-Phenylphenol (4-hydroxybiphenyl) *[92-69-3]* **M 170.2, m 166-167°.** Crystd from benzene, EtOH or EtOH/water, and vacuum dried in a desiccator over $CaCl_2$. [Buchanan et al. *JACS* **108** 7703 *1986*].

2-Phenylpropanal *[93-53-8]* **M 134.2, b 206°/760mm, d 1.001, n 1.5183.** May contain up to 15% of acetophenone. Purified *via* the bisulphite addition compound [Lodge and Heathcock *JACS* **109** 3353 *1987*].

Phenyl-2-propanone see **phenylacetone.**

Phenylpropiolic acid *[637-44-5]* **M 146.2, m 137.8-138.4°.** Crystd from benzene, CCl_4 or aqueous EtOH.

α-Phenylpropionic acid *[492-37-5]* **M 150.2, m 49°.** Crystd from pet ether (b 40-60°).

R-(-)- *[7782-26-5]* **and** *S*-(+)- *[7782-24-3]* **2-Phenylpropionic acid M 150.2, m 30.3-31°, 30-32°, b 121-123°/0.5mm, 115°/1-2mm, $[\alpha]_D^{20}$ ±99.7° (l = 1, neat), ±81° (c 1.7, EtOH), ±73° (c 1.6, $CHCl_3$).** Purified by vacuum distn and by recrystn from pet ether. The *anilide* has **m** 99-100°, $[\alpha]_D^{20}$ ±120° (c 1.1, EtOH) [Fodor and Csepregly *TET LETT* **no 7** p16 *1959*; Bernstein and Whitmore *JACS* **61** 1324 *1939*].

3-Phenylpropyl bromide *[637-59-2]* **M 199.1, b 110°/12mm, 128-129°/29mm, d 1.31.** Washed successively with conc H_2SO_4, water, 10% aqueous Na_2CO_3 and again with water, then dried with $CaCl_2$ and fractionally distd just before use.

Phenyl 2-pyridyl ketoxime *[1826-28-4]* **M 198.2, m 151-152°.** Crystd from EtOH (charcoal).

Phenylpyruvic acid *[156-06-9]* **M 164.2, m 150-154°, 158-159°.** Recrystd from C_6H_6. The *phenylhydrazone* has **m** 173° [Zeller *HCA* **26** 1614 *1943*; Hopkins and Chisholm *Canad J Research* [B] **24** 89 *1946*]. The *2,4-dinitrophenylhydrazone* has **m** 162-164° (189°, 192-194°) [Fones *JOC* **17** *1952*].

6-Phenylquinoline *[162-95-3]* **M 205.3, m 110.5-111.5°**. Crystd from EtOH (charcoal).

2-Phenylquinoline-4-carboxylic acid *[132-60-5]* **M 249.3, m 215°.** Crystd from EtOH (*ca* 20ml/g).

Phenyl salicylate *[118-55-8]* **M 214.2, m 41.8-42.6°.** Fractionally crystd from its melt, then crystd from benzene.

2-Phenylsalicylic acid *[304-06-3]* **M 214.3, m 186-187.5°.** Dissolved in *ca* 1 equivalent of saurated aqueous Na_2CO_3, filtered and ppted by adding 0.8 equivalents of M HCl. Crystd from ethylene dichloride (charcoal), and sublimed at 0.1mm. [Brooks, Eglington and Norman *JCS* 661 *1961*].

1-Phenylsemicarbazide *[103-03-7]* **M 151.2, m 172°,**
4-Phenylsemicarbazide *[537-47-3]* **M 151.2, m 122°.** Crystd from water and dried in vac over KOH.

R-(-)- *[46292-93-7]* **and** *S*-(+)- *[4036-30-1]* **Phenylsuccinic acid M 194.2, m 173-176°, 178.5-179°, 179-180°, $[\alpha]_D^{25}$ ±171° (c 2, Me_2CO), $[\alpha]_D^{26-30}$ ±148° (c 0.27-5, EtOH).** Purified by repptn from alkali and recrystn from H_2O. [Naps and Johns *JACS* **62** 2450 *1940*; Fredga and Matell *Bull Soc Chim Belges* **62** 47 *1953*; Wren and Williams *JCS* **109** 572 *1916*]. The *racemate [635-51-8]* has **m** 166-168°, 168° after recrystn from H_2O or MeCN and pKa^{25} values in H_2O of 3.78 and 5.55; its *S-benzylthiouronium salt* has **m** 164-165° (from EtOH) [Griediger and Pedersen *Acta Chem Scand* **9** 1425 *1955*].

1-Phenyl-5-sulphanilamidopyrazole *[526-08-9]* **M 314.3, m 179-183°,**
1-Phenylthiosemicarbazide *[645-48-7]* **M 167.2, m 200-201°(dec),**
4-Phenylthiosemicarbazide *[5351-69-9]* **M 167.2, m 140°.** Crystd from EtOH.

1-Phenyl-2-thiourea *[103-85-5]* **M 152.1, m 154°.** Crystd from water and dried at 100° in air.

Phenyltoloxamine hydrochloride *[6152-43-8]* **M 291.8, m 119-120°.** Crystd from isobutyl methyl ketone.

Phenyl 4-toluenesulphonate *[640-60-8]* **M 248.2, m 94.5-95.5°.** Crystd from MeOH or glacial acetic acid.

Phenyl 4-tolylcarbonate *[13183-20-5]* **M 228.2, m 67°.** Purified by preparative GLC with 20% Apiezon on Embacel, and sublimed *in vacuo.*

4-Phenyl-1,2,4-triazole-3,5-diol *[15988-11-1]* **M 175.2, m 207-209°.** Crystd from water.

R-(-)- *[10531-50-7]* **and** *S*-(+)- *[340-06-7]* **1-Phenyl-2,2,2-trifluoroethanol M 176.1, b 74-76°/10mm, 125-127°/760mm, d_4^{20} 1.301, n_D^{20} 1.4632, $[\alpha]_D^{20}$±31° (neat).** Purified by fractional distn preferably in a vacuum. [Morrison and Ridgeway *TET LETT* 573 *1969*; NMR: Pirkle and Beare *JACS* **90** 6250 *1968*]. The *racemate [340-05-6]* has **b** 52-54°/2mm, 57-59°/2mm, 64-65°/5mm, d_4^{20} 1.293, n_D^{20} 1.457, and it *2-carbobenzoyl* derivative has **m** 137-138° [Mosher et al. *JACS* **78** 4374 *1956*].

4-Phenylurazole see **4-phenyl-1,2,4-triazole-3,5-diol.**

Phenylurea *[64-10-8]* **M 136.2, m 148°.** Crystd from boiling water (10ml/g). Dried in a steam oven at 100°.

9-Phenyl-9-xanthenol (hydroxypixyl) *[596-38-3]* **M 274.3, m 158-161°, 158.5-159°, 159°.** Dissolve in AcOH and add H_2O whereby it separates as colourless prisms. It is slightly soluble in $CHCl_3$, soluble in C_6H_6 but insoluble in pet ether. It sublimes on heating. UV in H_2SO_4: λmax 450nm (ε 5620) and 370nm (ε 24,900) and the $HClO_4$ salt in $CHCl_3$ has λmax 450 (ε 404) and 375nm (ε 2420). [Sharp *JCS* 2558 *1958*; Bünzly and Decker *B* **37** 2983 *1904*; Chattopadhyaya and Reece *JCSCC* 639 *1978*; Gomberg and Cone *A* **370** 142 *1909*].

Phloretic acid see **3-*p*-hydroxyphenylpropionic acid.**

Phloretin *[60-82-2]* **M 274.3, m 264-271°(dec).** Crystd from aqueous EtOH.

Phlorizin ($2H_2O$) *[60-81-1]* **M 472.5, m 110°, $[\alpha]_{546}^{20}$ -62° (c 3.2, EtOH).** Crystd as dihydrate from water.

Phloroacetophenone ($2H_2O$) *[480-66-0]* **M 186.2, m 218-219°.** Crystd from hot water (35ml/g).

Phloroglucinol ($2H_2O$) *[6099-90-7]* **M 126.1, m 217-219°, 117° (anhydrous).** Crystd from water, and stored in the dark under nitrogen.

Phorone *[504-20-1]* **M 138.2, m 28°, b 197°/743mm.** Crystd repeatedly from EtOH.

"Phosphine" (a dye, CI 793). Crystd from benzene/EtOH.

Phthalaldehyde *[643-79-8]* **M 134.1, m 54-56°, 55.5-56°, 58°, b 83-84°/0.8mm.** Purified by steam distillation better by using super heated steam (at 175-180°) and efficient cooling. The distillate is saturated with Na_2SO_4 extracted exhaustively with EtOAc, dried (Na_2SO_4), filtered and evaporated. The residue is recrystd from pet ether (b 90-100°) [Beill and Tarbell *Org Synth* Coll Vol IV 808 *1963*]. It can be distd under vacuum. The bis-*2,4-dinitrophenylhydrazone* has **m** 278-280° [Hatt and Stephenson *JCS* 199 *1952*].

Phthalazine *[253-52-1]* **M 130.2, m 90-91°.** Crystd from ethyl ether or benzene, and sublimed under vacuum.

Phthalazine-1,4-dione *[1445-69-8]* **M 162.2.** Twice recrystd from 0.1M KOH [Merenyi et al. *JACS* **108** 7716 *1986*].

Phthalazone *[119-39-1]* **M 146.2, m 183-184°, b 337°/760mm.** Crystd from water and sublimed *in vacuo.*

Phthalein complexon *[2411-89-4]* **M 654.6.** *o*-Cresolphthalein is a contaminant and is one of the starting materials. It can be removed by dissolving the reagent in water and adding a 3-fold excess of sodium acetate and fractionally precipitating it by dropwise addition of HCl to the clear filtrate. The pure material gives a single spot on paper chromatography (eluting solvent EtOH/water/phenol, 6:3:1; and developing with NaOH). [Anderre et al. *HCA* **37** 113 *1954*].

Phthalhydrazide see **phthalazine-1,4-dione.**

o-**Phthalic acid** *[88-99-3]* **M 166.1, m 211-211.5°.** Crystd from water.

Phthalic anhydride *[85-44-9]* **M 148.1, m 132°, b 295°.** Distd under reduced pressure. Purified from the acid by extraction with hot $CHCl_3$, filtered and evaporated. The residue was crystd from $CHCl_3$, CCl_4 or benzene. Fractionally crystd from its melt. Dried under vacuum at 100°. [Saltiel *JACS* **108** 2674 *1986*].

Phthalide *[87-41-2]* **M 134.1, m 72-73°.** Crystd from water (75ml/g) and dried in air on filter paper.

Phthalimide *[85-41-6]* **M 147.1, m 235°.** Crystd from EtOH (20ml/g) (charcoal), or by sublimation.

Phthalimide potassium salt (potassium phthalimide) *[1074-82-4]* **M 185.2, m >300°.** The solid may contain phthalimide and K_2CO_3 from hydrolysis. If too much hydrolysis has occurred (this can be checked by extraction with cold Me_2CO in which the salt is insoluble, evaporation of the Me_2CO and weighing the residue) then it would be better to prepare it afresh. If little hydrolysis had occurred then recryst from a large vol of EtOH, and wash solid with a little Me_2CO and dry in a continuous vac to constant weight. [Salzerg and Supriawski *Org Synth* Coll Vol I 119 *1941*; Raman and IR: Hase *J Molecular Structure* **48** 33 *1978*; Dykman *Chemistry and Industry (London)* 40 *1972*; IR, NMR: Assef et al. *Bull Soc Chim France* II 167 *1979*].

Phthalimidoglycine *[4702-13-0]* **M 205.2, m 192-193°.** Crystd from water or EtOH.

Phthalonitrile *[91-15-6]* **M 128.1, m 141°.** Crystd from EtOH or benzene. Can also be distd under high vacuum.

Phthalylsulphacetamide *[131-69-1]* **M 362.3, m 196°.** Crystd from water.

Phthiocol *[483-55-6]* **M 188.1, m 173-174°.** Crystd from ethyl ether/pet ether.

Physalien *[144-67-2]* **M 1044, m 98.5-99.5°,** $\varepsilon^{1\%}_{1m}$ **1410 (449nm), 1255 (478nm) in hexane.** Purified by chromatography on water-deactivated alumina, using hexane/ethyl ether (19:1) to develop the column. Crystd from benzene/EtOH. Stored in the dark, in inert atmosphere, at 0°.

Physostigmine (Eserine) *[57-47-6]* **M 275.4, m 105-106°,** $[\alpha]^{20}_{546}$ **-91° (c 1.7, $CHCl_3$).** Crystd from ethyl ether or benzene.

Phytoene *[540-04-5]* **M 544.9,** $\varepsilon^{1\%}_{1m}$ **850 (287nm) in hexane,** λ_{max} **275, 287 and 297nm nm.** Purified by chromatography on columns of magnesia-Supercel or alumina [Rabourn et al. *Arch Biochem Biophys* **48** 267 *1954*]. Stored as a solution in pet ether under nitrogen at -20°.

Phytofluene *[27664-65-9]* **M 542.9,** $\varepsilon^{1\%}_{1m}$ **1350 (348nm) in pet ether,** λ_{max} **331, 348, 267.** Purified by chromatography on partially deactivated alumina [Kushwaha et al. *JBC* **245** 4708 *1970*]. Stored as a soln in pet ether under nitrogen at -20°.

Picein *[530-14-3]* **M 298.3, m 195-196°.** Crystd from MeOH or (as monohydrate) from water.

Picene *[213-14-3]* **M 278.3, m 364°.** Crystd from isopropylbenzene/xylene. Can also be sublimed.

Picoline see **methylpyridine.**

2-Picoline-*N*-oxide (2-methylpyridine 1-oxide) *[931-19-1]* **M 109.1, m 41-45°, b 89-90°/0.8-0.9mm, 90-100°/1mm, 110°/4mm, 135°/5mm, 123°/9mm, 123-124°/15mm, 259-261°/atm,** n_D^{25} **1.5854 (supercooled).** Purified by fractional distillation and could be recrystd from C_6H_6-hexane but is *hygroscopic.* [Bullitt and Maynard *JACS* **76** 1370 *1954*; Ross et al. *JACS* **78** 3625 *1956*; IR: Wiley and SlaymAker *JACS* **79** 2233 *1957*]. The *picrate* has **m** 125-126.5° (from EtOH) [Boekelheide and

Linn *JACS* **76** 1286 *1954*]. The *phthalate* has **m** 115-116° (from EtOH) [den Hertog et al. *Rec Trav Chim Pays Bas* **70** 591 *1951*].

3-Picoline-*N*-oxide (3-methylpyridine 1-oxide) *[1003-73-2]* **M 109.1, m 37-39°, 37-38° (evac capillary) , 84-85°/0.3mm, 101-103°/0.7-0.8mm, 114-115°/1.5mm, 118°/2mm.** Purified by careful fractionation *in vacuo*. The distillate remains supercooled for several days before solidifying. It is a slightly *hygroscopic* solid which could melt in the hand. It has a pKa^{25} if 1.08 in H_2O. The *picrate* has **m** 149-151° (from EtOH). [Taylor and Corvetti *Org Synth* Coll Vol IV 654 *1963*; IR: Katritzky et al. *JCS* 3680 *1959*; Jaffé and Doak *JACS* **77** 4441, 4481 *1955*; Boekelheide and Linn *JACS* **76** 1286 *1954*].

4-Picoline-*N*-oxide (4-methylpyridine 1-oxide) *[1003-67-4]* **M 109.1, m 182-184°, 185-186°, 186-188°.** Recryst from EtOH-EtOAc, or C_6H_6. [Bullitt and Maynard *JACS* **76** 1370 *1954*; Boekelheide and Linn *JACS* **76** 1286 *1954*].

Picolinic acid *[98-98-6]* **M 123.1, m 138°.** Crystd from water or benzene.

α-Picolinium chloride *[14401-91-3]* **M 129.6, m 200°.** 1:1 Mixture of α-picoline and HCl, distd at 275°. Then vacuum sublimed at 91-91.5°.

***N*-Picolinoylbenzimidazole M 173.3, m 105-107°.** Recrystd three times from hexane [Fife and Przystas *JACS* **108** 4631 *1986*].

Picric acid *[88-89-1]* **M 229.1, m 122-123°.** Crystd first from acetic acid then acetone, toluene, $CHCl_3$, aqueous 30% EtOH, 95% EtOH, MeOH or H_2O. Dried in a vacuum oven at 80° for 2h. Alternatively, dried over $Mg(ClO_4)_2$ or fused and allowed to freeze under vacuum three times. Because it is **EXPLOSIVE**, picric acid should be stored moistened with H_2O, and only small portions should be dried at any one time. The dried acid should **NOT** be heated.

Picrolonic acid (picrolic acid) *[550-74-3]* **M 264.2, m 120°(dec),116.5° (dec at 125°) 125°.** Crystd from water or EtOH (Solubility is 0.123% at 15° and 1.203% at 100° in H_2O; and 1.107% at 0° and 11.68% at 81° in EtOH). It forms Ca, Cu and Pb complexes [Maquestian et al *Bull Soc Chim Belges* **82** 233 *1973*; Isaki et al. *B* **74** 1420 *1941*].

Picrotoxin *[124-87-8]* **M 602.6, m 203°, $[\alpha]_{546}^{20}$ -40° (c 1, EtOH).** Crystd from water.

Picryl chloride *[88-880]* **M 226.3, m 83°.** Crystd from $CHCl_3$ or EtOH.

Picryl iodide *[4436-27-5]* **M 340.0, m 164-165°.** Crystd from benzene.

Pimelic acid *[111-16-0]* **M 160.2, m 105-106°.** Crystd from water or from benzene containing 5% ethyl ether.

Pinacol (hexahydrate) *[6091-58-3]* **M 194.3, m 46.5°, b 59°/4mm.** Distd then crystd repeatedly from water.

Pinacol (anhydrous) *[76-09-5]* **M 118.1, m 41.1°, b 172°.** The hydrate is rendered anhydrous by azeotropic distn of water with benzene. Recrystd from benzene or toluene/pet ether, absolute EtOH or dry ethyl ether. Recrystn from water gives the hexahydrate.

Pinacolone oxime *[2475-93-6]* **M 115.2, m 78°.** Crystd from aqueous EtOH.

Pinacyanol chloride *[2768-90-3]* **M 388.9, m 270°(dec).** Crystd from EtOH/ethyl ether.

***R*-α-Pinene** *[7785-70-8]* **M 136.2, b 61°/30mm, 156.2°/760mm, d 0.858, n^{15} 1.4634, n 1.4658, $[\alpha]_D^{25}$ +47.3°,**

***S*-α-Pinene** *[7785-26-4]* **M 136.2, b 155-156°/760mm, d 0.858, n 1.4634, $[\alpha]_D^{20}$ -47.2°.** Isomerised by heat, acids and certain solvents. Should be distd under reduced pressure under nitrogen and stored in the dark. Purified *via* the nitrosochloride [Waterman et al. *Rec Trav Chim Pays-Bas* **48** 1191 *1929*]. For purification of optically active forms see Lynn [*JACS* **91** 361 *1919*].
Small quantities (0.5ml) have been purified by GLC using helium as carrier gas and a column at 90° packed with 20 wt% of polypropylene sebacate on a Chromosorb support. Larger quantities were fractionally distd under reduced pressure in a column packed with stainless steel gauze spirals. Material could be dried with CaH_2 or sodium, and stored in a refrigerator: $CaSO_4$ and silica gel were not satisfactory because they induced spontaneous isomerisation. [Bates, Best and Williams *JCS* 1521 *1962*].

***dl*-Pipecolinic acid** *[4043-87-2]* **M 129.1, m 264°.** Crystd from water.

Piperazine *[110-85-0]* **M 86.1, m 110-112°, 44° (hexahydrate** *142-63-2***) b 125-130°/760mm.** Crystd from EtOH or anhydrous benzene, and dried at 0.01mm. It can be sublimed under vacuum and purified by zone melting.

Piperazine-*N,N'*-bis(2-ethanesulphonic acid) (PIPES) *[5625-37-6]* **M 302.4.** Crystd from boiling water (maximum solubility is about 1g/L) or as described for ADA, pK_a^{20} 7.85.

Piperazine dihydrochloride (H_2O) *[6094-40-2]* **M 177.1, m 82.5-83.5°.** Crystd from aqueous EtOH. Dried at 110°

Piperazine-2,5-dione *[106-57-0]* **M 114.1, m 309-310°.** Crystd from water.

Piperazine phosphate (H_2O) *[18534-18-4]* **M 197.6.** Crystd twice from water, air-dried and stored for several days over Drierite. The salt dehydrates slowly if heated at 70°.

Piperic acid *[136-72-1]* **M 218.2, m 217°.** Crystd from EtOH. Protect from light.

Piperidine *[110-89-4]* **M 85.2, f.p. -9°, b 35.4°/40mm, 106°/760mm, d 0.862, n 1.4535, n^{25} 1.4500.** Dried with BaO, KOH, CaH_2, or sodium, and fractionally distd (optionally from sodium, CaH_2, or P_2O_5). Purified from pyridine by zone melting.

***dl*-Piperidine-2-carboxylic acid** see **pipecolinic acid.**

Piperidinium hydrochloride *[6091-44-7]* **M 121.6, m 244-245°.** Crystd from EtOH/ethyl ether in the presence of a small amount of HCl.

Piperidinium nitrate *[6091-45-8]* **M 145.2, m 110°.** Crystd from acetone/ethyl acetate.

Piperine *[94-62-2]* **M 285.4, m 129-129.5°.** Crystd from EtOH or benzene/ligroin.

Piperonal *[120-57-0]* **M 150.1, m 37°, b 140°/15mm, 263°/760mm.** Crystd from aqueous 70% EtOH or EtOH/water.

Piperonylic acid *[94-53-1]* **M 166.1, m 229°.** Crystd from EtOH or water.

Pivalic acid (trimethylacetic acid) *[75-98-9]* **M 102.1, m 35.4°, b 71-73°/0.1mm.** Fractionally distd under reduced pressure, then fractionally crystd from its melt. Recrystd from benzene.

Pivaloyl chloride (trimethylacetyl chloride) *[3282-30-2]* **M 120.6, b 57.6°/150mm, 70-.5-71/250mm, 104°/754mm, 104-105°/atm, 105-108°/atm, d_4^{20} 1.003, n_D^{20} 1.4142.** First check the IR to see if OH bands are present. If absent, or present in small amounts, then redistil under moderate vac. If present in large amounts then treat with oxalyl chloride or thionyl chloride and reflux for 2-3h, evap and distil

residue. **Strongly LACHRYMATORY - work in a fumecupboard.** Store in sealed ampoules under N_2. [Traynham and Battiste *JOC* **22** 1551 *1957*; Grignard reactns: Whitmore et al. *JACS* **63** 647 *1941*].

Pixyl chloride see **9-chloro-9-phenylxanthene.**

Plumbagin *[481-42-5]* **M 188.1, m 78-79°.** Crystd from aqueous EtOH.

Polyacrylonitrile *[25014-41-9].* Ppted from dimethylformamide by addition of MeOH.

Polybrene see **1,5-Dimethyl-1,5-diazaundecamethylene polymethobromide.**

Poly(diallyldimethylammonium) chloride. Ppted from water in acetone, and dried in vacuum for 24h. [Hardy and Shriner *JACS* **107** 3822 *1985*].

Polyethylene *[9002-88-4].* Crystd from thiophen-free benzene and dried over P_2O_5 under vacuum.

Polygalacturonic acid see **pectic acid.**

Polymethyl acrylate *[9002-21-8].* Ppted from a 2% soln in acetone by addition of water.

Polystyrene *[9003-53-6].* Ppted repeatedly from $CHCl_3$ or toluene soln by addition of MeOH. Dried *in vacuo* [Miyasaka et al. *JPC* **92** 249 *1988*].

Polystyrenesulphonic acid (sodium salt) *[25704-18-1].* Purified by repeated pptn of the sodium salt from aqueous soln by MeOH, with subsequent conversion to the free acid by passage through an Amberlite IR-120 ion-exchange resin. [Kotin and Nagasawa *JACS* **83** 1026 *1961*].
Also purified by passage through cation and anion exchange resins in series (Rexyn 101 cation exchange resin and Rexyn 203 anion exchange resin), then titrated with NaOH to pH 7. The sodium form of polystyrenesulphonic acid ppted by addition of 2-propanol. Dried in a vac oven at 80° for 24h, finally increasing to 120° prior to use. [Kowblansky and Ander *JPC* **80** 287 *1976*].

Polyvinyl acetate *[9003-20-7].* Ppted from acetone by addition of *n*-hexane.

Poly(*N*-vinylcarbazole) *[25067-59-8].* Ppted seven times from tetrahydrofuran with MeOH, with a final freeze-drying from benzene. Dried under vacuum.

Polyvinyl chloride *[9002-81-2].* Ppted from cyclohexanone by addition of MeOH.

Poly(4-vinylpyridine) *[25232-41-1]* **M $(105.1)_n$.** Purified by repeated pptn from solns in EtOH and dioxane, and then EtOH and ethyl acetate. Finally, freeze-dried from *tert*-butanol.

Poly(*N*-vinylpyrrolidone) *[9003-39-8]* **M $(111.1)_n$, crosslinked** *[25249-54-1]* **m >300°.** Purified by dialysis, and freeze-dried. Also by pptn from $CHCl_3$ soln by pouring into ether. Dried in a vacuum over P_2O_5. For the crosslinked polymer purification is by boiling for 10min in 10% HCl and then washing with glass-distilled water until free from Cl ions. Final Cl ions were removed more readily by neutralising with KOH and continued washing.

Pontacyl Carmine 2G *[3734-67-6]* **M 510.4,**
Pontacyl Light Yellow GX *[6359-98-4]* **M 552.3.** Salted out three times with sodium acetate, then repeatedly extracted with EtOH. See *Chlorazol Sky Blue FF*. [McGrew and Schneider *JACS* **72** 2547 *1950*].

Prednisone *[53-03-2]* **M 358.5, m 238°(dec), $[\alpha]_D^{20}$ +168° (c 1, dioxane), λ_{max} 238nm (log ε 4.18) in MeOH.** Crystd from acetone/hexane.

Pregnane *[24909-91-9]* **M 300.5, m 83.5°, $[\alpha]_D^{20}$ +21° ($CHCl_3$).** Crystd from MeOH.

5β-Pregnane-3α,20α-diol *[80-92-2]* **M 320.5, m 243-244°, $[\alpha]_{546}^{20}$ +31° (c 1, EtOH).** Crystd from acetone.

5β-Pregnane-3α,20β-diol *[80-91-1]* **M 320.5, m 244-246°, $[\alpha]_{546}^{20}$ +22° (c 1, EtOH).** Crystd from EtOH.

Pregnenolone see **3β-hydroxy-5-pregnen-20-one.**

Prehnitine see **1,2,3,4-trimethylbenzene.**

Procaine *[59-46-1]* **M 236.3, m 51° (dihydrate), 61° (anhydrous).** Crystd as the dihydrate from aqueous EtOH and as anhydrous material from pet ether or ethyl ether. The latter is *hygroscopic*.

Proclavine (3,6-diaminoacridine) *[92-62-6]* **M 209.2, m 284-286°.** Crystd from aqueous MeOH.

Prodiene see **allene.**

Proflavine see **3,6-diaminoacridine hydrochloride.**

Progesterone *[57-83-0]* **M 314.5, m 128.5°, $[a]_{546}^{20}$ +220° (c 2, dioxane).** Crystd from EtOH. When crystd from pet ether **m** is 121°, λ_{max} 240nm, log ε 4.25 (EtOH).

L-Proline *[147-85-3]* **M 115.1, m 215-220°(dec)(D-isomer), 220-222°(dec) (L-form), 205°(dec)(DL-isomer), $[\alpha]_D^{25}$ (H_2O, L-isomer).** Likely impurity are hydroxyproline. Purified *via* its picrate which was crystd twice from water, then decomposed with 40% H_2SO_4. The picric acid was extracted with ethyl ether, the H_2SO_4 was pptd with $Ba(OH)_2$, and the filtrate evapd. The residue was crystd from hot absolute EtOH [Mellan and Hoover *JACS* **73** 3879 *1951*] or EtOH/ether. *Hygroscopic*. Stored in a desiccator.

Prolycopene *[2361-24-2]* **M 536.5, m 111°, λ_{max} 443.5, 470nm in pet ether.** Purified by chromatography on deactivated alumina [Kushwaha et al. *JBC* **245** 4708 *1970*]. Crystd from pet ether. Stored in the dark, in an inert atmosphere at -20°.

L-Prolylglycine *[2578-57-6]* **M 172.2.** Crystd from water at 50-60° by addition of EtOH.

Proneurosporene *[10467-46-6]* **M 538.9, λ_{max} 408, 432, 461 nm, $\varepsilon_{1cm}^{1\%}$ 2040 (432nm) in hexane.** Purified by chromatography on deactivated alumina [Kushwaha et al. *JBC* **245** 4708 *1970*]. Stored in the dark, in an inert atmosphere at 0°.

Propane *[74-98-6]* **M 44.1, m -189.7, b -42.1°/760mm, d 0.5005, n 1.2898.** Purified by bromination of the olefinic contaminants. Propane was treated with bromine for 30min at 0°. Unreacted bromine was quenched, and the propane was distd through two -78° traps and collected at -196° [Skell et al. *JACS* **108** 6300 *1986*].

Propane-1,2-diamine *[78-90-0]* **M 74.1, b 120.5°, d 0.868, n 1.446.** Purified by azeotropic distn with toluene. [Horton, Thomason and Kelly *AC* **27** 269 *1955*].

Propane-1,2-diol *[57-55-6]* **M 76.1, b 104°/32mm, d 1.040, n 1.433.** Dried with Na_2SO_4, decanted and distd under reduced pressure.

Propane-1,3-diol *[504-63-2]* **M 76.1, b 110-122°/12mm, d 1.053, $n^{18.5}$ 1.4398.** Dried with K_2CO_3 and distd under reduced pressure. More extensive purification involved conversion with benzaldehyde to *2-phenyl-1,3-dioxane* (**m** 47-48°) which was subsequently decomposed by shaking with 0.5M HCl (3ml/g) for 15min and standing overnight at room temperature. After neutralisation with K_2CO_3, the benzaldehyde was removed by distn and the diol was recovered from the remaining aqueous soln by continuous extraction with

$CHCl_3$ for 1day. The extract was dried with K_2CO_3, the $CHCl_3$ was evaporated and the diol was distd. [Foster, Haines and Stacey *TET* **6** 177 *1961*].

Propane-1-thiol *[1120-71-4]* **M 76.1, b 65.3°/702mm, d^{25} 0.83598, n^{25} 1.43511,**
Propane-2-thiol *[75-33-2]* **M 76.1, b 49.8°/696mm, d^{25} 0.80895, n^{25} 1.42154.** Purified by soln in aqueous 20% NaOH, extraction with a small amount of benzene and steam distn until clear. After cooling, the soln was acidified slightly with 15% H_2SO_4, and the thiol was distd out, dried with anhydrous $CaSO_4$ or $CaCl_2$, and fractionally distd under nitrogen. [Mathias and Filho *JPC* **62** 1427 *1958*]. Also purified by liberation of the mercaptan by adding dilute HCl to the residue remaining after steam distn. After direct distn from the flask, and separation of the water, the mercaptan was dried (Na_2SO_4) and distd under nitrogen.

1,2,3-Propanetricarboxylic acid see **tricarballic acid.**

Propan-1-ol see ***n*-propyl alcohol.**

Propan-2-ol see **isopropyl alcohol.**

Propargyl alcohol *[107-19-7]* **M 56.1, b 54°/57mm, 113.6°/760mm, d 0.947, n 1.432.** Commercial material contains a stabiliser. An aqueous soln of propargyl alcohol can be concentrated by azeotropic distn with butanol or butyl acetate. Dried with K_2CO_3 and distd under reduced pressure, in the presence of about 1% succinic acid, through a glass helices-packed column.

Propene *[115-07-1]* **M 42.1, m -185.2°, b -47.8°/750mm, d 0.519, n^{-71} 1.357.** Purified by freeze-pump-thaw cycles and trap-to-trap distn.

p-**(1-Propenyl)phenol** *[539-12-8]* **M 134.2, m 93-94°.** Crystd from water.

β-Propiolactone *[57-57-8]* **M 72.1, b 83°/45mm, d 1.150, n^{25} 1.4117.** Fractionally distd under reduced pressure, from sodium. **CARCINOGEN.**

Propionaldehyde *[123-38-6]* **M 58.1, b 48.5-48.7°, d 0.804, n 1.3733, n^{25} 1.37115.** Dried with $CaSO_4$ or $CaCl_2$, and fractionally distd under nitrogen or in the presence of a trace of hydroquinone (to retard oxidation). Blacet and Pitts [*JACS* **74** 3382 *1952*] repeatedly vacuum distd the middle fraction until no longer gave a solid polymer when cooled to -80°. It was stored with $CaSO_4$.

Propionamide *[79-05-0]* **M 73.1, m 79.8-80.8°.** Crystd from acetone, benzene, $CHCl_3$, water or acetone/water, then dried in a vacuum desiccator over P_2O_5 or conc H_2SO_4.

Propionic acid *[79-09-4]* **M 74.1, b 141°, d 0.992, n 1.3865, n^{25} 1.3843.** Dried with Na_2SO_4 or by fractional distn, then redistd after refluxing with a few crystals of $KMnO_4$. An alternative purification uses the conversion to the ethyl ester, fractional distn and hydrolysis. [Bradbury *JACS* **74** 2709 *1952*]. Propionic acid can also be heated for 0.5h with an amount of benzoic anhydride equivalent to the amount of water present (in the presence of CrO_3 as catalyst), followed by fractional distn. [Cham and Israel *JCS* 196 *1960*].

Propionic anhydride *[123-62-6]* **M 130.2, b 67°/18mm, 168°/780mm, d 1.407, n 1.012.** Shaken with P_2O_5 for several nimutes, then distd.

Propionitrile *[107-12-0]* **M 55.1, b 97.2°, d 1.407, n^{15} 1.36812, n^{30} 1.36132.** Shaken with 1:5 dil HCl, or with conc HCl until the odour of isonitrile has gone, then washed with water, and aqueous K_2CO_3. After a preliminary drying with silica gel or Linde type 4A molecular sieves, it is stirred with CaH_2 until hydrogen evolution ceases, then decanted and distd from P_2O_5 (not more than 5g/L, to minimise gel formation). Finally, it is refluxed with, and slowly distd from CaH_2 (5g/L), taking precautions to exclude moisture.

***n*-Propyl acetate** *[109-60-4]* **M 102.1, b 101.5°, d 0.887, n 1.38442.** Washed with satd aqueous $NaHCO_3$ until neutral, then with satd aqueous NaCl. Dried with $MgSO_4$ and fractionally distd.

***n*-Propyl alcohol** *[71-23-8]* **M 60.1, b 97.2°, d^{25} 0.79995, n 1.385.** The main impurities in *n*-propyl alcohol are usually water and 2-propen-1-ol, reflecting the commercial production by hydration of propene. Water can be removed by azeotropic distn either directly (azeotrope contains 28% water) or by using a ternary system, e.g. by adding benzene. Alternatively, for gross amounts of water, refluxing over CaO for several hours is suitable, followed by distn and a further drying. To obtain more nearly anhydrous alcohol, suitable drying agents are firstly NaOH, $CaSO_4$ or K_2CO_3, then CaH_2, aluminium amalgam, magnesium activated with iodine, or a small amount of sodium. Alternatively, the alcohol can be refluxed with *n*-propylsuccinate or phthalate in a method similar to the one described under EtOH. Allyl alcohol is removed by adding bromine (15ml/L) and then fractionally distilling from a small amount of K_2CO_3. Propionaldehyde, also formed in the bromination, is removed as the 2,4-dinitrophenylhydrazone. *n*-Propyl alcohol can be dried down to 20ppm of water by passage through a column of pre-dried molecular sieves (type A, K^+ form, heated for 3h at 300°) in a current of nitrogen. Distn from sulphanilic or tartaric acids removes impurities.
Albrecht [*JACS* **82** 3813 *1960*] obtained spectroscopically pure material by heating with charcoal to 50-60°, filtering and adding 2,4-dinitrophenylhydrazine and a few drops of conc H_2SO_4. After standing for several hours, the mixture was cooled to 0°, filtered and vac distd. Gold and Satchell [*JCS* 1938 *1963*] heated *n*-propyl alcohol with 3-nitrophthalic anhydride at 76-110° for 15h, then recrystd the resulting ester from H_2O, benzene/pet ether (b 100-120°)(3:1), and benzene. The ester was hydrolysed under reflux with aq 7.5M NaOH for 45min under nitrogen, followed by distn (also under nitrogen). The fraction (b 87-92°) was dried with K_2CO_3 and stirred under reduced pressure in the dark over 2,4-dinitrophenylhydrazine, then freshly distilled. Also purified by adding 2g $NaBH_4$ to 1.5L alcohol, gently bubbling with argon and refluxing for 1day at 50°. Then added 2g of freshly cut sodium (washed with propanol) and refluxed for one day. Distd, taking the middle fraction [Jou and Freeman *JPC* **81** 909 *1977*].

***n*-Propylamine** *[107-10-8]* **M 59.1, b 48.5°, d 0.716, n 1.38815.** Distd from zinc dust, at reduced pressure, in an atmosphere of nitrogen.

***n*-Propyl bromide.** *[106-94-5]* **M 123.0, b 71.0°, d 1.354., n^{15} 1.43695, n^{25} 1.43123.** Likely contaminants include *n*-propyl alcohol and isopropyl bromide. The simplest purification procedure uses drying with $MgSO_4$ or $CaCl_2$ (with or without a preliminary washed of the bromide with aq $NaHCO_3$, then water), followed by fractional distn away from bright light. Chien and Willard [*JACS* **79** 4872 *1957*] bubbled a stream of oxygen containing 5% ozone through *n*-propyl bromide for 1h, then shook with 3% hydrogen peroxide soln, neutralised with aq Na_2CO_3, washed with distilled water and dried. Then followed vigorous stirring with 95% H_2SO_4 until fresh acid did not discolour within 12h. The propyl bromide was separated, neutralised, washed dried with $MgSO_4$ and fractionally distd. The centre cut was stored in the dark. Instead of ozone, Schuler and McCauley [*JACS* **79** 821 *1957*] added bromine and stored for 4 weeks, the bromine then being extracted with aq $NaHSO_3$ before the sulphuric acid treatment was applied. Distd. Further purified by preparative gas chromatography on a column packed with 30% SE-30 (General Electric ethylsilicone rubber) on 42/60 Chromosorb P at 150° and 40psi, using helium. [Chu *JPC* **41** 226 *1964*].

***n*-Propyl chloride** *[540-54-5]* **M 78.5, b 46.6°, d 0.890, n 1.3880.** Dried with $MgSO_4$ and fractionally distd. More extensively purified using extraction with H_2SO_4 as for *n*-propyl bromide. Alternatively, Chien and Willard [*JACS* **75** 6160 *1953*] passed a stream of oxygen containing about 5% ozone through the *n*-propyl chloride for three times as long as was needed to cause the first coloration of starch iodide paper by the exit gas. After washing with aqueous $NaHCO_3$ to hydrolyse ozonides and remove organic acids, the chloride was dried with $MgSO_4$ and fractionally distd.

1-Propyl-3-(*p*-chlorobenzenesulphonyl) urea *[94-20-2]* **M 260.7, m 127-129°.** Crystd from aqueous EtOH.

Propylene carbonate *[108-32-7]* **M 102.1, b 110°/0.5-1mm, 238-239°/760mm, d 1.204, n 1.423.** Manufactured by reaction of 1,2-propylene oxide with CO_2 in the presence of a catalyst (quaternary ammonium halide). Contaminants include propylene oxide, carbon dioxide, 1,2- and 1,3-propanediols, allyl alcohol and ethylene carbonate. It can be purified by percolation through molecular sieves (Linde 5A, dried at 350° for 14h under a stream of argon), followed by distn under vac. [Jasinski and Kirkland *AC* **39** 163 *1967*]. It can be stored over molecular sieves under an inert gas atmosphere. When purified in this way it contains less

than 2ppm water. Activated alumina and dried CaO have been also used as drying agents prior to fractional distn under reduced pressure. It has been dried with 3A molecular sieves and distd under nitrogen in the presence of *p*-toluenesulphonic acid. Then redistilled and the middle fraction collected.

Propylenediamine see **propane-1,2-diamine.**

Propyleneglycol see **propane-1,2-diol.**

***dl*-Propylene oxide** *[75-56-9]* **M 58.1, b 34.5°, d 0.829, n 1.3664.** Dried with Na_2SO_4 or CaH_2, and fractionally distd through a packed column (glass helices), after refluxing with Na, CaH_2, or KOH pellets.

***n*-Propyl ether** *[111-43-3]* **M 102.2, b 90.1°, d 0.740, n^{15} 1.38296, n 1.3803.** Purified by drying with $CaSO_4$, by passage through an alumina column (to remove peroxides), and by fractional distn.

Propyl formate *[110-74-7]* **M 88.1, b 81.3°, d 0.9058, n 1.3779.** Distd, then washed with satd aq NaCl, and with satd aq $NaHCO_3$ in the presence of solid NaCl, dried with $MgSO_4$ and fractionally distd.

***n*-Propyl gallate** *[121-79-9]* **M 212.2, m 150°.** Crystd from aqueous EtOH.

***n*-Propyl iodide** *[107-08-4]* **M 170.0, b 102.5°, d 1.745, n 1.5041.** Should be distd at reduced pressure to avoid decomposition. Dried with $MgSO_4$ or silica gel and fractionally distd. Stored under nitrogen with mercury in a brown bottle. Prior to distn, free iodine can be removed by shaking with copper powder or by washing with aq $Na_2S_2O_3$ and drying. Alternatively, the *n*-propyl iodide can be treated with bromine, then washed with aq $Na_2S_2O_3$ and dried. See also *n-butyl iodide.*

***n*-Propyl propionate** *[106-36-5]* **M 120.2, b 122°, d 0.881, n 1.393.** Treated with anhydrous $CuSO_4$, then distd under nitrogen.

6-Propyl-2-thiouracil (propacil, propyail) *[51-52-5]* **M 170.2, m218-220°, 218-220°.** Purified by recrystn from H_2O (sol in 900 parts at 20°, and 100 parts at 100°). UV, MeOH: λmax 277nm. [Anderson et al. *JACS* **67** 2197 *1945*; Vanderhaegue *Bull Soc Chim Belges* **59** 689 *1950*].

Propyne *[74-99-7]* **M 40.1, m -101.5°, b -23.2°/760mm, d^{-50} 0.7062, n^{-40} 1.3863.** Purified by preparative gas chromatography.

2-Propyn-1-ol see **propargyl alcohol.**

Protocatechualdehyde *[139-85-5]* **M 138.1, m 153°.** Crystd from water or toluene.

Protopine *[130-86-9]* **M 353.4, m 208°.** Crystd from EtOH/chloroform.

Protoporphyrin *[553-12-8]* **M 562.7, m >300°.** Crystd from ethyl ether.

Pseudocumene see **1,2,4-trimethylbenzene.**

***S,S*-Pseudoephedrine** *[90-82-4]* **M 165.2, m 118-119°, $[a]_D^{20}$ +53.0° (EtOH), +40.0° (H_2O).** Crystd from dry ethyl ether, or from water and dried in a vacuum desiccator.

Pseudoephedrine hydrochloride *[347-78-8]* **M 210.7, m 181-182°,**
Pseudoisocyanine iodide, Crystd from EtOH.

Pteridine *[91-18-9]* **M 132.2, m 139.5-140°.** Crystd from EtOH, benzene, *n*-hexane, *n*-heptane or pet ether. It sublimes at 120-130°/20mm. Stored at 0°, in the dark; turns green in the presence of light.

2,4-(1*H*,3*H*)-Pteridinedione (H_2O) *[487-21-8]* **M 182.1, m >350°.** Crystd from water.

Pterin (2-aminopteridin-4(3*H*)-one) *[2236-60-4]* **M 163.1, m >300°.** It was dissolved in hot 1% aqueous ammonia, filtered, and an equal volume of hot 1M aqueous formic acid was added. The soln was allowed to cool at 0-2° overnight. The solid was collected and washed with distilledd water several times by centrifugation and dried *in vacuo* over P_2O_5 overnight, and then at 100° overnight.

Pterocarpin *[524-97-0]* **M 298.3, m 165°,** $[\alpha]_D^{20}$ **-220°.** Crystd from EtOH.

Pteroic acid *[119-24-4]* **M 312.3, m >300°(dec).** Crystd from dilute HCl.

***R*(+)-Pulegone** *[89-82-7]* **M 152.2, b 69.5°/5mm, n 1.4849, d 0.935,** $[\alpha]_{546}^{20}$ **+23.5°(neat).** Purified *via* the semicarbazone. [Erskine and Waight *JCS* 3425 *1960*].

Purine *[120-73-0]* **M 120.1, m 216-217°.** Crystd from toluene or EtOH.

Purpurin *[81-54-9]* **M 256.2, m 253-256°.** Crystd from aqueous EtOH. Dried at 100°.

Purpurogallin *[569-77-7]* **M 220.2, m 274° (rapid heating).** Crystd from acetic acid.

Pyocyanine *[573-77-3]* **M 210.2, m 133°.** Crystd from water.

Pyrazine *[290-37-9]* **M 80.1, m 47°, b 115.5-115.8°.** Distd in steam and crystd from water. Purified by zone melting.

Pyrazinecarboxamide *[98-96-4]* **M 123.1, m 189-191° (sublimes slowly at 159°).** Crystd from water or EtOH.

Pyrazinecarboxylic acid *[98-97-5]* **M 124.1, m 225-229°(dec).** Crystd from water.

Pyrazine-2,3-dicarboxylic acid *[89-01-0]* **M 168.1, m 183-185°(dec).** Crystd from water. Dried at 100°.

Pyrazole *[288-13-1]* **M 68.1, m 70°.** Crystd from pet ether, cyclohexane, or water. [Barszcz et al. *JCSDT* **2025** *1986*].

Pyrazole-3,5-dicarboxylic acid *[3112-31-0]* **M 174.1, m 287-289°(dec).** Crystd from water or EtOH.

Pyrene *[129-00-0]* **M 202.3, m 149-150°.** Crystd from EtOH, glacial acetic acid, benzene or toluene. Purified by chromatography of CCl_4 solns on alumina, with benzene or *n*-hexane as eluent. [Backer and Whitten *JPC* **91** 865 *1987*]. Also zone refined, and purified by sublimation. Marvel and Anderson [*JACS* **76** 5434 *1954*] refluxed pyrene (35g) in toluene (400ml) with maleic anhydride (5g) for 4days, then added 150ml of aqueous 5% KOH and refluxed for 5h with occasional shaking. The toluene layer was separated, washed thoroughly with H_2O, concentrated to about 100ml and allowed to cool. Crystalline pyrene was filtered off and recrystd three times from EtOH or acetonitrile. [Chu and Thomas *JACS* **108** 6270 *1986*; Russell et al. *AC* **50** 2961 *1986*]. The material was free from anthracene derivatives. Another purification step involved passage of pyrene in cyclohexane through a column of silica gel. It can be sublimed in a vacuum and zone refined. [Kano et al. *JPC* **89** 3748 *1985*].

Pyrene-1-aldehyde *[3029-19-4]* **M 230.3, m 125-126°.** Recrystd three times from aqueous EtOH.

1-Pyrenebutyric acid *[3443-45-6]* **M 288.4, m 184-186°.** Crystd from benzene, EtOH or EtOH/water (7:3 v/v). Dried over P_2O_5. [Chu and Thomas *JACS* 108 6270 *1986*].

1-Pyrenecarboxylic acid *[3029-19-4]* **M 230.3, m 126-127°.** Crystd from benzene or 95% EtOH.

1-Pyrenesulphonic acid *[26651-23-0]* **M 202.2.** Crystd from EtOH/water.

1,3,6,8-Pyrenetetrasulphonic acid *[6528-53-6]* **M 522.2.** Crystd from water.

Pyridine *[110-86-1]* **M 79.1, f.p. -41.^{8}, b 115.6°, d 0.9831, n 1.51021.** Likely impurities are H_2O and amines such as the picolines and lutidines. Pyridine is *hygroscopic* and is miscible with H_2O and organic solvents. It can be dried with solid KOH, NaOH, CaO, BaO or sodium, followed by fractional distn. Other methods of drying include standing with Linde type 4A molecular sieves, CaH_2 or $LiAlH_4$, azeotropic distn of the H_2O with toluene or benzene, or treated with phenylmagnesium bromide in ether, followed by evaporation of the ether and distn of the pyridine. A recommended [Lindauer and Mukherjee *PAC* **27** 267 *1971*] method dries pyridine over solid KOH (20g/Kg) for 2weeks, and fractionally distils the supernatant over Linde type 5A molecular sieves and solid KOH. The product is stored under CO_2-free nitrogen. Pyridine can be stored in contact with BaO, CaH_2 or molecular sieves. Non-basic materials can be removed by steam distilling a soln containing 1.2 equivalents of 20% H_2SO_4 or 17% HCl until about 10% of the base has been carried over along with the non-basic impurities. The residue is then made alkaline, and the base is separated, dried with NaOH and fractionally distd.
Alternatively, pyridine can be treated with oxidising agents. Thus pyridine (800ml) has been stirred for 24h with a mixture of ceric sulphate (20g) and anhydrous K_2CO_3 (15g), then filtered and fractionally distd. Hurd and Simon [*JACS* **84** 4519 *1962*] stirred pyridine (135ml), water (2.5L) and $KMnO_4$ (90g) for 2h at 100°, then stood for 15h before filtering off the ppted manganese oxides. Addition of solid KOH (*ca* 500g) caused pyridine to separate. It was decanted, refluxed with CaO for 3h and distd.
Separation of pyridine from some of its homologues can be achieved by crystn of the oxalates. Pyridine is ppted as its oxalate by adding it to the stirred soln of oxalic acid in acetone. The ppte is filtered, washed with cold acetone, and pyridine is regenerated and isolated. Other methods are based on complex formation with $ZnCl_2$ or $HgCl_2$. Heap, Jones and Speakman [*JACS* **43** 1936 *1921*] added crude pyridine (1L) to a soln of $ZnCl_2$ (848g) in 730ml of water, 346ml of conc HCl and 690ml of 95% EtOH. The crystalline ppte of $ZnCl_2$.2(pyridine) was filtered off, recrystd twice from absolute EtOH, then treated with a conc NaOH soln, using 26.7g of solid NaOH to 100g of the complex. The ppte was filtered off, and the pyridine was dried with NaOH pellets and distd. Similarly, Kyte, Jeffery and Vogel [*JCS* 4454 *1960*] added pyridine (60ml) in 300ml of 10% (v/v) HCl to a soln of $HgCl_2$ (405g) in hot water (2.3L). On cooling, crystals of pyridine-$HgCl_2$ (1:1) complex separated and were filtered off, crystd from 1% HCl (to **m** 178.5-179°), washed with a little EtOH and dried at 110°. The free base was liberated by addition of excess aq NaOH and separated by steam distn. The distillate was saturated with solid KOH, and the upper layer was removed, dried further with KOH, then BaO and distd. Another possible purification step is fractional crystn by partial freezing.
Small amounts of pyridine have been purified by vapour-phase chromatography, using a 180-cm column of polyethyleneglycol-400 (Shell 5%) on Embacel (May and Baker) at 100°, with argon as carrier gas. The Karl Fischer titration can be used for determining water content. A colour test for pyrrole as a contaminant is described by Biddiscombe et al. [*JCS* 1957 *1954*].

Pyridine-2-aldehyde *[1121-60-4]* **M 107.1, b 81.5°/25mm, d 1.121, n 1.535,**
Pyridine-3-aldehyde *[500-22-1]* **M 107.1, b 89.5°/14mm, d 1.141, n 1.549,**
Pyridine-4-aldehyde *[872-85-5]* **M 107.1, b 79.5°/12mm, d 1.137, n 1.544.** Sulphur dioxide was bubbled into a soln of 50g in 250ml of boiled out water, under nitrogen, at 0°, until pptn was complete. The addition compound was filtered off rapidly and, after washing with a little water, it was refluxed in 17% HCl (200ml) under nitrogen until a clear soln was obtained. Neutralisation with $NaHCO_3$ and extraction with ether separated the aldehyde which was recovered by drying the extract, then distilling twice, under nitrogen. [Kyte, Jeffery and Vogel *JCS* 4454 *1960*].

Pyridine-2-aldoxime *[873-69-8]* **M 122.1, m 113°,**
Pyridine-3-aldoxime *[1193-92-6]* **M 122.1, m 150°,**
Pyridine-4-aldoxime *[696-54-8]* **M 122.1, m 129°.** Crystd from water.

Pyridine-2-carboxylic acid see **picolinic acid.**

Pyridine-3-carboxylic acid see **nicotinic acid.**

Pyridine-4-carboxylic acid see **isonicotinic acid.**

2,6-Pyridinedialdoxime *[2851-68-5]* **M 165.1, m 212°.** Crystd from water.

Pyridine-2,5-dicarboxylic acid *[100-26-5]* **M 167.1, m 254°.** Crystd from dilute HCl.

Pyridine-2,6-dicarboxylic acid see **dipicolinic acid.**

Pyridine-3,4-dicarboxylic acid *[490-11-9]* **M 167.1, m256°.** Crystd from dilute aqueous HCl.

Pyridine hydrobromide perbromide (pyridinium bromide perbromide) *[39416-48-3]* **M 319.9, m 130° (dec), 132-134° (dec).** It is a very good brominating agent - liberating one mol. of Br_2. Purified by recrystn from glacial acetic acid (33g from 100ml of AcOH). [Fieser and Feiser *Reagents for Organic Chemistry* Vol 1 967 *1967*].

Pyridine hydrochloride *[628-13-7]* **M 115.6, m 144°, b 218°.** Crystd from $CHCl_3$/ethyl acetate and washed with ethyl ether.

Pyridine *N*-oxide *[694-59-7]* **M 95.1, m 67°.** Purified by vacuum sublimation.

Pyridine 3-sulphonic acid *[636-73-7]* **M 159.2, m 352-356°, 365-366° (dec), 356-357°, 357°.** Purified by recrystn from H_2O or aqueous EtOH as needles or plates. It has a basic pKa^{25} of 3.22 (in H_2O) and 2.89 (in 12% aqueous EtOH) [Evans and Brown *JOC* **27** 3127 *1962*; IR: Arnett and Chawla *JACS* **100** 214 *1978*]. UV in 50% aqueous EtOH: λmax at 208 and 262nm. The *ammonium salt* has **m** 243° (from H_2O), the *sulphonyl chloride* has **m** 133-134° (from pet ether), the *amide* has **m** 110-111° (from H_2O), the *hydrochloride* has **m** > 300° (dec), and the *N-methyl betaine* has **m** 130° (from H_2O). [Gastel and Wibaut *Rec Trav Chim Pays Bas* **53** 1031 *1934*; McIlvain and Goese *JACS* **65** 2233 *1943*; Machek *M* **72** 77*1938*].

Pyridoxal hydrochloride, pyridoxamine hydrochloride and pyridoxine hydrochloride (vitamin B_6) see entries in Chapter 5.

1-(2-Pyridylazo)-2-naphthol (PAN) *[85-85-8]* **M 249.3, m 140-142°.** Purified by repeated crystn from MeOH. It can also be purified by sublimation under vacuum. Purity can be checked by TLC using a mixed solvent (pet ether, ethyl ether, EtOH; 10:10:1) on a silica gel plate.

4-(2-Pyridylazo)resorcinol (PAR) *[1141-59-9]* **M 215.2, m >195°(dec), λ_{max} 415nm, ε 2,59 x 10^4 (pH 6-12).** Purified as the sodium salt by recrystn from 1:1 EtOH/water. Purity can be checked by TLC using a silica gel plate and a mixed solvent (*n*-BuOH:EtOH:2M NH_3; 6:2:2).

Pyridyldiphenyltriazine *[1046-56-6]* **M 310.4, m 191-192°.** Purified by repeated recrystn from EtOH/dimethylformamide.

***R*-(+)-** *[27854-88-2]* **and *S*-(-)-** *[42732-22-9]* **1-(4-pyridyl)ethanol M 123.2, m 63-65°67-69°, $[\alpha]_D^{20}$ ±49.8° (c 0.5, EtOH).** Purified by recrystn from pet ether. The (-)-*di-O-benzoyl tartrate salt* has **m** 146-148° (from EtOH). [UV, ORD: Harelli and Samori *JCS Perkin Trans 2* 1462 *1974*]. The *racemate* recrystallises from Et_2O **m** 74-76°, **b** 90-94°/1mm [Ferles and Attia *Coll Czech Chem Commun* **38** 611 *1973*; UV, NMR: Nielson et al. *JOC* **29** 2898 *1964*].

Pyrocatechol see **catechol.**

Pyrogallol *[87-66-1]* **M 126.1, m 136°.** Crystd from EtOH/benzene.

L-Pyroglutamic acid *[98-66-1]* **M 129.1, m 162-164°, $[\alpha]_{546}^{20}$ -10° (c 5, H_2O).** Crystd from EtOH by addition of pet ether.

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Pyromellitic acid *[89-05-4]* **M 254.2, m 276°.** Dissolved in 5.7 parts of hot dimethylformamide, decolorised and filtered. The ppte obtained on cooling was separated and air dried, the solvent being removed by heating in an oven at 150-170° for several hours. Crystd from water.

Pyromellitic dianhydride *[89-32-7]* **M 218.1, m 286°.** Crystd from ethyl methyl ketone or dioxane. Dried, and sublimed *in vacuo.*

α-Pyrone (2*H*-pyran-2-one) *[504-31-4]* **M 96.1, m 5°, 8-9°, b 103-111°/19-22mm, 110°/26mm, 104°/ 30mm, 115-118°/37mm, 206-207°/atm, d_4^{20} 1.1972, n_D^{20} 1.5298.** Dissolve in Et_2O, wash with brine, dry (Na_2SO_4), filter, evaporate, distil residue under vacuum and redistil. It is a colourless liquid. [Zimmermann et al. *Org Synth* Coll Vol V 982 *1973*; Nakagawa and Saegusa *Org Synth* **56** 49 *1977*; Elderfield *JOC* **6** 566 *1941*]. The *picrate* has **m** 106-107° (from EtOH).

γ-Pyrone (4*H*-pyran-4-one) *[108-97-4]* **M 96.1, m 32.5-32.6°, 33°, 32-34°, b 88.5°/7mm, 91-91.5°/9mm, 95-97°/13mm, 105°/23mm, 215°/atm.** Purified by vacuum distn, the distillate crystallises and is *hygroscopic*. It is non-steam volatile. The *hydrochoride* has **m** 139° (from EtOH), and the *picrate* has **m** 130.2-130.3° (from EtOH or H_2O). [Mayer *B* **90** 2362 *1957*; IR: Jones et al. *Canad J Chem* **37** 2007 *1959*; Neelakatan *JOC* **22** 1584 *1957*].

Pyronin B *[2150-48-3]* **M 358.9.** Crystd from EtOH.

Pyronin Y, CI 739 *[92-32-0]* **M 302.8.** Commercial material contained a large quantity of zinc. Purified by dissolving 1g in 50ml of hot water containing 5g NaEDTA. Cooled to 0°, filtered, evapd to dryness and the residue extracted with EtOH. The soln was evaporated to 5-10ml, filtered, and the dye pptd by addition of excess dry ethyl ether. It was centrifuged and the crystals were washed with dry ether. The procedure was repeated, then the product was dissolved in $CHCl_3$, filtered and evapd. The dye was stored in a vacuum.

Pyrrole *[109-97-7]* **M 67.1, b 129-130°, d 0.966, n 1.5097.** Dried with NaOH, CaH_2 or $CaSO_4$. Fractionally distd under reduced pressure from sodium or CaH_2. Stored under nitrogen. Redistd immediately before use.

Pyrrolidine *[123-75-1]* **M 71.1, b 87.5-88.5°, d 0.860, n 1.443.** Dried with BaO or sodium, then fractionally distd, under nitrogen, through a Todd column packed with glass helices.

Pyrrolidine-1-carbodithioic acid ammonium salt *[5108-96-3]* **M 164.3, m 128-130°.** Purified by recryst twice by dissolving in MeOH and adding Et_2O. Also by recrystn from EtOH. [Synth and Polarography: Kitagawa and Taku *Bull Chem Soc Japan* **64** 2151 *1973*; Malissa and Schöffmann *Mikrochim Acta* 187 *1955*].

2-Pyrrolidone-5-carboxylic acid (D-pyroglutamic acid) *[4042-36-8]* **M 129.1, m 182-183°, $[\alpha]_D^{20}$ +10.7° (H_2O).** Crystd from EtOH/pet ether.

Pyruvic acid *[127-17-3]* **M 88.1, m 13°, b 65°/10mm.** Distd twice, then fractionally crystd by partial freezing.

p-Quaterphenyl *[135-70-6]* M 306.4, m 312-314°.

Recrystd from dimethyl sulphoxide at *ca* 50°.

Quercetin ($2H_2O$) *[6151-25-3]* **M 338.3, m *ca* 315°(dec).** Crystd from aq EtOH and dried at 100°.

Quercitrin *[117-39-3]* **M 302.2, m 168°.** Crystd from aq EtOH and dried at 135°.

Quinaldic acid *[93-10-7]* **M 173.2, m 156-157°.** Crystd from benzene.

Quinaldine see **2-methylquinoline.**

Quinalizarin *[81-61-8]* **M 272.2, m 275°.** Crystd from acetic acid or nitrobenzene. It can be sublimed under vacuum.

Quinazoline *[253-82-7]* **M 130.2, m 48.0-48.5°, b 120-121°/17-18mm.** Purified by passage through an activated alumina column in benzene or pet ether (b 40-60°). Distd under reduced pressure, sublimed under vacuum and crystd from pet ether. [Armarego *J Appl Chem* **11** 70 *1961*].

Quinhydrone *[106-34-3]* **M 218.2, m 168°.** Crystd from water heated to 65°, then dried in a vacuum desiccator.

1*R*,3*R*,4*R*,5*R*-Quinic acid *[77-95-2]* **M 192.3, m 172°(dec), $[\alpha]_{546}^{20}$ -51° (c 20, H_2O).** Crystd from water.

Quinidine *[56-54-2]* **M 324.4, m 171°, $[\alpha]_{546}^{20}$ +301.1° ($CHCl_3$ contg 2.5% (v/v) EtOH).** Crystd from benzene or dry $CHCl_3$/pet ether (b 40-60°), discarding the initial, oily crop of crystals. Dried under vacuum at 100° over P_2O_5.

Quinine *[130-95-0]* **M 324.4, m 177°(dec), $[\alpha]_{546}^{20}$ -160° (c 1, $CHCl_3$).** Crystd from abs EtOH.

Quinine bisulphate *[804-63-7]* **M 422.4, m 160° (anhydrous).** Crystd from 0.1M H_2SO_4, forms heptahydrate when crystd from water

Quinine sulphate ($2H_2O$) *[6591-63-5]* **M 783.0, m 205°.** Crystd from water, dried at 110°.

Quinizarin *[81-64-1]* **M 240.2, m 200-202°.** Crystd from glacial acetic acid.

Quinol see **hydroquinone.**

Quinoline *[91-22-5]* **M 129.2, m -16°, b 111.5°, 236°/758mm, d 1.0937, n 1.625.** Dried with Na_2SO_4 and vac distd from zinc dust. Also dried by boiling with acetic anhydride, then fractionally distilling. Calvin and Wilmarth [*JACS* **78** 1301 *1956*] cooled redistd quinoline in ice and added enough HCl to form its hydrochloride. Diazotization removed aniline, the diazo compound being broken down by warming the soln to 60°. Non-basic impurities were removed by ether extraction. Quinoline was liberated by neutralising the hydrochloride with NaOH, then dried with KOH and fractionally distd at low pressure. Addition of cuprous acetate (7g/L of quinoline) and shaking under hydrogen for 12h at 100° removed impurities due to the nitrous acid treatment. Finally the hydrogen was pumped off and the quinoline was distd. Other purification procedures depend on conversion to the phosphate (**m** 159°, pptd from MeOH soln, filtered, washed with MeOH, then dried at 55°) or the picrate (**m** 201°) which, after crystn were reconverted to the amine.
The method using the picrate [Packer, Vaughan and Wong *JACS* **80** 905 *1958*] is as follows: quinoline is added to picric acid dissolved in the minimum volume of 95% EtOH, giving yellow crystals which were washed with EtOH, air-dried and crystd from acetonitrile. These were dissolved in dimethyl sulphoxide (previously dried over 4A molecular sieves) and passed through basic alumina, on which the picric acid is adsorbed. The free base in the effluent is extracted with *n*-pentane and distd under vacuum. Traces of solvent can be removed by vapour-phase chromatography. [Moonaw and Anton *JPC* **80** 2243 *1976*]. The $ZnCl_2$ and dichromate complexes have also been used. [Cumper, Redford and Vogel *JCS* **1176** *1962*].

2-Quinolinealdehyde *[5470-96-2]* **M 157.2, m 71°.** Steam distd. Crystd from H_2O. Protected from light.

8-Quinolinecarboxylic acid *[86-59-9]* **M 173.2, m 186-187.5°.** Crystd from water.

Quinoline ethiodide *[634-35-5]* **M 285.1, m 158-159°.** Crystd from aqueous EtOH.

Quinolinium chlorochromate see entry in Chapter 4.

Quinolinol see **hydroxyquinoline.**

Quinoxaline *[91-19-0]* **M 130.2, m 28° (anhydr), 37°(H_2O), b 108-110°/0.1mm, 140°/40mm.** Crystd from pet ether. Crystallises as the monohydrate on addition of water to a pet ether soln.

Quinoxaline-2,3-dithiol *[1199-03-7]* **M 194.1, m 345°(dec).** Purified by repeated dissolution in alkali and re-pptn by acetic acid.

p-**Quinquephenyl** *[61537-20-0]* **M 382.5, m 388.5°.** Recrystd from boiling dimethyl sulphoxide (**b** 189°, lowered to 110°). The solid obtained on cooling was filtered off and washed repeatedly with toluene, then with conc HCl. The final material was washed repeatedly with hot EtOH. It was also recrystd from pyridine, then sublimed *in vacuo.*

Quinuclidine *[100-76-5]* **M 111.2, m 158°(sublimes).** Crystd from ethyl ether.

D-Raffinose ($5H_2O$)

[512-69-6] **M 594.5, m 80°, $[\alpha]_{546}^{20}$ +124° (c 10, H_2O).** Crystd from aqueous EtOH.

Rauwolscine hydrochloride *[6211-32-1]* **M 390.0, m 278-280°.** Crystd from water.

RDX see **cyclotrimethylenetrinitramine.**

Reductic acid *[80-72-8]* **M 114.1, m 213°.** Crystd from ethyl acetate.

Rescinnamine *[24815-24-5]* **M 634.7, m 238-239°(vac), $[\alpha]_D^{20}$ -87-97° (c 1, $CHCl_3$).** Crystd from benzene.

Reserpic acid *[83-60-3]* **M 400.5, m 241-243°.** Crystd from MeOH. The *hydrochloride 1/2 H_2O* has **m** 257-259°, $[\alpha]_D$ -81° (H_2O).

Reserpine *[50-55-5]* **M 608.7, m 262-263°, $[\alpha]_{546}^{20}$ -148° (c 1, $CHCl_3$).** Crystd from aq acetone.

Resorcinol *[108-46-3]* **M 110.1, m 111.2-111.6°.** Crystd from benzene, toluene or benzene/ethyl ether.

Resorufin (7-hydroxy-3H-phenoxazine-3-one Na salt) *[635-78-9]* **M 213.2.** Washed with water and recrystd from EtOH several times.

Retene *[483-65-8]* **M 234.3, m 99°.** Crystd from EtOH.

Retinal (vitamin A aldehyde),
Retinoic acid (vitamin A acid),
Retinol (vitamin A alcohol) see entries in Chapter 5.

Retinyl acetate *[127-49-9]* **M 328.5, m 57°.** Separated from retinol by column chromatography, then crystd from MeOH. See Kofler and Rubin [*Vitamin Hormones* **18** 315 *1960*] for review of purification methods. Stored in the dark, under inert atmosphere, at 0°. See Vitamin A acetate in Chapter 5.

Retinyl palmitate *[79-81-2]* **M 524.9,** $\varepsilon^{1\%}_{1cm}$ **(*all-trans*) 1000 (325 nm) in EtOH.** Separated from retinol by column chromatography on water-deactivated alumina with hexane containing a very small percentage of acetone. Also chromatographed on TLC silica gel G, using pet ether/isopropyl ether/acetic acid/water (180:20:2:5) or pet ether/acetonitrile/acetic acid/water (190:10:1:15) to develop the chromatogram. Then recrystd from propylene.

Rhamnetin (3,3'-4'5-tetrahydroxy-7-methoxy flavone, 7-methyl quercitin) *[90-19-7]* **M 316.3, m >300°(dec).** Crystd from EtOH.

L-α-Rhamnose (H_2O) *[3615-41-6]* **M 182.2, m 105°,** $[\alpha]_D^{15}$ **+9.1° (c 5, H_2O).** Crystd from water or EtOH.

Rhodamine B, CI 749 *[81-88-9]* **M 442.5.** Major impurities are partially dealkylated compounds not removed by crystn. Purified by chromatography, using ethyl acetate/isopropanol/ammonia (0.888 sg)(9:7:4, R_F 0.75 on Kieselgel G). Crystd from conc soln in MeOH by slow addition of dry ethyl ether. Stored in the dark.

Rhodamine B chloride *[81-88-9]* **M 479.0.** Crystd from EtOH containing a drop of conc HCl by slow addition of ten volumes of dry ethyl ether. The solid was washed with ether and air dried. The dried material has also been extracted with benzene to remove oil-soluble material prior to recrystn.

Rhodamine 6G *[989-38-8]* **M 479.3.** Crystd from MeOH or EtOH, and dried in a vacuum oven.

Rhodanine *[141-84-4]* **M 133.2, m 168.5° (capillary).** Crystd from glacial acetic acid or water.

Rhodizonic acid sodium salt (5,6-dihydroxycyclohex-5-ene-1,2,3,4-tetraone disodium salt) *[523-21-7]* **M 214.0.** The free acid, obtained by acidifiying and extracting with Et_2O, drying ($MgSO_4$), filtering, evaporating and distilling in vacuum (**b** 155-160°/14mm). The *free acid* solidifies on cooling and the colourless crystals can be recrystd from tetrahydofuran-pet ether or C_6H_6. It forms a *dihydrate* **m** 130-140°. The pure di Na salt is formed by dissolving in 2 equivs of NaOH and evaporating in a vacuum. It forms violet crystals which give an orange soln in H_2O that is unstable for extended periods even at 0°, and should be prepared freshly before use. Salts of rhodizonic acid cannot be purified by recrystn without great loss due to conversion to croconate, so that the original material must be prepared pure. It can be washed with NaOAc soln then EtOH to remove excess NaOAc dried under vacuum and stored in the dark. [UV and tautomerism: Schwarzenbach and Suter *HCA* **24** 617 *1941*; Polarography: Preisler and Berger *JACS* **64** 67 *1942*; Souchay and Taibouet *J Chim Phys* **49** C108 *1952*].

Riboflavin see entry in Chapter 5.

Riboflavin-5'-phosphate (Na salt, $2H_2O$) *[130-40-5]* **M 514.4.** Crystd from acidic aqueous soln. See Chapter 5.

Ribonucleic acid see Chapter 5.

α-D-Ribose *[50-69-1]* **M 150.1, m 90°,** $[\alpha]_{546}^{20}$ **-24° (after 24h, c 10, H_2O).** Crystd from aqueous 80% EtOH, dried under vacuum at 60° over P_2O_5 and stored in a vacuum desiccator.

Ricinoleic acid *[141-22-0]* **M 298.5, m 7-8° (α-form), 5.0° (γ-form), n 1.4717.** Purified as methyl acetylricinoleate [Rider *JACS* **53** 4130 *1931*], fractionally distilling at 180-185°/0.3mm, then 87g of this ester was refluxed with KOH (56g), water (25ml), and MeOH (250ml) for 10min. The free acid was separated, crystd from acetone at -50°, and distd in small batches, **b** 180°/0.005mm. [Bailey et al. *JCS* 3027 *1957*].

Rosaniline (Fuchsin) *[632-99-5]* **M 323.8,** λ_{max} **544 nm.** Crystd from water. Dried *in vacuo* at 40°.

Rose Bengal *[11121-48-5]* **M 1017.7.** Purified chromatographically on silica TLC ring using a 35:65 mix of EtOH/acetone as eluent.

***p*-Rosolic acid (4-[bis-{4-hydroxyphenyl}methylene]-2,5-cyclohexadien-one, 4',4"-dihydroxy-fuschson, aurin, corallin)** *[603-45-2]* **M 290.3, m 292°, 295-300° (dec with liberation of phenol), 308-310°.(dec).** It forms green crystals with a metallic lustre but the colour depends on the solvent used. When recrystd from brine (satd aqueous NaCl) acidified with HCl it forms red needles, but when recrystd from EtOH-AcOH the crystals have a beetle green colour. It has been recrystd from Me_2CO (although it dissolves slowly), methyl ethyl ketone, 80-95% AcOH and from AcOH-C_6H_6. An aq KOH soln is golden yellow and a 70% H_2SO_4 soln is deep red in colour. An alternative purification is to dissolve this triphenylmethane dye in 1.5% of aq NH_3, filter, and heat to 70-80°, then acidify with dilute AcOH by adding it slowly with vigorous stirring, whereby the aurin separates as a brick-red powder or as purplish crystals depending on the temperature and period of heating. Filter off the solid, wash with H_2O and a little dilute AcOH then H_2O again. Stir this solid with Et_2O to remove any ketones and allow to stand overnight in the Et_2O, then fiter and dry in air then in a vacuum. [Gomberg and Snow *JACS* 47 202 *1925*; Baines and Driver *JCS* 123 1216 *1923*; UV: Burawoy *B* 64 462 *1941*; Neuk and Schmid *J Prakt Chem* [2] **23** 549 *1881*].

Rubijervine *[79-58-3]* **M 413.6.** Crystd from EtOH. It has solvent of crystn.

Rubene see **naphthacene.**

Rubrene *[517-51-1]* **M 532.7, m >320°.** Recrystd from benzene (under red light).

(+)-Rutin *[153-18-4]* **M 610.5, m 188-189, $[\alpha]_{546}^{20}$ +13° (c 5, EtOH).** Crystd from MeOH or water/EtOH, air dried, then dried for several hours at 110°.

Saccharic acid *[81-07-2]* M 183.2, m 125-126°. Crystd from 95% EtOH.

Saccharin see ***o*-benzoic acid sulphimide.**

Safranine O *[477-73-6]* **M 350.9, λ_{max} 530nm.** Crystd from benzene/MeOH (1:1) or water. Dried under vacuum over H_2SO_4.

Safrole (5-allyl-1,3-benzodioxole, 4-allyl-1,2-methylenedioxybenzene) *[94-59-7]* **M 162.1, m~ 11°, b 69-70°/1.5mm, 104-105°/6mm, 231.5-232°/atm, 235-237°/atm, d_4^{20} 1.0993, n_D^{20} 1.53738.** It has been purified by fractional distn, although it has also been recrystd from low boiling pet ether at low temperatures. [IR: Briggs et al. *AC 29* **904** *1957*; UV: Patterson and Hibbert *JACS* **65** 1962 *1943*]. The *maleic anhydride adduct* forms yellow crystals from toluene **m** 257° [Hickey *JOC* **13** 443 *1948*], and the *picrate* forms orange-red crystals from $CHCl_3$ [Baril and Magrdichian *JACS* **58** 1415 *1936*].

D(-)-Salicin *[138-52-3]* **M 286.3, m 204-208°, $[\alpha]_D^{25}$ -63.5° (c *ca* 3, H_2O).** Crystd from EtOH.

Salicylaldehyde *[90-02-8]* **M 122.1, b 93°/25mm, 195-197°/760mm, d 1.167, n 1.574.** Ppted as the bisulphite addition compound by pouring the aldehyde slowly and with stirring into a 25% soln of $NaHSO_3$ in 30% EtOH, then standing for 30min. The ppte, after filtering at the pump, and washing with EtOH, was decomposed with aq 10% $NaHCO_3$, and the aldehyde was extracted into ethyl ether, dried with Na_2SO_4 or $MgSO_4$, and distd, under reduced pressure. Alternatively, salicylaldehyde can be pptd as its copper complex by adding it to warm, satd soln of copper acetate, shaking and then standing in ice. The ppte was filtered off, washed thoroughly with EtOH, then with ethyl ether, and decomposed with 10% H_2SO_4, the aldehyde was extracted into ethyl ether, dried and distd. It has also been purified by repeated vacuum distn, and by dry column chromatography on Kiesel gel G [Nishiya et al. *JACS* **108** 3880 *1986*]. The *acetyl* derivative has **m** 38-39° (from pet ether or EtOH) and **b** 142°/18mm, 253°/atm.

Salicylaldoxime *[94-67-7]* **M 137.1, m 57°.** Crystd from $CHCl_3$/pet ether (b 40-60°).

Salicylamide *[65-45-2]* **M 137.1, m 142-144°.** Crystd from water or repeatedly from chloroform [Nishiya et al. *JACS* **108** 3880 *1986*].

Salicylanilide *[97-17-2]* **M 213.2, m 135°.** Crystd from water.

Salicylhydroxamic acid *[89-73-6]* **M 153.1, m 179-180°(dec).** Crystd from acetic acid.

Salicyclic acid (2-hydroxybenzoic acid) *[69-72-7]* **M 138.1, m 157-159°, 158-160°, 159.5°, 159-160°, 162°, b 211°/20mm.** It has been purified by steam distn, by recrystn from H_2O (solubility is 0.22% at room temp and 6.7% at 100°), absolute MeOH, or cyclohexane and by sublimation in a vacuum at 76°. It has pKa_1^{20} of 3.08 and pKa_1^{25} 13.43 (13.01) in H_2O. The *acid chloride* (needles) has **m** 19-19.5°, **b** 92°/15mm, *amide* **m** 133° (yellow needles from H_2O), and *anilide* (prisms fron H_2O) **m** 135°. The *O-acetyl* derivative has **m** 135° (rapid heating and the liquid resolidifies at 118°) and the *o-benzoyl* derivative has **m** 132° (aq EtOH). [IR: Hales et al. *JCS* 3145 *1954*; UV: Bergmann et al. *JCS* 2351 *1950*].

Sarcosine *[107-97-1]* **M 89.1, m 212-213°(dec).** Crystd from absolute EtOH.

Sarcosine anhydride *[5076-82-4]* **M 142.2, m 146-147°.** Crystd from water, EtOH or ethyl acetate. Dried in vacuum at room temperature.

Scopolamine see **hyoscine.**

Scopoletin *[92-61-5]* **M 192.2, m 206°.** Crystd from water or acetic acid.

Sebacic acid *[111-20-6]* **M 202.3, m 134.5°.** Purified *via* the disodium salt which, after crystn from boiling water (charcoal), was again converted to the free acid. The free acid was crystd repeatedly from hot distd water and dried under vacuum.

Secobarbital *[76-73-3]* **M 238.4.** A soln of the salt in 10% HCl was ppted and the acid form was extracted by the addition of ether. Then purified by repeated crystn from $CHCl_3$. [Buchet and Sandorfy *JPC* **88** 3274 *1984*].

Selenopyronine *[85051-91-8]* **M 365.8, λ_{max} 571 (e 81,000).** Purified as the hydrochloride from hydrochloric acid [Fanghanel et al. *JPC* **91** 3700 *1987*].

Selenourea *[630-10-4]* **M 123.0, m 214-215°(dec).** Crystd from water under nitrogen.

Semicarbazide hydrochloride *[563-41-7]* **M 111.5, m 175°.** Crystd from aqueous 75% EtOH and dried under vacuum over $CaSO_4$. Also crystd from a mixture of 3.6 mole % MeOH and 6.4 mole % of water. [Kovach et al. *JACS* **107** 7360 *1985*].

Sennoside A *[81-27-6]* **M 862.7,**
Sennoside B *[128-57-4]* **M 962.7.** Crystd from aqueous acetone.

L-Serine *[56-45-1]* **M 105.1, m 228°(dec), $[\alpha]_D^{25}$ +14.5° (1M HCl), $[\alpha]_{546}^{20}$ +16° (c 5, 5M HCl).** Likely impurity is glycine. Crystd from water by adding 4 volumes of EtOH. Dried. Stored in a desiccator.

Serotonin creatinine sulphate (H_2O) *[61-47-1]* **M 405.4, m 220°(dec).** Crystd (as monohydrate) from water.

Shikimic acid *[138-59-0]* **M 174.2, m 190°, $[\alpha]_{546}^{20}$ -210° (c 2, H_2O).** Crystd from water.

Sinapinic acid see **3-(4-hydroxy-3,5-dimethoxyphenyl)acrylic acid.**

Sinomenine hydrochloride *[6080-33-7]* **M 365.9, m 231°.** Crystd from water.

Sitosterols *[12002-39-0],* **M 414.7.** Crystd from EtOH.

β-Sitosterol *[83-46-5]* **M 414.7, m 136-137°, $[\alpha]_{546}^{20}$ -42° (c 2, $CHCl_3$).** Crystd from MeOH. Also purified by zone melting.

Skatole see **3-methylindole.**

Skellysolve A is essentially *n*-pentane, **b** 28-30°,
Skellysolve A is essentially *n*-hexane, **b** 60-68°,
Skellysolve C is essentially *n*-heptane, **b** 90-100°,
Skellysolve D is mixed heptanes, **b** 75-115°,
Skellysolve E is mixed octanes, **b** 100-140°,
Skellysolve F is pet ether, **b** 30-60°,
Skellysolve G is pet ether, **b** 40-75°,
Skellysolve H is hexanes and heptanes, **b** 69-96°,
Skellysolve L is essentially octanes, **b** 95-127°. For methods of purification, see **petroleum ether**.

Smilagenin *[126-18-1]* **M 416.6, m 185°.** Crystd from acetone.

Solanidine *[80-78-4]* **M 397.6, m 218-219°.** Crystd from $CHCl_3$/MeOH.

Solanine-S *[51938-42-2]* **M 884.1, m 284°(dec).** Crystd from aqueous 85% EtOH.

Solasodine *[126-17-0]* **M 413.6, m 202°.** Crystd (as monohydrate) from aqueous 80% EtOH.

Solasonine *[19121-58-5]* **M 884.0, m 279°.** Crystd from aqueous 80% dioxane.

Solochrome Violet R *[2092-55-9]* **M 367.3.** Converted to the monosodium salt by pptn with sodium acetate/acetic acid buffer of pH 4, then purified as described for *Chlorazole Sky Blue FF*. Dried at 110°. It is *hygroscopic*. [Coates and Rigg *TFS* **57** 1088 *1961*].

Sorbic acid *[110-44-1]* **M 112.1, m 134°.** Crystd from boiling water.

Sorbitol *[50-70-4]* **M 182.2, m 89-93° (hemihydrate), 110-111° (anhydrous), $[\alpha]_{546}^{20}$ -1.8° (c 10, H_2O).** Crystd (as hemihydrate) several times from EtOH/water (1:1), then dried by fusing and storing over $MgSO_4$.

(-)-Sparteine sulphate pentahydrate *[6160-12-9]* **M 422.5, loses H_2O at 100° and turns brown at 136° (dec), $[\alpha]_D^{20}$ -22° (c 5, H_2O), $[\alpha]_D^{21}$ -16° (c 10, EtOH for free base).** Recrystd from aq EtOH or H_2O although the solubility in the latter is high. It has pKa_1^{20} 2.24 and pKa_2^{20} 9.46 in H_2O. The *free (-)-base* has **b** 173°/8mm and is steam volatile but resinifies in air. The *dipicrate* forms yellow needles from EtOH-Me_2CO, **m** 205-206° [Clemo et al. *JCS* 429 *1931*; see also Bolnmann and Schuman *The Alkaloids* (ed Manske) **Vol 9** 175 *1967*]. The *free (±)-base* has **m** 71-72.5° [van Tamelen and Foltz *JACS* **82** 2400 *1960*].

Spirilloxanthin *[34255-08-8]* **M 596.9, m 216-218°, λ_{max} 463, 493, 528 nm, $\varepsilon_{1cm}^{1\%}$ 2680 (493 nm), in pet ether (b 40-70°).** Crystd from $CHCl_3$/pet ether, acetone/pet ether, benzene/pet ether or benzene. Purified by chromatography on a column of $CaCO_3$/$Ca(OH)_2$ mixture or deactivated alumina. [Polgar et al. *Arch Biochem Biophys* **5** 243 *1944*]. Stored in the dark in an inert atmosphere, at -20°.

Squalene *[111-01-3]* **M 422.8, f.p. -5.4°, b 213°/1mm, d^{25} 0.8670, n 1.4905.** Crystd repeatedly from acetone (1.4ml of acetone per ml) by cooling in a Dry-ice bath, washing the crystals with cold acetone,

then freezing the squalene from the solvent under vacuum. The squalene was further purified by passage through a column of silica gel. It has also been chromatographed on activated alumina, using pet ether as eluent. Dauben et al. [*JACS* **74** 4321 *1952*] purified squalene *via* its hexachloride. See also Capstack et al. [*JBC* **240** 3258 *1965*] and Krishna et al. [*Arch Biochem Biophys* **114** 200 *1966*].

Squaric acid (3,4-dihydroxy-3-cyclobutene-1,2-dione) *[2892-51-5]* **M 114.1, m 293°(dec), 294°(dec), >300°.** Purified by recryst from H_2O — this is quite simple because the acid is ~ 7% soluble in boiling H_2O and only 2% at room temperature. It is not soluble in Me_2CO or Et_2O hence it can be rinsed with these solvents and dried in air or a vacuum. It is not hygroscopic and gives an intense purple colour with $FeCl_3$. It has IR ν at 2326 (strong H band), 1820 (C=O) and 1640 (C=C) cm^{-1}; and UV λmax at 269.5nm (ε 37K $M^{-1}cm^{-1}$).) [Cohn et al. *JACS* **81 3480** ***1959***; Park et al. *JACS* **84** 2919 *1962*] It has pKa values of 0.59 ±0.09 and 3.48 ±0.023 [Scwartz and Howard *JPC* **74** 4374 *1970*].

Starch *[9005-84-9]* **M (162.1)n.** Defatted by Soxhlet extraction with ethyl ether or 95% EtOH. For fractionation of starch into "amylose" and "amylopectin" fractions, see Lansky, Kooi and Schoch [*JACS* **71** 4066 *1949*].

Stearic acid (octadecanoic acid). *[57-11-4]* **M 284.5, m 71.4°.** Crystd from acetone, acetonitrile, EtOH (5 times), aq MeOH, ethyl methyl ketone or pet ether (b 60-90°), or by fractional pptn by dissolving in hot 95% EtOH and pouring into distd water, with stirring. The ppte, after washing with distd water, was dried under vacuum over P_2O_5. It has also been purified by zone melting. [Tamai et al. *JPC* **91** 541 *1987*].

Stearyl alcohol see ***n*-octadecyl alcohol.**

Stigmasterol *[83-48-7]* **M 412.7, m 170°, $[\alpha]_D^{22}$ -51° ($CHCl_3$), $[\alpha]_{546}^{20}$ -59° (c 2, $CHCl_3$).** Crystd from hot EtOH. Dried in vacuum over P_2O_5 for 3h at 90°. Purity was checked by NMR.

***cis*-Stilbene** *[645-49-8]* **M 180.3, b 145°/12mm.** Purified by chromatography on alumina using hexane and distd under vacuum. (The final product contains *ca* 0.1% of the *trans*-isomer). [Lewis et al. *JACS* **107** 203 *1985*; Saltiel *JPC* **91** 2755 *1987*].

***trans*-Stilbene** *[103.30-0]* **M 180.3, m 125.9°, b 305-307°/744mm, d 0.970.** Purified by vac distn. (The final product contains about 1% of the *cis* isomer). Crystd from EtOH. Purified by zone melting. [Lewis et al. *JACS* **107** 203 *1985*; Bollucci et al. *JACS* **109** 515 *1987*; Saltiel *JPC* **91** 2755 *1987*].

(-)-Strychnine *[57-24-9]* **M 334.4, m 268°, $[\alpha]_{546}^{20}$ -139° (c 1, $CHCl_3$).** Crystd as the hydrochloride from water, then neutralised with ammonia.

Styphnic acid *[82-71-3]* **M 245.1, m 179-180°.** Crystd from ethyl acetate. [**EXPLODES violently on rapid heating**].

Styrene *[100-42-5]* **M 104.2, b 41-42°/18mm, 145.2°/760mm, d 0.907, n 1.5469, n^{25} 1.5441.** Styrene is difficult to purify and keep pure. Usually contains added inhibitors (such as a trace of hydroquinone). Washed with aqueous NaOH to remove inhibitors (e.g. *tert*-butanol), then with water, dried for several hours with $MgSO_4$ and distd at 25° under reduced pressure in the presence of an inhibitor (such as 0.005% *p-tert*-butylcatechol). It can be stored at -78°. It can also be stored and kept anhydrous with Linde type 5A molecular sieves, CaH_2, $CaSO_4$, BaO or sodium, being fractionally distd, and distd in a vacuum line just before use. Alternatively styrene (and its deuterated derivative) were passed through a neutral alumina column before use [Woon et al. *JACS* **108** 7990 *1986*; Collman *JACS* **108** 2588 *1986*].

(±)-Styrene glycol (±-1-phenyl-1,2-ethanediol) *[93-56-1]* **M 138.2, m 67-68°.** Crystd from pet ether.

Styrene oxide *[96-09-3]* **M 120.2, b 84-86°/16.5mm, d 1.053, n 1.535.** Fractional distn at reduced pressure does not remove phenylacetaldehyde. If this material is present, the styrene oxide is treated with

hydrogen under 3 atmospheres pressure in the presence of platinum oxide. The aldehyde, but not the oxide, is reduced to ß-phenylethanol) and separation is now readily achieved by fractional distn. [Schenck and Kaizermen *JACS* **75** 1636 *1953*].

Suberic acid *[505-48-6]* **M 174.2, m 141-142°.** Crystd from acetone.

Succinamide *[110-14-5]* **M 116.1, m 262-265°(dec).** Crystd from hot water.

Succinic acid *[110-15-6]* **M 118.1, m 185-185.5°.** Washed with ethyl ether. Crystd from acetone, distd water, or *tert*-butanol. Dried under vacuum over P_2O_5 or conc H_2SO_4. Also purified by conversion to the disodium salt which, after crystn from boiling water (charcoal), is treated with mineral acid to regenerate the succinic acid. The acid is then recrystd and vacuum dried.

Succinic anhydride *[108-30-5]* **M 100.1, m 119-120°.** Crystd from redistd acetic anhydride or $CHCl_3$, then filtered, washed with ethyl ether and dried under vacuum.

Succinimide *[123-56-8]* **M 99.1, m 124-125°.** Crystd from EtOH (1ml/g) or water.

Succinonitrile *[110-61-2]* **M 80.1, m 57.9°, b 108°/1mm, 267°/760mm.** Purified by vacuum sublimation, also crystd from acetone.

D(+)-Sucrose *[57-50-1]* **M 342.3, m 186-188°, $[\alpha]_{546}^{20}$ +78° (c 10, H_2O).** Crystd from water. *Sucrose diacetate hexaisobutyrate:* melted and, while molten, treated with $NaHCO_3$ and charcoal, then filtered.

D-Sucrose octaacetate *[126-14-7]* **M 678.6, m 83-85°, $[\alpha]_{546}^{20}$ +70° (c 1, $CHCl_3$).** Crystd from EtOH.

Sudan III, CI 248 *[85-86-9]* **M 352.4, m 199°(dec), λ_{max} 354, 508 nm.** Crystd from EtOH, EtOH/water or benzene/abs EtOH (1:1).

Sudan IV *[85-83-6]* **M 380.5, m 184°.** Crystd from EtOH/water or acetone/water.

Sudan Yellow *[824-07-9]* **M 248.3, m 135°.** Crystd from EtOH.

Sulphaguanidine *[57-67-0]* **M 214.2, m 189-190°.** Crystd from hot water (7ml/g).

Sulphamethazine *[57-68-1]* **M 278.3, m 198-200°.** Crystd from dioxane.

Sulphanilamide *[63-74-1]* **M 172.2, m 166°.** Crystd from water or EtOH.

Sulphanilic acid *[121-57-3]* **M 173.2.** Crystd (as dihydrate) from boiling water. Dried at 105° for 2-3h, then over 90% H_2SO_4 in a vacuum desiccator.

Sulphapyridine *[144-83-2]* **M 349.2, m 193°.** Crystd from 90% acetone and dried at 90°.

***o*-Sulphobenzoic acid (H_2O)** *[632-25-7]* **M 202.2, m 68-69°,**
***o*-Sulphobenzoic acid (monoammonium salt)** *[6939-89-5]* **M 219.5.** Crystd from water.

***o*-Sulphobenzoic anhydride** *[81-08-3]* **M 184.2, m 128°, b 184-186°/18mm.** Crystd from dry benzene. It can be distd under vacuum.

Sulpholane *[126-33-0]* **M 120.2, m 28.5°, b 153-154°/18mm, 285°/760mm, d 1.263, n^{30} 1.4820.** Prepared commercially by Diels-Alder reaction of 1,3-butadiene and sulphur dioxide, followed by Raney nickel hydrogenation. The principle impurities are water, 3-sulpholene, 2-sulpholene and 2-isopropyl sulpholanyl ether. It is dried by passage through a column of molecular sieves. Distd under reduced pressure

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through a column packed with stainless steel helices. Again dried with molecular sieves and distd. [Cram et al. *JACS* **83** 3678 *1961*; Coetzee *PAC* **49** 211 *1977*].
Also, it was stirred at 50° and small portions of solid $KMnO_4$ were added until the colour persisted during 1h. Dropwise addition of MeOH then destroyed the excess $KMnO_4$, the soln was filtered, freed from potassium ions by passage through an ion-exchange column and dried under vacuum. It has also been vacuum distd from KOH pellets. It is *hygroscopic*. [See Sacco et al. *JPC* **80** 749 *1976; JCSFT 1* **73** 1936 *1977*; **74** 2070 *1978*; *TFS* **62** 2738 *1966*]. Coetzee has reviewed the methods of purification of sulpholane, and also the removal of impurities. [Coetzee in *Recommended Methods of Purification of Solvents and Tests for Impurities*, Coetzee ed. Pergamon Press, 1982].

5-Sulphosalicylic acid *[5965-83-3]* **M 254.2, m 108-110°.** Crystd from water. Alternatively, it was converted to the monosodium salt which was crystd from water and washed with a little water, EtOH and then ethyl ether. The free acid was recovered by acidification.

Syringaldehyde (3,5-dimethoxy-4-hydroxybenzaldehyde) *[134-96-3]* **M 182.2, m 113°.** Crystd from pet ether.

Syringic acid (3,5-dimethoxy-4-hydroxybenzoic acid) *[530-57-4]* **M 198.2, m 204-205°, 206.5°, 206-209°, 209-210°.** Recrystd from H_2O using charcoal [Bogert and Coyne *JACS* **51** 571 *1929*; Anderson and Nabenhauer *JACS* **48** 3001 *1926*]. It has pKa^{25} values of 4.2 and 9.1. The *methyl ester* has **m** 107° (from MeOH), the *4-acetyl* derivative has **m** 190° and the *4-benzoyl* derivative has **m** 229-232°. [Hahn and Wassmuth *B* **67** 2050 *1934*; UV: Lemon *JACS* **69** 2998 *1947* and Pearl and Beyer *JACS* **72** 1743 *1950*].

D(-)-Tagatose *[87-81-0]* **M 180.2, m 134-135°, $[\alpha]_{546}$ -6.5° (c 1, H_2O).** Crystd from aqueous EtOH.

***d*- Tartaric acid** *[147-71-7]* **M 150.1, m 169.5-170° (2*S*,3*S*-form, natural) $[\alpha]^{20}_{546}$ -15° (c 10, H_2O); m 208° (2*RS*,3*RS*-form).** Crystd from distilled H_2O or benzene/ethyl ether containing 5% of pet ether (b 60-80°) (1:1). Soxhlet extraction with ethyl ether has been used to remove an impurity absorbing at 265nm. It has also been crystd from absolute EtOH/hexane, and dried in a vacuum for 18h [Kornblum and Wade *JOC* **52** 5301 *1987*].

***meso*-Tartaric acid** *[147-73-9]* **M 150.1, m 139-141°.** Crystd from water, washed with cold MeOH and dried at 60° under vacuum.

Taurocholic acid *[81-24-3]* **M 515.6, m 125°(dec), $[\alpha]_D$ +38.8 (c 2, EtOH).** Crystd from EtOH/ethyl ether. It has pKa 1.4 in water.

Terephalaldehyde *[623-27-8]* **M 134.1, m 116°, b 245-248°/771mm.** Crystd from water.

Terephthalic acid *[100-21-0]* **M 166.1, sublimes >300° without melting.** Purified *via* the sodium salt which, after crystn from water, was reconverted to the acid by acidification with mineral acid.

Terephthaloyl chloride *[100-20-9]* **M 203.0, m 80-82°.** Crystd from dry hexane.

***o*-Terphenyl** *[84-15-1]* **M 230.3, m 57-58°,**
***m*-Terphenyl** *[92-06-8]* **M 230.3, m 88-89°.** Crystd from EtOH. Purified by chromatography of CCl_4 solns on alumina, with pet ether as eluent, followed by crystn from pet ether (b 40-60°) or pet ether/benzene. They can also be distd under vacuum.

***p*-Terphenyl** *[92-94-4]* **M 230.3, m 212.7°.** Crystd from nitrobenzene or trichlorobenzene. It was purified by chromatography on alumina in a darkened room, using pet ether, and then crystallizing from pet ether (b 40-60°) or pet ether/benzene.

Terpin hydrate *[2451-01-6]* **M 190.3, m 105.5° (*cis*), 156-158° (*trans*).** Crystd from H_2O or EtOH.

2,2':6',2"-Terpyridyl *[1148-79-4]* **M 233.3, m 91-92°.** Crystd from ethyl ether, toluene or from pet ether, then aqueous MeOH, followed by vacuum sublimation at 90°.

Terramycin *[79-57-2]* **M 248.4, sinters at 182°, melts at 184-185°(dec), $[\alpha]_D^{20}$ -196.6° (equilibrium in 0.1M HCl), -2.1° (equilibrium in 0.1M NaOH).** Crystd (as dihydrate) from water or aqueous EtOH.

Terric acid *[121-40-4]* **M 154.1, m 127-127.5°.** Crystd from benzene or hexane. Sublimed *in vacuo.*

Terthiophene (2,5-di[thienyl]thiophene; α–terthienyl) *[1081-34-1]* **M 248.4, m 94-95.5°, 94-96°.** Possible impurities are bithienyl and polythienyls. Suspend in H_2O and steam distil to remove bithienyl. The residue is cooled and extracted with $CHCl_3$, dried ($MgSO_4$), filtered, evaporated and the residue chromatographed on Al_2O_3 using pet ether-3% Me2CO as eluant. The terphenyl zone is then eluted from the Al_2O_3 with Et_2O, the extract is evaporated and the residue is recrystd from MeOH (40ml per g). The platelets are washed with cold MeOH and dried in air. [UV: Sease and Zechmeister *JACS* **69** 270 *1947*; Uhlenbroek and Bijloo *Rec Trav Chim Pays Bas* **79** 1181 *1960*].

Testosterone *[58-22-0]* **M 288.4, m 155°, $[\alpha]_{546}^{20}$ +130° (c 1, dioxane).** Crystd from aq acetone.

Testosterone propionate *[57-85-2]* **M 344.5, m 118-122°, $[\alpha]_{546}^{20}$ +100° (c 1, dioxane).** Crystd from aqueous EtOH.

2,3,4,6-Tetraacetyl-α-D-glucopyranosyl bromide see **acetobromoglucose.**

2,4,5,6-Tetraaminopyrimidine sulphate *[5392-28-9]* **M 238.2, m 255° (dec), >300°, >350° (dec).** Purified by recrystn from H_2O, 2N H_2SO_4 (20 parts, 67% recovery) or 0.1N H_2SO_4 (40 parts, 62% recovery), and dried in air. It has a pKa^{20} of 6.82 in H_2O. [UV: Konrad and Pfleiderer *B* **103** 722 *1970*; Malletta et al. *JACS* **69** 1814 *1947*; Cavalieri et al. *JACS* **70** 3875 *1948*].

Tetra-*n*-amylammonium bromide *[866-97-7]* **M 278.6, m 100-101°.** Purified by crystn from acetone/ether mixtures, and dried *in vacuo* at 60° for 2 days.

Tetra-*n*-amylammonium iodide *[2498-20-6]* **M 425.5, m 135-137°.** Crystd from EtOH and dried at 35° under vac. Also purified by dissolving in acetone and pptd by adding ethyl ether; and dried at 50° for 2 days.

1,4,8,11-Tetraazacyclotetradecane *[295-37-4]* **M 200.33, m 173° (closed capillary and sublimes at 125°), 183-185°, 185°.** Purified by recrystn from dioxane (white needles) which sublime above 120°. It has been distilled, **b** 132-140°/4-8mm. It forms complexes with metals and gives a sparingly soluble nitrate salt. [UV: Bosnich et al. *Inorganic Chemistry* **4** 1102 *1963*, van Alphen *Rec Trav Chim Pays Bas* **56**343 *1937*].

Tetrabenazine (2-oxo-3-isobutyl-9,10-dimethoxy-1,2,3,4,6,7,-hexahydro-11bH-benzo[a]-quinolizine) *[58-46-8]* **M 317.4, m 127-128°.** Crystd from MeOH.

3',3",5',5"-Tetrabromo-*m*-cresolsulphophthalein see **bromocresol green.**

1,1,2,2,-Tetrabromoethane *[79-27-6]* **M 345.7, f.p. 0.0°, b 243.5°, d 2.965, n 1.63533.** Washed successively with conc H_2SO_4 (three times) and H_2O (three times), dried with K_2CO_3 and $CaSO_4$ and distd.

Tetrabromophenolphthalein ethyl ester *[1176-74-5]* **M 662.0.** Crystd from benzene, dried at 120° and kept under vacuum.

3',3",5',5"-Tetrabromophenolsulphonephthalein see **bromophenol blue.**

Tetra-*n*-butylammonium bromide *[1643-19-2]* **M 322.4, m 119.6°.** Crystd from benzene (5ml/g) at 80° by adding hot *n*-hexane (three volumes) and allowing to cool. Dried over P_2O_5 or $Mg(ClO_4)_2$, under vacuum. The salt is *very* ***hygroscopic.*** It can also be crystd from ethyl acetate or dry acetone by adding ethyl ether and dried *in vacuo* at 60° for 2 days. It has been crystd from acetone by addition of ethyl ether. So *hygroscopic* that all manipulations should be carried out in a dry-box. Purified by pptn of a saturated soln in dry CCl_4 by addition of cyclohexane or by recrystn from ethyl acetate, then heating in vacuum to 75° in the presence of P_2O_5. [Symons et al. *JCSFT 1* **76** 2251 *1908*]. Also crystd from CH_2Cl_2/ethyl ether [Blau and Espenson *JACS* **108** 1962 *1986*].

Tetra-*n*-butylammonium chloride *[1112-67-0]* **M 295.9.** Crystd from acetone by addition of ethyl ether. *Very* ***hygroscopic.***

Tetra-*n*-butylammonium fluoroborate *[429-42-5]* **M 329.3, m 161-163°.** Recrystd from ethyl acetate/pentane in dry acetonitrile. [Hartley and Faulkner *JACS* **107** 3436 *1985*].

Tetra-*n*-butylammonium hexafluorophosphate *[3109-27-8]* **M 387.5, m 239-241°.** Recrystd from satd EtOH/water and dried for 10h in vac at 70°. It was also recrystd three times from abs EtOH and dried for 2 days in a drying pistol under vac at boiling toluene temperature [Bedard and Dahl *JACS* **108** 5933 *1986*].

Tetra-*n*-butylammonium hydrogen sulphate *[32503-27-8]* **M 339.5, m 171-172°.** Crystd from acetone.

Tetra-*n*-butylammonium iodide *[311-28-4]* **M 369.4, m 146°.** Crystd from toluene/pet ether (see entry for the corresponding bromide), acetone, ethyl acetate, EtOH/ethyl ether, nitromethane, aq EtOH or water. Dried at room temperature under vac. It has also been dissolved in MeOH/acetone (1:3, 10ml/g), filtered and allowed to stand at room temperature to evaporate to *ca* half its original volume. Distd water (1ml/g) was then added, and the ppte was filtered off and dried. It was also dissolved in acetone, ppted by adding ether and dried in vac at 90° for 2 days. Crystd from CH_2Cl_2/pet ether or hexane, or anhydrous MeOH and stored over P_2O_5. [Chau and Espenson *JACS* **108** 1962 *1986*].

Tetra-*n*-butylammonium nitrate *[1941-27-1]* **M 304.5, m 119°.** Crystd from benzene (7ml/g) or EtOH., dried in a vacuum over P_2O_5 at 60° for 2 days.

Tetra-*n*-butylammonium perchlorate *[1923-70-2]* **M 341.9°, m 210°(dec).** Crystd from EtOH, ethyl acetate, from *n*-hexane or ethyl ether/acetone mixture, ethyl acetate or hot CH_2Cl_2. Dried in vacuum at room temperature over P_2O_5 for 24h. [Anson et al. *JACS* **106** 4460 *1984*; Ohst and Kochi *JACS* **108** 2877 *1986;* Collman et al. *JACS* **108** 2916 *1986*; Blau and Espenson *JACS* **108** 1962 *1986*; Gustowski et al. *J ACS* **108** *1986*; Ikezawa and Kutal *JOC* **52** 3299 *1987*].

Tetra-*n*-butylammonium picrate *[914-45-4]* **M 490.6, m 89°.** Crystd from EtOH. Dried under vac.

Tetra-*n*-butylammonium tetrabutylborate (Bu_4N^+ Bu_4B^-) *[23231-91-6]* **M 481.7, m 109.5°.** Dissolved in MeOH or acetone, and crystd by adding distd water. Dried in vacuum at 70°. It has also been successively recrystd from isopropyl ether, isopropyl ether/acetone (50:1) and isopropyl ether/EtOH (50:1) for 10h, then isopropyl ether/acetone for 1h, and dried at 65° under reduced pressure for 1 week. [Kondo et al. *JCSFT 1* **76** 812 *1980*].

Tetra-*n*-butylammonium tetrafluoroborate *[429-42-5]* **M 329.3, m 160-162°.** Recrystd from ethyl acetate, and dried at 80° under vacuum [Detty and Jones *JACS* **109** 5666 *1987*].

1,2,4,5-Tetrachloroaniline *[634-83-3]* **M 230.9, m 119-120°,**
2,3,5,6-Tetrachloroaniline *[3481-20-7]* **M 230.9, m 107-108°.** Crystd from EtOH.

1,2,3,4-Tetrachlorobenzene *[634-66-2]* **M 215.9, m 45-46°, b 254°/760mm,**
1,2,3,5-Tetrachlorobenzene *[634-90-2]* **M 215.9, m 51°, b 246°/760mm.** Crystd from EtOH.

1,2,4,5-Tetrachlorobenzene *[95-94-3]* **M 215.9, m 139.5-140.5°, b 240°/760mm.** Crystd from EtOH, ether, benzene, benzene/EtOH or carbon disulphide.

3,4,5,6-Tetrachloro-1,2-benzoquinone *[2435-53-2]* **M 245.9, m 130°.** Crystd from AcOH. Dry in vacuum desiccator over KOH.

2,3,5,6-Tetrachloro-1,4-benzoquinone see ***p*-chloranil.**

1,1,2,2-Tetrachloro-1,2-difluoroethane *[72-12-0]* **M 203.8, f.p. 26.0°, b 92.8°/760mm.** Purified as for trichlorotrifluoroethane.

***sym*-Tetrachloroethane** *[79-34-5]* **M 167.9, b 146.2°, d 1.588, n^{15} 1.49678.** Stirred, on a steam-bath, with conc H_2SO_4 until a fresh portion of acid remained colourless. The organic phase was then separated, distd in steam, dried ($CaCl_2$ or K_2CO_3), and fractionally distd.

Tetrachloroethylene *[127-18-4]* **M 165.8, b 121.2°, d^{15} 1.63109, d 1.623, n^{15} 1.50759, n 1.50566** It decomposes under similar conditions to $CHCl_3$, to give phosgene and trichloroacetic acid. Inhibitors of this reaction include EtOH, ethyl ether and thymol (effective at 2-5ppm). Tetrachloroethylene should be distd under a vac (to avoid phosgene formation), and stored in the dark out of contact with air. It can be purified by washing with 2M HCl until the aq phase no longer becomes coloured, then with water, drying with Na_2CO_3, Na_2SO_4, $CaCl_2$ or P_2O_5, and fractionally distilling just before use. 1,1,2-Trichloroethane and 1,1,1,2-tetrachloroethane can be removed by counter-current extraction with EtOH/water.

Tetrachloro-*N*-methylphthalimide *[14737-80-5]* **M 298.9, m 209.7°.** Crystd from absolute EtOH.

2,3,4,6-Tetrachloronitrobenzene *[879-39-0]* **M 260.9, m 42°,**
2,3,5,6-Tetrachloronitrobenzene *[117-18-0]* **M 260.9, m 99-100°.** Crystd from aqueous EtOH.

2,3,4,5-Tetrachlorophenol *[4901-51-3]* **M 231,9, m 116-117°,**
2,3,4,6-Tetrachlorophenol *[58-90-2]* **M 231.9, m 70°, b 150°/15mm,**
2,3,5,6-Tetrachlorophenol *[935-95-5]* **M 231.9, m 115°.** Crystd from ligroin.

Tetrachlorophthalic anhydride *[117-08-8]* **M 285.9, m 255-257°.** Crystd from chloroform or benzene, then sublimed.

2,3,4,6-Tetrachloropyridine *[14121-36-9]* **M 216.9, m 74-75°, b 130-135°/16-20mm.** Crystd from 50% EtOH.

Tetracosane *[646-31-1]* **M 338.7, m 54°, b 243-244°/15mm.** Crystd from ether.

Tetracosanoic acid *[557-59-5]* **M 368.7, m 87.5-88°.** Crystd from acetic acid.

1,2,4,5-Tetracyanobenzene *[712-74-3]* **M 178.1, m 270-272° (280°).** Crystd from EtOH and sublimed *in vacuo*. [Lawton and McRitchie *JOC* **24** 26 *1959*; Bailey et al. *TET* **19** 161 *1963*].

Tetracyanoethylene *[670-54-2]* **M 128.1, m 199-200° (sealed tube).** Crystd from chlorobenzene, dichloroethane, or methylene dichloride [Hall et al. *JOC* **52** 5528 *1987*]. Stored at 0° in a desiccator over NaOH pellets. (It slowly evolves HCN on exposure to moist air.) It can also be sublimed at 120° under vacuum. Also purified by repeated sublimation at 120-130°/0.5mm. [Frey et al. *JACS* **107** 748 *1985*; Traylor and Miksztal *JACS* **109** 2778 *1987*].

7,7,8,8-Tetracyanoquinodimethane *[1518-16-7]* **M 204.2, m 287-290°(dec).** Recrystd from redistd dried acetonitrile.

Tetracycline *[60-54-8]* **M 444.4, m 172-174°(dec), $[\alpha]_{546}^{20}$ +270° (c 1, MeOH).** Crystd from toluene.

Tetradecane *[629-59-4]* **M 198.4, m 6°, b 122°/10mm, 252-254°, d 0.763, n 1.429.** Washed successively with 4M H_2SO_4 and water. Dried over $MgSO_4$ and distd several times under reduced pressure [Poë et al. *JACS* **108** 5459 *1986*].

Tetradecanoic acid see **myristic acid.**

1-Tetradecanol *[112-72-1]* **M 214.4, m 39-39.5°, b 160°/10mm, 170-173°/20mm.** Crystd from aq EtOH. Purified by zone melting.

Tetradecyl ether *[5412-98-6]* **M 410.7.** Distd under vac and then crystd repeatedly from MeOH/benzene.

Tetradecyltrimethylammonium bromide *[1119-97-7]* **M 336.4, m 244-249°.** Crystd from acetone or a mixture of acetone and >5% MeOH. Washed with ethyl ether and dried in a vacuum oven at 60°. [Dearden and Wooley *JPC* **91** 2404 *1987*].

Tetraethoxymethane *[62695-86-7]* **M 192.2, b 159°.** Dried with Na_2SO_4 and distd.

Tetraethylammonium bromide *[71-91-0]* **M 210.2, m 284°(dec).** Recrystd from EtOH, $CHCl_3$ or ethyl ether, or, recrystd from acetonitrile, and dried over P_2O_5 under reduced pressure for several days. Also recrystd from EtOH/ethyl ether (1:2), ethyl acetate, water or boiling MeOH/acetone (1:3) or by adding equal volume of acetone and allowing to cool. Dried at 100° *in vacuo* for 12 days, and stored over P_2O_5.

Tetraethylammonium chloride *[56-34-8]* **M 165.7.** Crystd from EtOH by adding ethyl ether, from warm water by adding EtOH and ethyl ether, from dimethylacetamide or from CH_2Cl_2 by addition of ethyl ether. Dried over P_2O_5 in vacuum for several days. Also crystd from acetone/CH_2Cl_2/hexane (2:2:1) [Blau and Espenson *JACS* **108** 1962 *1986*; White and Murray *JACS* **109** 2576 *1987*].

Tetraethylammonium iodide *[68-05-3]* **M 257.2, m >300°(dec).** Crystd from acetone/MeOH, EtOH/water, dimethylacetamide or ethyl acetate/EtOH (19:1). Dried under vacuum at 50° and stored over P_2O_5.

Tetraethylammonium perchlorate *[2567-83-1]* **M 229.7.** Crystd repeatedly from water, aqueous MeOH, acetonitrile or acetone, and dried at 70° under vacuum for 24h. [Cox et al. *JACS* **106** 5965 *1984*; Liu et al. *JACS* **108** 1740 *1986*; White and Murray *JACS* **109** 2576 *1987*]. Also twice crystd from ethyl acetate/95% EtOH (2:1) [Lexa et al. *JACS* **109** 6464 *1987*].

Tetraethylammonium picrate *[741-03-7]* **M 342.1.** Purified by successive crystns from water or 95% EtOH followed by drying in vacuum at 70°.

Tetraethylammonium tetrafluoroborate *[429-06-1]* **M 217.1.** Recrystd three times from a mixture of ethyl acetate/hexane (5:1) or MeOH/pet ether, then stored at 95° for 48h under vacuum [Henry and Faulkner *JACS* **107 3436** *1985*; Huang et al. *AC* **58** 2889 *1986*].

Tetraethylammonium tetraphenylborate *[12099-10-4]* **M 449.4.** Recrystd from aqueous acetone. Dried in a vacuum oven at 60° for several days. *Similarly for the propyl and butyl homologues.*

Tetraethyl 1,1,2,2-ethanetetracarboxylate *[632-56-4]* **M 318.3, m 73-74°.** Twice recrystd from EtOH by cooling to 0°.

Tetraethylene glycol dimethyl ether *[143-24-8]* **M 222.3, b 105°/1mm, d 1.010, n 1.435.** Stood with CaH_2, $LiAlH_4$ or sodium, and distd when required.

Tetraethylenepentamine *[112-57-2]* **M 189.3, b 169-171°/0.05mm, d 0.999, n 1.506.** Distd under vacuum. Purified *via* its pentachloride, nitrate or sulphate. Jonassen, Frey and Schaafsma [*JPC* **61** 504 *1957*] cooled a soln of 150g of the base in 300ml of 95% EtOH, and added dropwise 180ml of conc HCl, keeping the temperature below 20°. The white ppte was filtered, crystd three times from EtOH/water, then washed with ethyl ether and dried by suction. Reilley and Holloway [*JACS* **80** 2917 *1958*], starting with a similar soln cooled to 0°, added slowly (keeping the temperature below 10°) a soln of 4.5g-moles of HNO_3 in 600ml of aqueous 50% EtOH (also cooled to 0°). The ppte was filtered by suction, recrystd five times from aqueous 5% HNO_3, then washed with acetone and absolute EtOH and dried at 50°. [For purification *via* the sulphate see Reilley and Vavoulis (*AC* **31** 243 *1959*), and for an additional purification step using the Schiff base with benzaldehyde see Jonassen et al. *JACS* **79** 4279 *1957*].

Tetraethyl orthocarbonate (ethyl orthocarbonate, tetraethoxy ethane) *[78-09-1]* **M 192.3, b 59.6-60°/14mm, 158°/atm, 159°/atm, 160-161°/atm, d_4^{20} 0.9186, n_D^{20} 1.3932.** Likely impurities are hydrolysis products. Shake with brine (satd NaCl; dilute with a little Et_2O if amount of material is small) and dry ($MgSO_4$). The organic layer is filtered off and evaporated, and the residue is distd through a helices packed fractionating column with a total reflux partial take-off head. All distns can be done at atmospheric pressure in an inert atmosphere (e.g. N_2). [Robertys and McMahon *Org Synth* Coll Vol IV 457 *1963*; Connolly and Dyson *JCS* 828 *1937*; Tieckelmann and Post *JOC* **13** 266 *1948*].

1,1,2,2-Tetrafluorocyclobutane *[374-12-9]* **M 128.1.** Purified by preparative gas chromatography using a 2m x 6mm(i.d.) column packed with ß,ß'-oxydipropionitrile on Chromosorb P at 33°. [Conlin and Fey *JCSFT 1* **76** 322 *1980*].

Tetrafluoro-1,3-dithietane *[1717-50-6]* **M 164.1, m -6°, b 47-48°/760mm, d^{25} 1.6036, n^{25} 1.3908.** Purified by preparative gas chromatography or by distn through an 18in spinning band column. Also purified by shaking vigorously *ca* 40ml with 25ml of 10% NaOH, 5ml of 30% H_2O_2 until the yellow colour disappeared The larger layer was separated, dried over silica gel to give a colourless liquid boiling at 48°. It had a single line at -1.77ppm in the NMR spectrum. [Middleton, Howard and Sharkey, *JOC* **30** 1375 *1965*].

2,2,3,3-Tetrafluoropropanol *[76-37-9]* **M 132.1, b 106-106.5°.** Tetrafluoropropanol (450ml) was added to a soln of 2.25g of $NaHSO_3$ in 90ml of water, shaken vigorously and stood for 24h. The fraction distilling at or above 99° was refluxed for 4h with 5-6g of KOH and rapidly distd, followed by a final fractional distn. [Kosower and Wu *JACS* **83** 3142 *1961*]. Alternatively, shaken with alumina for 24h, dried overnight with anhydrous K_2CO_3 and distd, taking the middle fraction (**b** 107-108°).

Tetera-*n*-heptylammonium bromide *[4368-51-8]* **M 490.7, m 89-91°.** Crystd from *n*-hexane, then dried in a vacuum oven at 70°.

Tetra-*n*-heptylammonium iodide *[3535-83-9]* **M 537.7.** Crystd from EtOH.

Tetra-*n*-hexylammonium bromide *[4328-13-6]* **M 434.6, m 99-100°.** Washed with ether, and dried in a vacuum at room temperature for 3 days.

Tetra-*n*-hexylammonium chloride *[5922-92-9]* **M 390.1.** Crystd from EtOH.

Tetra-*n*-hexylammonium iodide *[2138-24-1]* **M 481.6, m 99-101°.** Washed with ethyl ether and dried at room temperature *in vacuo* for 3 days.

Tetrahexylammonium perchlorate *[4656-81-9]* **M 454.1, m 104-106°.** Crystd from acetone and dried *in vacuo* at 80° for 24h.

Tetrahydrofuran *[109-99-9]* **M 72.1, b 25°/176mm, 65.4°/atm, 66°/760mm, d_4^{20} 0.889, n_D^{20} 1.4070,** It is obtained commercially by catalytic hydrogenation of furan from pentosan-containing agricultural residues. It was purified by refluxing with, and distilling from $LiAlH_4$ which removes water, peroxides, inhibitors and other impurities [Jaeger et al. *JACS* **101** 717 *1979*]. Peroxides can also be removed by passage through a column of activated alumina, or by treatment with aq ferrous sulphate and sodium bisulphate, followed by solid KOH. In both cases, the solvent is then dried and fractionally distd from sodium. Lithium wire or vigorously stirred molten potassium have also been used for this purpose. CaH_2 has also been used as a drying agent.
Several methods are available for obtaining the solvent almost anhydrous. Ware [*JACS* **83** 1296 *1961*] dried vigorously with sodium-potassium alloy until a characteristic blue colour was evident in the solvent at Dry-ice/cellosolve temperatures. The solvent was kept in contact with the alloy until distd for use. Worsfold and Bywater [*JCS* 5234 *1960*], after refluxing and distilling from P_2O_5 and KOH, in turn, refluxed the solvent with sodium-potassium alloy and fluorenone until the green colour of the disodium salt of fluorenone was well established. [Alternatively, instead of fluorenone, benzophenone, which forms a blue ketyl, can be used]. The tetrahydrofuran was then fractionally distd, degassed and stored above CaH_2. *p*-Cresol or hydroquinone inhibit peroxide formation. The method described by Coetzee and Chang [*PAC* **57** 633 *1985*] for 1,4-dioxane also applies here. Distns should always be done in the presence of a reducing agent, e.g. $FeSO_4$. **It irritates the skin, eyes and mucous membranes and the vapour should never be inhaled. It is HIGHLY FLAMMABLE and the necessary precautions should be taken.**

1,2,3,4-Tetrahydronaphthalene see **tetralin.**

***l*-Tetrahydropalmatine** **M 355.4, m 148-149°, $[\alpha]_D^{20}$ -291° (EtOH).** Crystd from MeOH by addition of water [see *JCS,C* 530 *1967*].

Tetrahydropyran *[142-68-7]* **M 86.1, b 88.0°, n 1.4202, d 0.885.** Dried with CaH_2, then passed through a column of silica gel to remove olefinic impurities and fractionally distd. Freed from peroxides and moisture by refluxing with sodium, then distilling from $LiAlH_4$. Alternatively, peroxides can be removed by treatment with aqueous ferrous sulphate and sodium bisulphate, followed by solid KOH, and fractional distn from sodium.

Tetrahydro-4*H*-pyran-4-one *[29943-42-8]* **M 100.1, b 57-59°/11mm, 65-66°/15mm, 67-68°/18mm, 73°/20mm, 164.7°/atm, 166-166.5°/atm, d_4^{20} 1.0844, n_D^{20} 1.4551.** Purified by repeated distn preferably in a vacuum. [Baker *JCS* 296 *1944*; IR: Olsen and Bredoch *B* **91** 1589 *1958*]. The *oxime* has **m** 87-88° and **b** 110-111°/13mm [Cornubert et al. *Bull Soc Chim France* 36 *1950*]. The *4-nitrophenylhydrazone* forms orange-brown needles from EtOH, **m** 186° [Cawley and Plant *JCS* 1214 *1938*].

Tetrahydrothiophene *[110-01-0]* **M 88.2, m -96°, b 14.5°/10mm, 120.9°/760mm d 0.997, n 1.5289,.** Crude material was purified by crystn of the mercuric chloride complex to a constant melting point. It was then regenerated, washed, dried, and fractionally distd. [Whitehead et al. *JACS* **73** 3632 *1951*]. It has been dried over Na_2SO_4 and distd in a vacuum [Roberts and Friend *JACS* **108** 7204 *1986*].

Tetrahydro-4*H*-thiopyran-4-one *[1072-72-6]* **M 116.2, m 60-62°, 61-62°, 64-65°, 65-67°.** Purified by recrystn from diisopropyl ether or pet ether and dried in air. If too impure then dissolve in Et_2O, wash with aq $NaHCO_3$, then H_2O, dried ($MgSO_4$), filtd, evapd and the residue recrystd as before. [Cardwell *JCS* 715 *1949*]. The *oxime* can be recrystd from $CHCl_3$-pet ether (at -20°) and has **m** 84-85° [Barkenbus et al. *JOC* **20** 871 *1955*]. The *2,4-dinitrophenylhydrazone* has **m** 186° (from EtOAc) [Barkenbus et al. *JOC* **16** 232 *1951*]. The *S-dioxide* is recrystd from AcOH, **m** 173-174° [Fehnel and Carmack *JACS* **70** 1813 *1948*].

Tetrahydroxy-*p*-benzoquinone ($2H_2O$) *[5676-48-2]* **M 208.1.** Crystd from water.

Tetrakis(dimethylamine)ethylene *[996-70-3]* **M 300.2, b 60°/1mm, d 0.861, n 1.4817.** Impurities include tetramethylurea, dimethylamine, tetramethylethanediamine and tetramethyloxamide. It was washed with water while being flushed with nitrogen to remove dimethylamine, dried over molecular sieves, then passed through a silica gel column (previously activated at 400°) under nitrogen. Degassed on a vacuum line by distn from a trap at 50° to one at -70°. Finally, it was stirred over sodium-potassium alloy for several days. [Holroyd et al. *JPC* **89** 4244 *1985*].

Tetralin *[119-64-2]* **M 132.2, n 65-66°/5mm, 207.6°/760mm, d 0.968, n 1.5413.** It was washed with successive portions of conc H_2SO_4 until the acid layer no longer became coloured, then washed with aq 10% Na_2CO_3, and then distd water. Dried ($CaSO_4$ or Na_2SO_4), filtered, refluxed and fractionally distd at under reduced pressure from sodium or BaO. It can also be purified by repeated fractional freezing.
Bass [*JCS* 3498 *1964*] freed tetralin, purified as above, from naphthalene and other impurities by conversion to ammonium tetralin-6-sulphonate. Conc H_2SO_4 (150ml) was added slowly to stirred tetralin (272ml) which was then heated on a water bath for about 2h to give complete soln. The warm mixture, when poured into aq NH_4Cl soln (120g in 400ml water), gave a white ppte which, after filtering off, was crystd from boiling water, washed with 50% aq EtOH and dried at 100°. Evapn of its boiling aq soln on a steam bath removed traces of naphthalene. The pure salt (229g) was mixed with conc H_2SO_4 (266ml) and steam distd from an oil bath at 165-170°. An ether extract of the distillate was washed with aq Na_2SO_4, and the ether was evapd, prior to distilling the tetralin from sodium. Tetralin has also been purified *via* barium tetralin-6-sulphonate, conversion to the sodium salt and decomposition in 60% H_2SO_4 using superheated steam.

Tetralin hydroperoxide *[771-29-9]* **M 164.2, m 56°.** Crystd from hexane.

α-Tetralone (1,2,3,4-tetrahydro-1-oxonaphthalene) *[529-34-0]* **M 146.2, m 2-7°, 7.8-8.0°, b 75-85°/0.3mm, 89°/0.5mm, 94-95°/2mm, 132-134°/15mm, 143-145°/20mm, d_4^{20} 1.0695, n_D^{20} 1.5665.** Check the IR first. Purify by dissolving 20ml in Et_2O (200ml), washing with H_2O (100ml), 5% aq NaOH (100ml), H_2O (100ml), 3% aq AcOH (100ml), 5% $NaHCO_3$ (100ml) then H_2O (100ml) and dry the ethereal layer over $MgSO_4$. Filter, evap and fractionate the residue through a 6in Vigreux column under reduced pres to give a colourless oil (~17g) with **b** 90-91°/0.5-0.7mm. [Snyder and Werber *Org Synth* Coll Vol III 798 *1955*]. It has also been fractionated through a 0.5metre packed column with a heated jacket under reflux using a partial take-off head. [Olson and Bader *Org Synth* Coll Vol IV 898 *1963*].

β-Tetralone (1,2,3,4-tetrahydro-2-oxonaphthalene) *[530-93-8]* **M 146.2, m 17-18°, ~18°, b 93-95°/2mm, 104-105°/4mm, 114-115°/4-5mm, 140°/18mm, d_4^{20} 1.1000, n_D^{20} 1.5598.** If reasonably pure then fractionate through an efficient column. Other wise purify *via* the *bisulphite adduct*. To a soln of $NaHSO_3$ (32.5g, 0.31mol) in H_2O (57ml) is added 95% EtOH (18ml) and set aside overnight. Any bisulphite-sulphate that separated is removed by filtration and the filtrate is added to the tetralone (14.6g, 0.1mol) and shaken vigorously. The adduct separates in a few minutes as a white ppte and kept on ice for ~3.5h with occasional shaking. The ppte is collected, washed with 95% EtOH (13ml), then with Et_2O (4 x 15ml, by stirring the suspension in the solvent, filtering and repeating the process). The colourless product is dried in air and stored in air tight containers in which it is stable for extended periods (yield is ~17g). This bisulphite (5g) is suspended in H_2O (25ml) and $NaCO_3.H_2O$ (7.5g) is added (pH of soln is ~10). The mixture is then extracted with Et_2O (5 x 10ml, i.e. until the aqueous phase does not test for tetralone — see below). Wash the combined extracts with 10% aqueous HCl (10ml), H_2O (10ml, i.e. until the washings are neutral), dry ($MgSO_4$), filter, evaporate and distil the residual oil using Claisen flask under reduced pressure and in a N_2 atm. The pure tetralone is a colourless liquid **b** 70-71°/0.25mm (see also above). The yield is ~2g. **Tetralone test:** Dissolve a few drops of the tetralone soln (ethereal or aqueous) in 95% EtOH in a test tube and add 10 drops of 25% NaOH down the side of the tube. A deep blue colour develops at the interface with air. [Soffer *Org Synth* Coll Vol IV 903 *1963*; Cornforth et al. *JCS* 689 *1942*; UV: Soffer et al. *JACS* 1556 *1952*]. The *phenylhydrazone* has **m** 108° [Crawley and Robinson *JCS* 2001 *1938*].

Tetramethylammonium bromide *[64-20-0]* **M 154.1, sublimes with dec >230°.** Crystd from EtOH, EtOH/ethyl ether, MeOH/acetone, water or from acetone/MeOH (4:1) by adding an equal volume of acetone. It was dried at 110° under reduced pressure or at 140° for 24h.

Tetramethylammonium chloride *[57-75-0]* **M 109.6, m >230°(dec).** Crystd from EtOH, EtOH/$CHCl_3$, EtOH/ethyl ether, acetone/EtOH (1:1), isopropanol or water. Traces of the free amine can be removed by washing with $CHCl_3$.

Tetramethylammonium hydroxide ($2H_2O$) *[10424-65-4]* **M 181.2, m 63°(dec).** Freed from chloride ions by passage through an ion-exchange column (Amberlite IRA-400, prepared in its OH^- form by passing 2M NaOH until the effluent was free from chloride ions, then washed with distilled H_2O until neutral). A modification, to obtain carbonate-free hydroxide, uses the method of Davies and Nancollas [*Nature* **165** 237 *1950*].

Tetramethylammonium iodide *[75-58-1]* **M 201.1, m >230°(dec).** Crystd from water or 50% EtOH, EtOH/ethyl ether, ethyl acetate, or from acetone/MeOH (4:1) by adding an equal volume of acetone. Dried in a vacuum desiccator.

Tetramethylammonium perchlorate *[2537-36-2]* **M 173.6, m >300 °(dec).** Crystd from acetone and dried *in vacuo* at 60° for several days.

Tetramethylammonium tetraphenylborate *[15525-13-0]* **M 393,3.** Recrystd from acetone, acetone/CCl_4 and from acetone/1,2-dichloroethane. Dried over P_2O_5 in vacuum, or in a vacuum oven at 60° for several days.

1,2,3,4-Teteramethylbenzene *[488-23-3]* **M 134.2, m -6.3°, b 79.4°/10mm, 204-205°/760mm, d 0.905, n 1.5203.** Dried over sodium and distd under reduced pressure.

1,2,3,5-Tetramethylbenzene (isodurene) *[527-53-7]* **M 134.2, m -23.7°, b 74.4°/10mm, 198°/760mm, d 0.890, n 1.5130.** Refluxed over sodium and distd under reduced pressure.

1,2,4,5-Tetramethylbenzene see **durene.**

***N,N,N',N'*-Tetramethylbenzidine** *[366-29-0]* **M 240.4, m 195.4-195.6°.** Crystd from EtOH or pet ether, then from pet ether/benzene, and sublimed in a vacuum. [Guarr et al. *JACS* **107** 5104 *1985*]. Dried under vac in an Abderhalden pistol, or carefully on a vacuum line.

2,2,4,4-Tetramethylcyclobutan-1,3-dione *[933-52-8]* **M 140.2, m 114.5-114.9°.** Crystd from benzene and dried under vacuum over P_2O_5 in an Abderhalden pistol.

3,3,5,5-Tetramethylcyclohexanone *[14376-79-5]* **M 154.3, m 11-12°, 13.2°, b 59-61°, b/5.5mm, 80-82°/13mm, 196°/760mm, 200-203°/atm, 203.8-204.8°/760mm, d_D^{20} 0.8954, n_D^{20} 1.4515.** Purified first through a 24in column packed with Raschig rings then a 40cm Vigreux colum under reduced pressure (**b** 69-69.3°/7mm, see above). The *oxime* has **m** 144-145° (from 60% EtOH) and the *semicarbazone* has **m** 196-197°, 197-198° (214.5°, 217-218°) [Karasch and Tawney *JACS* **63** 2308 *1941*; UV: Sandris and Ourisson *Bull Soc Chim France* 958 *1956*].

***p,p'*-Tetramethyldiaminophenylmethane** *[101-61-1]* **M 254.4, m 89-90°.** Crystd from EtOH (2ml/g).

3,3,4,4-Tetramethyldiazetidine dioxide M 144.2. Purified by recrystn from MeOH.

Tetramethylene glycol see **1,4-butanediol.**

Tetramethylenesulphone see **sulpholane.**

Tetramethylene sulphoxide (tetrahydrothiophen 1-oxide) *[1600-44-8]* **M 104.2, b 235-237°, d 1.175, n 1.525.** Shaken with BaO for 4 days, then distd from CaH_2 under reduced pressure.

***N,N,N',N'*-Tetramethylethylenediamine (TEMED)** *[110-18-9]* **M 116.2, b 122°, d 1.175, n^{25} 1.4153.** Partially dried with molecular sieves (Linde type 4A), and distd in vacuum from butyl lithium. This treatment removes all traces of primary and secondary amines and water. [Hay, McCabe and Robb *JCSTF I* **68** 1 *1972*]. Or, dried with KOH pellets. Refluxed for 2h with one-sixth its weight of *n*-butyric anhydride (to remove primary and secondary amines) and fractionally distd. Refluxed with fresh KOH, and distd under nitrogen. [Cram and Wilson *JACS* **85** 1245 *1963*]. Also distd from sodium.

Tetramethylethylenediamine dihydrochloride *[7677-21-8]* **M 198.2.** Crystd from 98% EtOH/conc HCl.

1,1,3,3-Tetramethylguanidine *[80-70-6]* **M 115.2, b 159-160°, d 0.917 n 1.470.** Refluxed over granulated BaO, then fractionally distd.

***N,N,N',N'*-Tetramethyl-1,8-naphthalenediamine** *[20734-58-1]* **M 214.3, m 45-48°, 47-48°, b 144-145°/4mm.** It is prepared by methylating 1,8-diaminonaphthalene and likely impurities are methylated products. The tetramethyl compound is a stronger base than the unmethylated, di and trimethylated derivatives. The pKa values are: 1,8-$(NH_2)_2$ = 4.61, 1,8-$(NHMe)_2$ = 5.61, 1-NHMe-8-$NHMe_2$ = 6.43 and 1,8-$(NMe_2)_2$ = 12.34. The mixture is then treated H_2O at pH 8 (where all but the required base are protenated) and extracted with Et_2O or $CHCl_3$. The dried extract (K_2CO_3) yields the tetramethyldiamine on evapn which can be distd. It is a strong base with weak nucleophilic properties, e.g. it could not be alkylated by refluxing with EtI in MeCN for 4 days and on treatment with methyl fluorosulphonate only the fluorosulphonate salt of the base is obtained. [NMR: Adler et al. *JCSCC* 723 *1968* ; *Brown and Letang* JACS **63** 358 *1941*].

Tetramethyl orthocarbonate (methyl orthocarbonate, tetramethoxy methane) *[1850-14-2]* **M 136.2, m -5.6°, -5°, -2°, b 113,5°/760mm, 113.5-114°/755mm, 112-114°/atm, d_4^{20} 1.0202, n_D^{20} 1.3860.** Purified in the same way as for tetraethyl orthocarbonate. [Smith *Acta Chem Scand* **10** 1006 *1956*; Tiekelmann and Post *JOC* **13** 266 *1948*].

2,6,10,14-Tetramethylpentadecane (pristane, norphytane) *[1921-70-6]* **M 268.5, b 68° (bath temp)/0.004mm, 158°/10mm, 296°/atm, d_4^{20} 0.7827, n_D^{20} 1.4385.** Purified by shaking with conc H_2SO_4 (care with this acid, if amount of pristane is too small then it should be diluted with pet ether *not* Et_2O which is quite sol in the acid), the H_2O (care as it may heat up if in contact with conc H_2SO_4), dried ($MgSO_4$) evaporated and distd over Na metal. [Sörensen and Sörensen *Acta Chem Scand* **3** 939 *1949*].

***N,N,N',N'*-Tetramethyl-1,4-phenylenediamine** *[100-22-1]* **M 164.3, m 51°, b 260°/760mm.** Crystd from pet ether or water. It can be sublimed or dried carefully in a vacuum line, and stored in the dark under nitrogen. Also recrystd from its melt.

***N,N,N',N'*-Tetramethyl-1,4-phenylenediamine dihydrochloride** *[637-01-4]* **M 237.2, m 222-224°.** Crystd from isopropyl or *n*-butyl alcohols, satd with HCl. Treated with aq NaOH to give the free base which was filtered, dried and sublimed in a vacuum. [Guarr et al. *JACS* **107** 5104 *1985*].

2,2,6,6-Tetramethylpiperidinyl-1-oxy (TEMPO) *[2564-83-2]* **M 156.3, m 36-38°.** Purified by sublimation (33°, water aspirator) [Hay and Fincke *JACS* **109** 8012 *1987*].

2,2,6,6-Tetramethyl-4-piperidone hydrochloride (triacetoneamine) *[33973-59-0]* **M 191.7, m 190° (dec).** Purified by recrystn from EtOH-Et_2O. The *free base* has **m** 37-39° (after sublimation), **b** 102-105°/18mm, and *hydrate* **m** 56-58° (wet Et_2O); the *hydrobromide* has **m** 203° (from EtOH-Et_2O) and the *picrate* has **m** 196° (from aq EtOH). [Sandris and Ourisson *Bull Soc Chim France* 345 *1958*].

Tetramethylthiuram disulphide [bis(dimethylthiocarbamyl)-disulphide] *[137-26-8]* **M 240.4, m 146-148°.** Crystd (three times) from boiling $CHCl_3$, then recrystd from boiling $CHCl_3$ by adding EtOH

dropwise to initiate pptn, and allowed to cool. Finally it was ppted from cold $CHCl_3$ by adding EtOH (which retained the monosulphide in soln). [Ferington and Tobolsky *JACS* **77** 4510 *1955*].

1,1,3,3-Tetramethyl urea *[632-22-4]* **M 116.2, f.p. -1.2°, b 175.2°/760mm, d 0.969, n 1.453.** Dried over BaO and distd under nitrogen.

Tetramethyl uric acid *[2309-49-1]* **M 224.2, m 228°.** Crystd from water.

1,3,5,5-Tetranitrohexahydropyrimidine *[81360-42-1]* **M 270.1.** Crystd five times from EtOH.

Tetranitromethane *[509-14-8]* **M 196.0, m 14.2°, b 21-23°/23mm, 126°/760mm, d 1.640, n 1.438.** Shaken with dilute NaOH, washed, steam distd, dried with Na_2SO_4 and fractionally crystd by partial freezing. The melted crystals were dried with $MgSO_4$ and fractionally distd under reduced pressure. Shaken with a large volume of dilute NaOH until no absorption attributable to the nitroform anion is observable in the water. Then washed with distilled water, and distilled at room temperature by passing a stream of air or nitrogen through the liquid and condensing in a trap at -80°. It can be dried with $MgSO_4$ or Na_2SO_4, fractionally crystd from the melt, and fractionally distd under reduced pressure.

Tetra(*p*-nitrophenyl)ethylene *[47797-98-8]* **M 512.4.** Crystd from dioxane and dried at 150°/0.1mm.

4,7,13,18-Tetraoxa-1,10-diazabicyclo[8.5.5]eicosane (Cryptand 211) *[31250-06-3]* **M 288.1.** Redistd, dried under high vacuum over 24h, and stored under nitrogen.

1,7,10,16-Tetraoxa-4,13-diazacyclooctadecane (4,13-diaza-18-crown-6) *[23978-55-4]* **M 262.3, m 118-116°.** Twice recrystd from benzene/*n*-heptane, and dried for 24h under high vacuum [D'Aprano and Sesta *JPC* **91** 2415 *1987*].

Tetrapentylammonium bromide *[866-97-7]* **M 378.5, m 100-101°.** Crystd from pet ether, benzene or acetone/ether and dried in vacuum at 40-50°.

Tetraphenylethylene *[632-51-9]* **M 332.4, m 223-224°, b 415-425°/760mm.** Crystd from dioxane or from EtOH/benzene. Sublimed under high vacuum.

Tetraphenylhydrazine *[632-52-0]* **M 336.4, m 147°.** Crystd from 1:1 $CHCl_3$/toluene or $CHCl_3$/EtOH. Stored in a refrigerator, in the dark.

***trans*-1,1,4,4-Tetraphenyl-2-methylbutadiene** *[20411-57-8]* **M 372.5.** Crystd from EtOH.

Tetraphenylphosphonium chloride *[2001-45-8]* **M 374.9, m 273-275°.** Crystd from acetone. Dried at 70° under vacuum. Also recrystd from a mixture of 1:1 or 1:2 dichloroethane/pet ether, the solvents having been dried under anhydrous K_2CO_3. The purified salt was dried at room temperature under vacuum for 3 days, and at 170° for a further 3 days. *Extremely hygroscopic.*

5,10,15,20-Tetraphenylporphyrin (TPP) *[917-23-7]* **M 614.7, λ_{max} 482nm.** Purified by chromatography on neutral (Grade I) alumina, and recrystd from CH_2Cl_2/MeOH [Yamashita et al. *JPC* **91** 3055 *1987*].

Tetra-*n*-propylammonium bromide *[1941-30-6]* **M 266.3, m >280°(dec).** Crystd from ethyl acetate/EtOH (9:1), acetone or MeOH. Dried at 110° under reduced pressure.

Tetra-*n*-propylammonium iodide *[631-40-3]* **M 313.3, m >280°(dec).** Purified by crystn from EtOH, EtOH/ethyl ether (1:1), EtOH/water or aqueous acetone. Dried at 50° under vacuum. Stored over P_2O_5 in a vacuum desiccator.

Tetra-*n*-propylammonium perchlorate *[15780-02-6]* **M 285.8, m 239-241°.** Crystd from acetonitrile/water (1:4.v/v), or conductivity water. Dried in an oven at 60° for several days, or dried under vacuum over P_2O_5.

5,10,15,20-Tetra-4'-pyridinylporphyrin *[16834-13-2]* **M 618.7.** Purified by chromatography on alumina (neutral, Grade I), followed by recrystn from CH_2Cl_2/MeOH [Yamashita et al. *JPC* **91** 3055 *1987*].

Tetrathiafulvalene *[31366-25-3]* **M 204.4, m 122-124°.** Recrystd from cyclohexane/hexane under an argon atmosphere [Kauzlarich et al. *JACS* **109** 4561 *1987*].

1,2,3,4-Tetrazole *[288-94-8]* **M 70.1, m 156°.** Crystd from EtOH, sublimed under high vacuum at *ca* 120° (*care should be taken due to possible* **EXPLOSION**).

TETREN see **tetraethylenepentamine.**

Thapsic acid see **1,14-hexadecanedioic acid.**

Thebaine *[115-37-7]* **M 311.4, m 193°, $[\alpha]_D^{25}$ -219° (EtOH).** Sublimed at 170-180°.

2-Thenoyltrifluoroacetone *[326-91-0]* **M 222.2.** Crystd from hexane or benzene. (Aqueous solns slowly decompose).

2-Thenylamine *[27757-85-3]* **M 113.1, b 78.5°/15mm.** Distd under reduced pressure (nitrogen), from BaO, through a column packed with glass helices.

Theobromine *[83-67-0]* **M 180.2, m 337°,**
Theophylline *[58-55-9]* **M 180.2, m 270-274°.** Crystd from water.

Thevetin *[11018-93-2]* **M 858.9, softens at 194°, m 210°.** Crystd (as trihydrate) from isopropanol. Dried at 100°/10mm to give the hemihydrate (*very hygroscopic*).

Thianthrene *[92-85-3]* **M 216.3, m 158°.** Crystd from acetone (charcoal), acetic acid or EtOH. Sublimed under vacuum.

ε-[2-(4-Thiazolidone)]hexanoic acid M 215.3, m 140°. Crystd from water, acetone or MeOH.

Thiazoline-2-thiol *[96-53-7]* **M 119.2, m 100-105°, 106-107°, 106-108°.** Purified by dissolution in alkali, pptn by addition of HCl and then recrystd from H_2O as needles. [IR: Flett *JCS* 347 *1953* and Mecke et al. *B* **90** 975; Gabriel and Stelzner *B* **28** 2931 *1895*].

4-(2-Thiazolylazo)resorcinol *[2246-46-0]* **M 221.2, m 200-202°(dec), λ_{max} 500 nm.** Dissolved in alkali, extracted with ethyl ether, and re-ppted with dil HCl. The purity was checked by TLC on silica gel using pet ether/ethyl ether/EtOH (10:10:1) as the mobile phase.

Thietane (trimethylene sulphide) *[287-27-4]* **M 74.1, m -64°, -73.2°, b 93.8-94.2°/752mm, 95°/atm, d_4^{20} 1.0200, n_D^{20} 1.5020.** Purified by preparative gas chromatography on a dinonyl phthalate column. It has also been purified by drying over anhydrous K_2CO_3, and distd through a 25 cm glass helices packed column (for 14g of thietane), then dried over $CaSO_4$ before sealing in a vac. [Haines et al. *JPC* **58** 270 *1954*]. It is characterised as the *dimethylsulphonium iodide* **m** 97-98° [Bennett and Hock *JCS* 2496 *1927*]. The *S-oxide* has **b** 102°/25mm, n_D^{21} 1.5075 [Tamres and Searles *JACS* **81** 2100 *1959*].

Thioacetamide *[62-55-5]* **M 75.1, m 112-113°.** Crystd from absolute ethyl ether or benzene. Dried at 70° in vacuum and stored over P_2O_5 at 0° under nitrogen. (*Develops an obnoxious odour on keeping*, and absorption at 269mm decreases, hence it should be freshly crystd before use).

Thioacetanilide *[677-53-6]* **M 151.2, m 75-76°.** Crystd from water and dried in a vacuum desiccator.

Thiobarbituric acid *[504-17-6]* **M 144.2, m 235°(dec).** Crystd from water.

Thiobenzanilide *[636-04-4]* **M 213.2, m 101.5-102°.** Crystd from MeOH at Dry-ice temperature.

(1*R*)-(-)-Thiocamphor (1*R*-bornane-2-thione, 1*R*-(-)-1,7,7-trimethylbicyclo[2.2.1]heptane-2-thione) *[53402-10-1]* **M 168.3, m 136-138°, 146°, $[\alpha]_D^{22}$ -22° (c 3, EtOAc).** Forms red prisms from EtOH and sublimes under vacuum. It possesses a sulphurous odour and is volatile as camphor. [Sen *JICS* **12** 647 *1935*; **18** 76 *1941*]. The *racemate* crystallises from C_6H_6 and has **m** 145° [138.6-139°, White and Bishop *JACS* **62** 10 *1940*].

Thiocarbanilide see ***sym*-diphenylthiourea.**

Thiochrome *[92-35-3]* **M 262.3, m 227-228°.** Crystd from chloroform.

Thiocresol see **toluenethiol.**

6,8-Thioctic acid see Chapter 5.

Thiodiglycollic acid *[123-93-3]* **M 150.2, m 129°,**
ß,ß'-Thiodipropionic acid *[111-17-1]* **M 178.2.** Crystd from water.

Thioflavine T *[2390-54-7]* **M 318.9.** Crystd from benzene/EtOH (1:1).

Thioformamide *[115-08-2]* **M 61.0, m 29°.** Crystd from ethyl acetate or ether/pet ether.

Thioglycollic acid *[68-11-1]* **M 92.1, b 95-96°/8mm, d 1.326, n 1.505.** Mixed with an equal volume of benzene, the benzene is then distd to dehydrate the acid. After heating to 100° to remove most of the benzene, the residue was distd under vacuum and stored in sealed ampoules at 3°. [Eshelman et al. *AC* **22** 844 *1960*].

Thioguanosine *[85-31-4]* **M 299.3, m 230-231°(dec).** Crystd (as hemihydrate) from water.

Thioindigo *[522-75-8]* **M 296.2, m >280°.** Adsorbed on silica gel from CCl_4/benzene (3:1), eluted with benzene, crystd from $CHCl_3$ and dried at 60-65°. [Wyman and Brode *JACS* **73** 1487 *1951*]. This paper also gives details of purification of other thioindigo dyes.

Thiomalic acid *[70-49-5]* **M 150.2, m 153-154°.** Extracted from aqueous soln several times with ethyl ether, and the aqueous soln freeze-dried.

Thio-Michler's Ketone *[1226-46-6]* **M 284.6, λ_{max} 457 nm (ε 2.92 x 10^4 in 30% aq *n*-propanol).** Purified by recrystn from hot EtOH or by triturating with a small volume of $CHCl_3$, followed by filtration and washing with hot EtOH [Terbell and Wystrade *JPC* **68** 2110 *1964*].

Thionanthone *[492-22-8]* **M 212.3, m 210-213°.** Recrystd from benzene [Ikezawa et al. *JACS* **108** 1589 *1986*].

2-Thionaphthol *[91-60-1]* **M 160.2, m 81°, b 153.5°/15mm, 286°/760mm.** Crystd from EtOH.

Thionin *[581-64-6]* **M 263.8, ε_{590} 6.2 x 10^4 $M^{-1}cm^{-1}$.** The standard biological stain is highly pure. It can be crystd from water or 50% EtOH, then chromatographed on alumina using $CHCl_3$ as eluent [Shepp, Chaberek and McNeil *JPC* **66** 2563 *1962*]. Dried overnight at 100° and stored in a vacuum. The hydrochloride can be crystd from 50% EtOH or dilute HCl and aqueous *n*-butanol. Purified also by column chromatography and washed with $CHCl_3$ and acetone. Dried *in vacuo* at room temperature.

Thiooxine hydrochloride (8-mercaptoquinoline hydrochloride) *[34006-16-1]* **M 197.7, m 170-175° (dec).** Crystallises from EtOH and the crystals are yellow in colour. It has pKa^{20} values of 2.05 and 8.29 in H_2O. [UV: Albert and Barlin *JCS* 2384 *1959*].

Thiophane (tetrahydrothiophen) *[110-01-0]* **M 88.2, b 40.3°/39.7mm, d 1.001, n 1.504.** Distd from sodium.

Thiophene *[110-02-1]* **M 84.1, f.p. -38.5°, b 84.2°, d 1.525, n 1.52890, n^{30} 1.5223.** The simplest purification procedure is to dry with solid KOH, or reflux with sodium, and fractionally distd through a glass-helices packed column. More extensive treatments include an initial wash with aq HCl, then water, drying with $CaSO_4$ or KOH, and passage through columns of activated silica gel or alumina. Fawcett and Rasmussen [*JACS* **67** 1705 *1945*] washed thiophene successively with 7M HCl, 4M NaOH, and distd water, dried with $CaCl_2$ and fractionally distd. Benzene was removed by fractional crystn by partial freezing, and the thiophene was degassed and sealed in Pyrex flasks. [Also a method is described for recovering the thiophene from the benzene-enriched portion].

2-Thiophenaldehyde *[98-03-3]* **M 112.2, b 106°/30mm, d 1.593, n 1.222.** Washed with 50% HCl and distd under reduced pressure just before use.

Thiophene-2-acetic acid *[1918-77-0]* **M 142.2, m 76°,**
Thiophene-3-acetic acid *[6964-21-2]* **M 142.2, m 79-80°.** Crystd from ligroin.

Thiophene-2-carboxylic acid *[527-72-0]* **M 128.2, m 129-130°,**
Thiophene-3-carboxylic acid *[88-31-1]* **M 128.1, m 137-138°.** Crystd from water.

Thiophenol see **benzenethiol**

Thiopyronine *[2412-14-8]* **M 318.9, λ_{max} 564nm (ε 78,500) H_2O.** Purified as the hydrochloride by recrystn from hydrochloric acid. [Fanghanel et al. *JPC* **91** 3700 *1987*].

Thiosalicylic acid *[147-93-3]* **M 154.2, m 164-165°.** Crystd from hot EtOH (4ml/g), after adding hot distd water (8ml/g) and boiling with charcoal. The hot soln was filtered, cooled, the solid collected and dried in vacuum over P_2O_5.

Thiosemicarbazide *[79-19-6]* **M 91.1, m 181-183°.** Crystd from water.

Thiothienoyltrifluoroacetone *[4552-64-1]* **M 228.2, m 61-62°.** Easily oxidised and has to be purified before use. This may be by recrystd from benzene or by dissolution in pet ether, extraction into 1M NaOH soln, acidification of the aqueous phase with 1-6M HCl soln, back extraction into pet ether and final evapn of the solvent. The purity can be checked by TLC. It was stored in ampoules under nitrogen at 0° in the dark. [Muller and Rother *Anal Chim Acta* **66** 49 *1973*].

Thiouracil *[141-90-2]* **M 128.2, m 240°(dec).** Crystd from water or EtOH.

Thiourea *[62-56-6]* **M 76.1, m 179°.** Crystd from absolute EtOH, MeOH, acetonitrile or water. Dried under vacuum over H_2SO_4 at room temperature.

Thioxanthene-9-one *[492-22-8]* **M 212.3, m 209°.** Crystd from $CHCl_3$ and sublimed *in vacuo*.

Thiram see **bis(dimethylcarbamyl)disulphide.**

L-Threonine *[72-19-5]* **M 119.1, m 251-253°, $[\alpha]_D^{26}$ -28.4° (H_2O).** Likely impurities are *allo*-threonine and glycine. Crystd from water by adding 4 volumes of EtOH. Dried and stored in a desiccator.

Thymidine *[50-89-5]* **M 242.2, m 185°.** Crystd from ethyl acetate.

Thymine *[65-71-4]* **M 126.1, m 326°.** Crystd from ethyl acetate or water. Purified by preparative (2mm thick) TLC plates of silica gel, eluting with ethyl acetate/isopropanol/water (75:16:9, v/v; R_F 0.75). Spot localised by uv lamp, cut from plate, placed in MeOH, shaken and filtered through a millipore filter, then rotary evapd. [Infante et al. *JCSFT 1* **68** 1586 *1973*].

Thymolphthalein complexone *[1913-93-5]* **M 720.8, m 190°(dec).** Purification as for phthalein complexone except that it was synthesised from thymolphthalein instead of cresolphthalein.

***S*-Thyroxine** *[57-48-9]* **M 776.9, m 235°, $[\alpha]_D^{22}$ +26° (EtOH/1M aq HCl; 1:1).** Likely impurities are tyrosine, iodotyrosine, iodothyroxines and iodide. Dissolved in dilute ammonia at room temperature, then crystd by adding dilute acetic acid to pH 6.

Tiglic acid *[80-59-1]* **M 100.1, m 63.5-64°, b 198.5°.** Crystd from water.

Tinuvin P *[50936-05-5].* Recrystd from *n*-heptane [Woessner et al. *JPC* **81** 3629 *1985*].

Tolan see **diphenylacetylene.**

***o*-Tolidine** *[119-93-7]* **M 212.3, m 131-132°.** Dissolved in benzene, percolated through a column of activated alumina and crystd from benzene/pet ether.

***p*-Tolualdehyde** *[104-87-0]* **M 120.2, b 83-85°/0.1mm, 199-200°/760mm, d 1.018, n 1.548.** Steam distd, dried with $CaSO_4$ and fractionally distd.

***o*-Toluamide** *[527-85-5]* **M 135.2, m 141°.** Crystd from hot water (10ml/g) and dried in air.

Toluene *[108-88-3]* **M 92.1, b 110.6°, d^{10} 0.87615, d^{25} 0.86231, n 1.49693, n^{25} 1.49413.** Dried with $CaCl_2$, CaH_2 or $CaSO_4$, and dried further by standing with sodium, P_2O_5 or CaH_2. It can be fractionally distd from sodium or P_2O_5. Unless specially purified, toluene is likely to be contaminated with methylthiophenes and other sulphur containing impurities. These can be removed by shaking with conc H_2SO_4, but the temperature must be kept below 30° if sulphonation of toluene is to be avoided. A typical procedure consists of shaking toluene twice with cold conc H_2SO_4 (100ml of acid per L), once with water, once with aqueous 5% $NaHCO_3$ or NaOH, again with H_2O, then drying successively with $CaSO_4$ and P_2O_5, with final distn from P_2O_5 or over $LiAlH_4$ after refluxing for 30min. Alternatively, the treatment with $NaHCO_3$ can be replaced by boiling under reflux with 1% sodium amalgam. Sulphur compounds can also be removed by prolonged shaking of the toluene with mercury, or by two distns from $AlCl_3$, the distillate then being washed with water, dried with K_2CO_3 and stored with sodium wire. Other purification procedures include refluxing and distn of sodium dried toluene from diphenylpicrylhydrazyl, and from $SnCl_2$ (to ensure freedom from peroxides). It has also been co-distd with 10% by volume of ethyl methyl ketone, and again fractionally distd. [Brown and Pearsall *JACS* **74** 191 *1952*]. For removal of carbonyl impurities see *benzene*. Toluene has been purified by distn under nitrogen in the presence of sodium benzophenone ketyl. Toluene has also been dried with $MgSO_4$, after the sulphur impurities have been removed, and then fractionally distd from P_2O_5 and stored in the dark [Tabushi et al. *JACS* **107** 4465 *1985*]. Toluene can be purified by passage through a tightly packed column of Fuller's earth.

Toluene-2,4-diamine (***asym*-xylidine**) *[95-80-7]* **M 122.2, m 99°, b 148-150°/8mm, 292°/760mm.** Recrystd from water containing a very small amount of sodium dithionite (to prevent air oxidation), and dried under vacuum.

***o*-Toluenesulphonamide** *[88-19-7]* **M 171.2, m 155.5°,**
***p*-Toluenesulphonamide** *[70-55-3]* **M 171.2, m 137-137.5°, 138°.** Crystd from hot water, then from EtOH or Et_2O-pet ether.

p*-Toluenesulphonic acid** *[6192-52-5]M 190.2, m 38° (anhydrous), m 105-107° (monohydrate).** Purified by pptn from a satd soln at 0° by introducing HCl gas. Also crystd from conc

HCl, then crystd from dilute HCl (charcoal) to remove benzenesulphonic acid. It has been crystd from EtOH/water. Dried in a vacuum desiccator over solid KOH and $CaCl_2$. *p*-Toluenesulphonic acid can be dehydrated by azeotropic distn with benzene or by heating at 100° for 4h under water-pump vacuum. The anhydrous acid can be crystd from benzene, $CHCl_3$, ethyl acetate, anhydrous MeOH, or from acetone by adding a large excess of benzene. It can be dried under vacuum at 50°.

***p*-Toluenesulphonyl chloride (tosyl chloride)** *[98-59-9]* **M 190.7, m 66-69°, 67.5-68.5°, 69°, b 138-139°/9mm, 146°/15mm, 167°/36mm.** Material that has been standing for a long time contains tosic acid and HCl and has **m** *ca* 65-68°. It is purified by dissolving (10g) in the minimum volume of $CHCl_3$ (*ca* 25ml) filtered, and diluted with five volumes (i.e. 125ml) of pet ether (b 30-60°) to precipitate impurities. The soln is filtered, clarified with charcoal and concentrated to 40ml by evaporation. Further evaporation to a very small volume gave 7g of white crystals which were analytically pure, **m** 67.5-68.5°. (The insoluble material was largely tosic acid and had m 101-104°). [Pelletier *Chem Ind* 1034 *1953*].
Also crystd from toluene/pet ether in the cold, from pet ether (b 40-60°) or benzene. Its soln in ethyl ether has been washed with aqueous 10% NaOH until colourless, then dried (Na_2SO_4) and crystd by cooling in powdered Dry-ice. It has also been purified by dissolving in benzene, washing with aqueous 5% NaOH , then dried with K_2CO_3 or $MgSO_4$, and distd under reduced pressure and can be sublimed at high vacuum [Ebel *B* **60** 2086*1927*].

α-Toluenethiol see **benzylmercaptan**.

***p*-Toluenethiol** *[106-45-6]* **M 124.2, m 43.5-44°.** Crystd from pet ether (b 40-70°).

Toluhydroquinone *[95-71-6]* **M 124.1, m 128-129°.** Crystd from EtOH.

***o*-Toluic acid** *[118-90-1]* **M 136.2, m 102-103°.** Crystd from benzene (2.5ml/g) and dried in air.

***m*-Toluic acid** *[99-04-7]* **M 136.2, m 111-113°.** Crystd from water.

***p*-Toluic acid** *[99-94-5]* **M 136.2, m 178.5-179.5°.** Crystd from water, water/EtOH (1:1), MeOH/water or benzene.

***o*-Toluidine** *[95-53-4]* **M 107.2, f.p. -16.3°, b 80.1°/10mm, 200.3°/760mm, d 0.999, n 1.57246, n^{25} 1.56987.** In general, methods similar to those for purifying aniline can be used, e.g. distn from zinc dust, at reduced pressure, under nitrogen. Berliner and May [*JACS* **49** 1007 *1927*] purified *via* the oxalate. Twice-distd *o*-toluidine was dissolved in four times its volume of ethyl ether and the equivalent amount of oxalic acid needed to form the dioxalate was added as its soln in ethyl ether. (If *p*-toluidine is present, its oxalate pptes and can be removed by filtration.) Evapn of the ether soln gave crystals of *o*-toluidine dioxalate. They were filtered off, recrystd five times from water containing a small amount of oxalic acid (to prevent hydrolysis), then treated with dilute aqueous Na_2CO_3 to liberate the amine which was separated, dried ($CaCl_2$) and distd under reduced pressure.

***m*-Toluidine** *[108-44-1]* **M 107.2, f.p. -30.4°, b 82.3°/10mm, 203.4°/760mm, d 0.989, n 1.56811, n^{25} 1.56570.** It can be purified as for aniline. Twice-distd, *m*-toluidine was converted to the hydrochloride using a slight excess of HCl, and the salt was fractionally crystd from 25% EtOH (five times), and from distd water (twice), rejecting, in each case, the first material that crystd. The amine was regenerated and distd as for *o*-toluidine. [Berliner and May *JACS* **49** 1007 *1927*].

***p*-Toluidine** *[106-49-0]* **M 107.2, m 44.8°, b 79.6°/10mm, 200.5°/760mm, d 0.962, n 1.5636, $n^{59.1}$ 1.5534.** In general, methods similar to those for purifying aniline can be used. It can be separated from the *o*- and *m*-isomers by fractional crystn from its melt. *p*-Toluidine has been crystd from hot water (charcoal), EtOH, benzene, pet ether or EtOH/water (1:4), and dried in a vacuum desiccator. It can also be sublimed at 30° under vacuum. For further purification, use has been made of the oxalate, the sulphate and acetylation. The oxalate, formed as described for *o*-toluidine, was filtered, washed and recrystd three times from hot distd water. The base was regenerated with aq Na_2CO_3 and recrystd three times from distd water. [Berliner and May *JACS* **49 1007** *1927*]. Alternatively, *p*-toluidine was converted to its acetyl derivative which, after

repeated crystn from EtOH, was hydrolysed by refluxing (50g) in a mixture of 500ml of water and 115ml of conc H_2SO_4 until a clear soln was obtained. The amine sulphate was isolated, suspended in water, and NaOH was added. The free base was distd twice from zinc dust under vacuum. The *p*-toluidine was then recrystd from pet ether and dried in a vacuum desiccator or in a vacuum for 6h at 40°. [Berliner and Berliner *JACS* **76** 6179 *1954*; Moore et al. *JACS* **108** 2257 *1986*].

Toluidine Blue *[93-31-9]* **M 305.8.** Crystd from hot water (18ml/g) by adding one and a half volumes of alcohol and chilling on ice. Dried at 100° in an oven for 8-10h.

p-**Toluidine hydrochloride** *[540-23-8]* **M 143.6, m 245.9-246.1°.** Crystd from MeOH containing a few drops of conc HCl. Dried under vacuum over paraffin chips.

2-*p*-**Toluidinylnaphthalene-6-sulphonic acid** *[7724-15-4]* **M 313.9.** Crystd twice from 2% aqueous KOH and dried under high vacuum for 4h at room temperature. Crystd from water. Tested for purity by TLC on silica gel with isopropanol as solvent. The free acid was obtained by acidifying a saturated aqueous soln.

o-**Tolunitrile** *[529-19-1]* **M 117.2, b 205.2°, d 0.992, n 1.5279.** Fractionally distd, washed with conc HCl or 50% H_2SO_4 at 60° until the smell of isonitrile had gone (this also removed any amines), then washed with saturated $NaHCO_3$ and dilute NaCl solns, then dried with K_2CO_3 and redistd.

m-**Tolunitrile** *[620-22-4]* **M 117.2, b 209.5-210°/773mm, d 0.986, n 1.5250.** Dried with $MgSO_4$, fractionally distd, then washed with aqueous acid to remove possible traces of amines, dried and redistd.

p-**Tolunitrile** *[104-85-8]* **M 117.2, m 29.5°, b 104-106°/20mm.** Melted, dried with $MgSO_4$, fractionally crystd from its melt, then fractionally distd under reduced pressure in a 6-in spinning band column. [Brown *JACS* **81** 3232 *1959*]. It can also be crystd from benzene/pet ether (b 40-60°).

p-**Toluquinone** see **methyl-1,4-benzoquinone.**

p-**Toluyl-***o*-**benzoic acid** *[7148-03-0]* **M 196.2, m 138-139°.** Crystd from toluene.

p-**Tolylacetic acid** *[622-47-9]* **M 150.2, m 90.8-91.3°.** Crystd from water.

4-*o*-**Tolylazo-***o*-**toluidine** see **2-amino-5-azotoluene.**

p-**Tolyl carbinol** *[589-18-4]* **M 122.2, m 61°, b 116-118°/20mm, 217°/760mm.** Crystd from pet ether (b 80-100°, 1g/ml). It can also be distd under reduced pressure.

Tolyl diphenyl phosphate *[26444-49-5]* **M 340.3, n^{25} 1.5758.** Vac distd, then percolated through a column of alumina. Finally, passed through a packed column maintained at 150° to remove traces of volatile impurities in a countercurrent stream of nitrogen at reduced pressure. [Dobry and Keller *JPC* **61** 1448 *1947*].

p-**Tolyl disulphide** *[103-19-5]* **M 246.4, m 45-46°.** Purified by chromatography on alumina using hexane as eluent, then crystd from MeOH. [Kice and Bowers *JACS* **84** 2384 *1962*].

p-**Tolyl urea** *[622-51-5]* **M 150.2, m 181°.** Crystd from EtOH/water (1:1).

Tosylmethyl isocyanide *[36635-51-7]* **M 195.2, m 114-115°.** Recrystd from EtOH (charcoal) [Saito and Itano, *JCSPT* 1 *1986*].

***trans*-Traumatic acid** *[6402-36-4]* **M 228.3, m 165-166°.** Crystd from EtOH or acetone.

α,α'-**Trehalose** (**$2H_2O$**) *[6138-23-4]* **M 378.3, m 96.5-97.5°, 203° (anhydrous).** Crystd (as the dihydrate) from aqueous EtOH. Dried at 13°.

TREN see **tris(2-aminoethyl)amine.**

1,2,3-Triaminopropane trihydrochloride *[free base 21291-99-6]* **M 198.7, m 250°.** Cryst from EtOH.

1,2,4-Triazole *[288-88-0]* **M 69.1, m 121°, 260°.** Crystd from EtOH or water [Barsczlaw et al. *JCSPT* 2025 *1986*].

Tribenzylamine *[620-40-6]* **M 287.4, m 93-94°.** Crystd from abs EtOH or pet ether. Dried in a vacuum over P_2O_5 at room temperature.

2,4,6-Tribromoacetanilide *[607-93-2]* **M 451.8, m 232°.** Crystd from EtOH.

2,4,6-Tribromoaniline *[147-82-0]* **M 329.8, m 120°.** Crystd from MeOH.

***sym*-Tribromobenzene** *[626-39-1]* **M 314.8, m 122°.** Crystd from glacial acetic acid/water (4:1), then washed with chilled EtOH and dried in air.

Tribromochloromethane *[594-15-0]* **M 287.2, m 55°.** Melted, washed with aqueous $Na_2S_2O_3$, dried with BaO and fractionally crystd from its melt.

2,4,6-Tribromophenol *[118-79-6]* **M 330.8, m 94°.** Crystd from EtOH or pet ether. Dried under vacuum over P_2O_5 at room temperature.

Tri-*n*-butylamine *[102-82-9]* **M 185.4, b 68°/3mm, 120°/44mm, d 0.7788, n 1.4294.** Purified by fractional distn from sodium under reduced pressure. Pegolotti and Young [*JACS* **83** 3251 *1961*] heated the amine overnight with an equal volume of acetic anhydride, in a steam bath. The amine layer was separated and heated with water for 2h on the steam bath (to hydrolyse any remaining acetic anhydride). The soln was cooled, solid K_2CO_3 was added to neutralize any acetic acid that had been formed, and the amine was separated, dried (K_2CO_3) and distd at 44mm pressure. Davis and Nakshbendi [*JACS* **84** 2085 *1926*] treated the amine with one-eighth of its weight of benzenesulphonyl chloride in aqueous 15% NaOH at 0-5°. The mixture was shaken intermittently and allowed to warm to room temperature. After a day, the amine layer was washed with aq NaOH, then water and dried with KOH. (This treatment removes primary and secondary amines.) It was further dried with CaH_2 and distd under vacuum.

Tri-*n*-butylamine hydrobromide *[37026-85-0]* **M 308.3, m 75.2-75-9°.** Crystd from ethyl acetate.

Tri-*n*-butylammonium nitrate *[1941-27-1]* **M 304.5.** Crystd from mixtures of *n*-hexane and acetone (95:5). Dried over P_2O_5.

Tri-*n*-butylammonium perchlorate *[14999-66-7]* **M 285.5.** Recrystd from *n*-hexane.

***sym*-Tri-*tert*-butylbenzene** *[1460-02-2]* **M 246.4, m 73.4-73.9°.** Crystd from EtOH.

2,4,6-Tri-*tert*-butylphenol *[732-26-3]* **M 262.4, m 129-132°, 131°/1mm, 147°/10mm, 278°/760mm.** Crystd from *n*-hexane or several times from 95% EtOH until the EtOH soln was colourless [Balasubramanian and Bruice *JACS* **108** 5495 *1986*]. It has also been purified by sublimation [Yuan and Bruice *JACS* **108** 1643 *1986*; Wong et al. *JACS* **109** 3428 *1987*]. Purification has been achieved by passage through a silica gel column followed by recrystn from *n*-hexane [Kajii et al. *JPC* **91** 2791 *1987*].

Tributyl phosphate see Chapter 4.

Tricarballylic acid *[99-14-9]* **M 176.1, m 166°.** Crystd from ethyl ether.

Trichloroacetamide *[594-65-0]* **M 162.4, m 139-141°, b 238-240°.** Its xylene soln was dried with P_2O_5, then fractionally distd.

Trichloroacetanilide *[2563-97-5]* **M 238.5, m 95°.** Crystd from benzene.

Trichloroacetic acid *[76-03-9]* **M 163.4, m 59.4-59.8°.** Purified by fractional crystn from its melt, then crystd repeatedly from dry benzene and stored over conc H_2SO_4 in a vac desiccator. It can also be crystd from $CHCl_3$ or cyclohexane, and dried over P_2O_5 or $Mg(ClO_4)_2$ in a vac desiccator. Trichloroacetic acid can be fractionally distd under reduced pressure from $MgSO_4$. Layne, Jaffé and Zimmer [*JACS* **85** 435 *1963*] dried trichloroacetic acid in benzene by distilling off the benzene-water azeotrope, then crystd the acid from the remaining benzene soln. Manipulations were carried out under nitrogen. *[Use a well ventilated fumecupboard].*

2,3,4-Trichloroaniline *[634-67-3]* **M 196.5, m 67.5°, b 292°/774mm,**
2,4,5-Trichloroaniline *[636-30-6]* **M 196.5, m 96.5°, b 270°/760mm,**
2,4,6-Trichloroaniline *[634-93-5]* **M 196.5, m 78.5°, b 262°/746mm.** Crystd from ligroin.

1,2,3-Trichlorobenzene *[87-61-6]* **M 181.5, m 52.6°.** Crystd from EtOH.

1,2,4-Trichlorobenzene *[120-82-1]* **M 181.5, m 17°, b 210°.** Separated from a mixture of isomers by washing with fuming H_2SO_4, then water, drying with $CaSO_4$ and slowly fractionally distilling. [Jensen, Marino and Brown *JACS* **81** 3303 *1959*].

1,3,5-Trichlorobenzene *[108-70-3]* **M 181.5, m 64-65°.** Recrystd from dry benzene or toluene.

1,1,1-Trichloro-2,2-bis(*p*-chlorophenyl)ethane (p.p'-DDT) *[50-29-3]* **M 354.5, m 108.5-109°.** Crystd from 95% EtOH, and checked by TLC.

3,4,5-Trichloro-*o*-cresol *[608-92-4]* **M 211.5, m 77°,**
2,3,5-Trichloro-*p*-cresol *[608-91-3]* **M 211.5, m 66-67°.** Crystd from pet ether.

1,1,1-Trichloroethane *[71-55-6]* **M 133.4, f.p. -32.7°, b 74.0°, d 1.337, n 1.4385,**
1,1,2-Trichloroethane *[79-00-5]* **M 133.4, f.p. -36.3°, b 113.6°, d 1.435, n 1.472.** Washed successively with conc HCl (or conc H_2SO_4), aq 10% K_2CO_3 (Na_2CO_3), aq 10% NaCl, dried with $CaCl_2$ or Na_2SO_4, and fractionally distd. It can contain up to 3% dioxane as preservative. This is removed by washing successively with 10% aq HCl, 10% aq $NaHCO_3$ and 10% aq NaCl; and distd over $CaCl_2$ before use.

Trichloroethylene *[79-01-6]* **M 131.4, f.p. -88°, b 87.2°, d 1.463, n^{21} 1.4767.** Undergoes decomposition in a similar way to $CHCl_3$, giving HCl, CO, $COCl_2$ and organic products. It reacts with KOH, NaOH and 90% H_2SO_4, and forms azeotropes with water, MeOH, EtOH, and acetic acid. It is purified by washing successively with 2M HCl, water and 2M K_2CO_3, then dried with K_2CO_3 and $CaCl_2$, and fractionally distd immediately before use. It has also been steam distd from 10% $Ca(OH)_2$ slurry, most of the water being removed from the distillate by cooling to -30° to -50° and filtering off the ice through chamois skin: the trichloroethylene was then fractionally distd at 250mm pressure and collected in a blackened container. [Carlisle and Levine *IEC* **24** 1164 *1932*].

2,4,5-Trichloro-1-nitrobenzene *[89-69-0]* **M 226.5, m 57°.** Crystd from EtOH.

3,4,6-Trichloro-2-nitrophenol *[82-62-2]* **M 242.4, m 92-93°.** Crystd from pet ether.

2,4,5-Trichlorophenol *[95-95-4]* **M 197.5, m 67°.** Crystd from EtOH or pet ether.

2,4,6-Trichlorophenol *[88-06-2]* **M 197.5, m 67-68°.** Crystd from benzene, EtOH or EtOH/water.

3,4,5-Trichlorophenol *[609-19-8]* **M 197.5, m 100°.** Crystd from pet ether/benzene mixture.

2,4,5-Trichlorophenoxyacetic acid *[93-76-5]* **M 255.5, m 153°.** Crystd from benzene.

1,1,1-Trichloro-2-(2,2,2-trichloro-1-hydroxyethoxy)-2-methylpropane see **chloralacetone chloroform.**

1,1,2-Trichlorotrifluoroethane *[76-13-1]* **M 187.4, b 47.6°/760mm, d 1.576, n 1.360.** Washed with water, then with weak alkali. Dried with $CaCl_2$ or H_2SO_4 and distd. [Locke et al. *JACS* **56** 1726 *1934*].

Tricycloquinazoline *[195-84-6]* **M 230.3, m 322-323°.** Crystd repeatedly from toluene, followed by vac sublimation at 210° at a pressure of 0.15-0.3 Torr in subdued light.

Tridecanoic acid *[638-53-9]* **M 214.4, m 44.5-45.5°, b 199-200°/24mm.** Crystd from acetone.

7-Tridecanone *[462-18-0]* **M 198.4, m 33°, b 255°/766mm.** Crystd from EtOH.

Tri-*n*-dodecylammonium nitrate *[2305-34-2]* **M 585.0.** Crystd from *n*-hexane/acetone (95:5) and kept in a desiccator over P_2O_5.

Tri-*n*-dodecylammonium perchlorate *[5838-82-4]* **M 622.4.** Recrystd from *n*-hexane or acetone and kept in a desiccator over P_2O_5.

TRIEN see **triethylenetetramine.**

Triethanolamine hydrochloride *[637-39-8]* **M 185.7, m 177°.** Crystd from EtOH. Dried at 80°.

1,1,2-Triethoxyethane *[4819-77-6]* **M 162.2, b 164°, d 0.897, n 1.401.** Dried with Na_2SO_4, and distd.

Triethylamine *[121-44-8]* **M 101.2, b 89.4°, d 0.7280, n 1.4005.** Dried with $CaSO_4$, $LiAlH_4$, Linde type 4A molecular sieves, CaH_2, KOH, or K_2CO_3, then distd, either alone or from BaO, sodium, P_2O_5 or CaH_2. It has also been distd from zinc dust, under nitrogen. To remove traces of primary and secondary amines, triethylamine has been refluxed with acetic anhydride, benzoic anhydride, phthalic anhydride, then distd, refluxed with CaH_2 (ammonia-free) or KOH (or dried with activated alumina), and again distd. Another purification involved refluxing for 2h with *p*-toluenesulphonyl chloride, then distd. Grovenstein and Williams [*JACS* **83** 412 1961] treated triethylamine (500ml) with benzoyl chloride (30ml), filtered off the ppte, and refluxed the liquid for 1h with a further 30ml of benzoyl chloride. After cooling, the liquid was filtered, distd, and allowed to stand for several hours with KOH pellets. It was then refluxed with, and distd from, stirred molten potassium. Triethylamine has been converted to its hydrochloride, crystd from EtOH (to **m** 254°), then liberated with aq NaOH, dried with solid KOH and distd from sodium under nitrogen.

Triethylammonium bromide *[4636-73-1]* **M 229.1, m 248°.** Equimolar portions of triethylamine and aqueous solutions of HBr in acetone were mixed. The ppted salt was washed with anhydrous acetone and dried in vacuum for 1-2h. [Odinekov et al. *JCSFT 2* **80** 899 *1984*]. Recrystd from $CHCl_3$ or EtOH.

Triethylammonium chloride *[554-68-7]* **M 137.7, m 257-260°(dec).** Purified like the bromide above.

Triethylammonium iodide *[4636-73-1]* **M 229.1, m 181°.** Purified as for triethylammonium bromide, except the soln for pptn was precooled acetone at -10° and the ppte was twice recrystd from a cooled acetone/hexane mixture at -10°.

Triethylammonium trichloroacetate *[4113-06-8]* **M 263.6.** Equimolar solns of triethylamine and trichloroacetic acid in *n*-hexane were mixed at 10°. The solid so obtained was recrystd from $CHCl_3$/benzene mixture.

Triethylammonium trifluoroacetate *[454-49-9]* **M 196.2.** Purified as for the corresponding trichloroacetate. The salt was a colourless liquid at ambient temperature.

1,2,4-Triethylbenzene *[877-44-1]* **M 162.3, b 96.8-97.1°/12.8mm, d 0.8738, n 1.5015, 1,3,5-Triethylbenzene** *[102-25-0]* **M 162.3, b 102-102.5°, d 0.8631, n 1.4951.** For separation from a commercial mixture see Dillingham and Reid [*JACS* **60** 2606 *1938*].

Triethylenediamine [Dabco, TED, 1,4-diazabicyclo(2.2.2)octane] *[280-57-9]* **M 112.2, m 156-157° (sealed tube).** Crystd from 95% EtOH, pet ether or MeOH/ethyl ether (1:1). Dried under vacuum over $CaCl_2$ and BaO. It can be sublimed *in vacuo*. Also purified by removal of water during azeotropic distn of a benzene soln. It was then recrystd twice from anhydrous ethyl ether under argon, and stored under argon [Blackstock et al. *JOC* **52** 1451 *1987*].

Triethylene glycol *[112-27-6]* **M 150.2, b 115-117°/0.1mm, 278°/760mm, n^{15} 1.4578, d^{15} 1.1274.** Dried with $CaSO_4$ for 1 week, then repeatedly and very slowly fractionally distd under vacuum. Stored in a vacuum desiccator over P_2O_5. It is very *hygroscopic*.

Triethylene glycol dimethyl ether *[112-49-2]* **M 178.2, b 225°, d 0.987, n 1.425.** Refluxed with, and distd from sodium hydride or $LiAlH_4$.

Triethylenetetramine (TRIEN) *[112-24-3]* **M 146.2, b 157°/20mm, d 0.971, n 1.497.** Dried with sodium, then distd under vac. Further purification has been *via* the nitrate or the chloride. For example, Jonassen and Strickland [*JACS* **80** 312 *1958*] separated TRIEN from admixture with TREN (38%) by soln in EtOH, cooling to approximately 5° in an ice-bath and adding conc HCl dropwise from a burette, keeping the temperature below 10°, until all of the white crystalline ppte of TREN.HCl had formed and been removed. Further addition of HCl then ppted thick creamy white TRIEN>HCl which was crystd several times from hot water by adding an excess of cold EtOH. The crystals were finally washed with acetone, then ether and dried in a vacuum desiccator.

Triethylenetetramine tetrahydrochloride *[4961-10-4]* **M 292.1, m 266-270°.** Crystd repeatedly from hot water by pptn with cold EtOH or EtOH/HCl. Washed with acetone and abs EtOH and dried in a vacuum oven at 80°.

Triethyloxonium fluoroborate *[368-39-8]* **M 190.0, m 92-93°(dec).** Crystd from ethyl ether. *Very hygroscopic*, and should be handled in a dry box and stored at 0°. [*Org Synth* **46** 113 *1966*]. Pure material should give a clear and colourless soln in dichloromethane (1 in 50, w/v).

Triethyl phosphate and **triethyl phosphite** see entries in Chapter 4.

Triethyl silane see entry in Chapter 4.

Trifluoroacetic acid *[76-86-7]* **M 114.0, f.p.-15.5°, b 72.4°, d 1.494, n 1.2850.** The purification of trifluoroacetic acid, reported in earlier editions of this work, by refluxing over $KMnO_4$ for 24h and slowly distilling has resulted in very **SERIOUS EXPLOSIONS** on various occasions, but not always. This apparently depends on the source and/or age of the acid. The method is NOT RECOMMENDED. Water can be removed by making 0.05% in trifluroacetic anhydride (to diminish water content) and distd. [Conway and Novak *JPC* **81** 1459 *1977*]. It can be refluxed and distd from P_2O_5. It is further purified by fractional crystn by partial freezing and again distd.

Trifluoroacetic anhydride *[407-25-0]* **M 210.0, b 38-40°/760mm, d 1.508.** Purification by distilling over $KMnO_4$, as for the acid above is **EXTREMELY DANGEROUS** due to the possiblility of **EXPLOSION**. It is best purified by distilling from P_2O_5 slowly, and collecting the fraction boiling at 39.5°. Store in a dry atmosphere.

1,1,1-Trifluoro-2-bromoethane *[421-06-7]* **M 163.0.** Washed with water, dried ($CaCl_2$) and distd.

2,2,2-Trifluoroethanol *[75-89-8]* **M 100.0, b 72.4°/738mm, d 1.400.** Dried with $CaSO_4$ and a little $NaHCO_3$ (to remove traces of acid).

4-(Trifluoromethyl)acetophenone *[728-86-9]* **M 250.2, m 115-116°.** Purified by sublimation *in vacuo*.

3-Trifluoromethyl-4-nitrophenol *[88-30-2]* **M 162.1, m 81°.** Crystd from benzene or from pet ether/benzene mixture.

α,α,α-Trifluorotoluene *[98-08-8]* **M 144.1, b 102.5°, d 1.190. n^{30} 1.4100.** Purified by repeated treatment with boiling aqueous Na_2CO_3 (until no test for chloride ion was obtained), dried with K_2CO_3, then with P_2O_5, and fractionally distd.

Triglycyl glycine (tetraglycine) *[637-84-3]* **M 246.2, m 270-275°(dec).** Crystd from distilled water (optionally, by the addition of EtOH).

Triglyme see **triethyleneglycol dimethyl ether.**

Trigonelline *[535-83-1]* **M 137.1, m 218°(dec).** Crystd (as monohydrate) from aqueous EtOH, then dried at 100°.

2,3,4-Trihydroxybenzoic acid *[610-02-6]* **M 170.1, m 207-208°,**
2,4,6-Trihydroxybenzoic acid *[83-30-7]* **M 170.1, m 205-212°(dec).** Crystd from water.

4',5,7-Trihydroxyflavone (apigenin) *[520-36-5]* **M 270.2, m 345-350°.** Crystd from aq pyridine.

1,3,8-Trihydroxy-6-methyl-9,10-anthracenedione see **emodine.**

3,4,5-Triiodobenzoic acid *[2338-20-7]* **M 499.8, m 289-290°.** Crystd from aqueous EtOH.

3,4,5-Triiodobenzyl chloride *[52273-54-8]* **M 504.3, m 138°.** Crystd from CCl_4/pet ether (charcoal).

3,3',5-Triiodo-*S*-thyronine *[6893-02-3]* **M 651.0, m 236-237°(dec), $[\alpha]_D^{29.5}$ +21.5° (EtOH/1M aq HCl, 2:1).** Likely impurities are as in *thyroxine*. Purified by dissolving in dilute ammonia at room temperature, then crystd by addition of dilute acetic acid to pH 6.

Triisoamyl phosphate, triisobutyl phosphate, triisooctyl thiophosphate and **triisopropyl phosphite** see entries in Chapter 4.

1,2,3-Triketohydrindene hydrate see **ninhydrin.**

Trimellitic acid *[528-44-9]* **M 210.1, m 218-220°.** Crystd from acetic acid or aqueous EtOH.

Trimesitylphosphine and **trimethallyl phosphate** see entries in Chapter 4.

1,2,3-Trimethoxybenzene *[634-36-6]* **M 168.2, m 45-46°,**
1,3,5-Trimethoxybenzene *[621-23-8]* **M 168.2, m 53°.** Sublimed under vacuum.

2-(Trimethoxyphenyl)ethylamine sulphate *see* **mescaline sulphate.**

Trimethylacetic acid see **pivalic acid.**

Trimethylamine *[75-50-3]* **M 59.1, b 3.5°.** Dried by passage of the gas through a tower filled with solid KOH. Water and impurities containing labile hydrogen were removed by treatment with freshly sublimed,

ground, P_2O_5. Has been refluxed with acetic anhydride, and then distd through a tube packed with HgO and BaO. [Comyns *JCS* 1557 *1955*]. For more extensive purification, trimethylamine has been converted to the hydrochloride, crystd (see below), and regenerated by treating the hydrochloride with excess aq 50% KOH, the gas passing through a $CaSO_4$ column into a steel cylinder containing sodium ribbon. After 1-2 days, the cylinder was cooled at -78° and hydrogen and air were removed by pumping. [Day and Felsing *JACS* **72** 1698 *1950*]. Trimethylamine has also been trap-to-trap distd and then freeze-pump-thaw degassed [Halpern et al. *JACS* **108** 3907 *1986*].

Trimethylamine hydrochloride *[593-81-7]* **M 95.7, m >280°(dec).** It crystallises from $CHCl_3$, EtOH or *n*-propanol, and is dried under vacuum. It has also been recrystallised from benzene/MeOH, MeOH/ethyl ether and dried under vacuum over paraffin wax and H_2SO_4. It is kept over P_2O_5 because it is *hygroscopic.*

Trimethylamine hydroiodide *[20230-89-1]* **M 186.0, m 263°.** Crystd from MeOH.

1,2,4-Trimethylbenzene (pseudocumene) *[95-63-6]* **M 120.2, m -43.8°, b 51.6°/10mm, 167-168°/760mm, d 0.889, n 1.5048.** Refluxed over sodium and distd under reduced pressure.

2,4,6-Trimethylbenzoic acid (mesitoic acid) *[480-63-7]* **M 164.2, m 155°.** Crystd from water, ligroin or carbon tetrachloride [Ohwada et al. *JACS* **108** 3029 *1986*].

Trimethyl-1,4-benzoquinone *[935-92-2]* **M 150.1.** Sublimed *in vacuo* before use.

***R*-(-)-2,2,6-Trimethyl-1,4-cyclohexanedione** *[60046-49-3]* **M 154.2, m 88-90°, 91-92°, $[\alpha]_D^{20}$ -270° (c 0.4%, MeOH), $[\alpha]_D^{20}$ -275° (c 1, $CHCl_3$).** Obtained from fermentation and purified by recrystn from diisopropyl ether. [ORD: Leuenberger et al. *HCA* **59** 1832 *1976*]. The *racemate* has **m** 65-67° and the *4-(4-phenyl)semicarbazone* has **m** 218-220° (from CH_2Cl_2-MeOH) [Isler et al. *HCA* **39** 2041 *1956*].

Trimethylene oxide see **oxetane.**

Trimethylene sulphide see **thietane.**

2,2,5-Trimethylhexane *[3522-94-9]* **M 128.3, m -105.8°, b 124.1°, d 0.716, n 1.39971, n^{25} 1.39727.** Extracted with conc H_2SO_4, washed with H_2O, dried (type 4A molecular sieves), and fractionally distd.

Trimethyl-1,4-hydroquinone *[700-13-0]* **M 152.2, m 173-174°.** Recrystd from water, under anaerobic conditions.

1',3',3'-Trimethyl-6-nitrospiro[2*H*-benzopyran-2,2'-indoline] *[1498-88-0]* **M 322.4, m 180°.** Recrystd from absolute EtOH [Hinnen et al. *Bull Soc Chim Fr* 2066 *1968*; Ramesh and Labes *JACS* **109** 3228 *1987*].

Trimethylolethane see **2-hydroxymethyl-2-methylpropane-1,3-diol.**

Trimethylolpropane *[77-99-6]* **M 134.2, m 57-59°.** Crystd from acetone and ether.

2,2,3-Trimethylpentane *[564-02-3]* **M 114.2, b 109.8°, d 0.7161, n 1.40295, n^{25} 1.40064.** It has been purified by azeotropic distillation with 2-methoxyethanol, which was subsequently washed out with water. The trimethylpentane was then dried and fractionally distd. [Forziati et al. *J Res Nat Bur Stand* **36** 129 *1946*].

2,2,4-Trimethylpentane (isooctane) *[540-84-1]* **M 114.2, b 99.2°, d 0.693, n 1.39145, n^{25} 1.38898.** Distd from sodium, passed through a column of silica gel or activated alumina (to remove traces of olefines), and again distd from sodium. Extracted repeatedly with conc H_2SO_4, then agitated with aqueous

$KMnO_4$, washed with water, dried ($CaSO_4$) and distd. Purified by azeotropic distn with EtOH, which was subsequently washed out with water, and the trimethylpentane was dried and fractionally distd. [Forziati et al. *J Res Nat Bur Stand* **36** 126 *1946*]. Also purified by fractional crystn.

2,3,5-Trimethylphenol *[697-82-5]* **M 136.2, m 95-96°, b 233°/760mm.** Crystd from water or pet ether.

2,4,5-Trimethylphenol *[496-78-6]* **M 136.2, m 70.5-71.5°.** Crystd from water.

2,4,6-Trimethylphenol *[527-60-6]* **M 136.2, m 69°, b 220°/760mm.** Crystd from water and sublimed *in vacuo.*

3,4,5-Trimethylphenol *[527-54-8]* **M 136.2, m 107°, b 248-249°/760mm.** Crystd from pet ether.

Trimethylphenylammonium benzenesulphonate *[16093-66-6]* **M 293.3.** Crystd repeatedly from MeOH (charcoal).

2,2,4-Trimethyl-6-phenyl-1,2-dihydroquinoline *[3562-69-4]* **M 249.3, m 102°.** Vacuum distd, then crystd from absolute EtOH.

Trimethyl phosphite see entry in Chapter 4.

2,4,6-Trimethylpyridine (sym-collidine) *[108-75-8]* **M 121.2, m -46°, b 10°/2.7mm, 36-37°/2mm, 60.7°/13mm, 65°/31mm, 170.4°/760mm, 175-178°/atm, d^{25} 0.9100 n_D^{20} 1.4939, 1.4981, n^{25} 1.4959.** Commercial samples may be grossly impure. Likely contaminants include 3,5-dimethylpyridine, 2,3,6-trimethylpyridine and water. Brown, Johnson and Podall [*JACS* **76** 5556 *1954*] fractionally distd 2,4,6-trimethylpyridine under reduced pressure through a 40-cm Vigreux column and added to 430ml of the distillate slowly, with cooling to 0°, 45g of BF_3-ethyl etherate. The mixture was again distd, and an equal volume of dry benzene was added to the distillate. Dry HCl was passed into the soln, which was kept cold in an ice-bath, and the hydrochloride was filtered off. It was recrystd from abs EtOH (1.5ml/g) to **m** 286-287°(sealed tube). The free base was regenerated by treatment with aq NaOH, then extracted with benzene, dried ($MgSO_4$) and distd under reduced pressure. Sisler et al. [*JACS* **75** 446 *1953*] ppted trimethylpyridine as its phosphate from a soln of the base in MeOH by adding 85% H_3PO_4, shaking and cooling. The free base was regenerated as above. Garrett and Smythe [*JCS* 763 *1903*] purified the trimethylpyridine via the $HgCl_2$ complex. It is more soluble in cold than hot H_2O [sol 20.8% at 6°, 3.5% at 20°, 1.8% at 100°].
Also purified by dissolving in $CHCl_3$, adding solid K_2CO_3 and Drierite, filtering and fractionally distilling through an 8in helix packed column. It has a pKa^{25} of 6.69 in H_2O. The *sulphate* has **m** 205°, and the *picrate* (from hot H_2O) has **m** 155-156°. [Frank and Meikle *JACS* **72** 4184 *1950*].

Trimethylsilylazide see entry in Chapter 4..

Trimethylsulphonium iodide *[2181-42-2]* **M 204.1, m 215-220°(dec).** Crystd from EtOH.

1,3,7-Trimethyluric acid *[5415-44-1]* **M 210.2, m 345°(dec),**
1,3,9-Trimethyluric acid *[519-32-4]* **M 210.2, m 347°.** Crystd from water.

1,7,9-Trimethyluric acid *[55441-72-0]* **M 210.2, m 345°.** Crystd from water or EtOH, and sublimed *in vacuo.*

Trimyristin *[555-45-3]* **M 723.2, m 56.5°.** Crystd from ethyl ether.

Trineopentyl phosphate see Chapter 4.

2,4,6-Trinitroanisole *[606-35-9]* **M 243.1, m 68°.** Crystd from EtOH or MeOH. Dried under vac.

1,3,6-Trinitrobenzene *[99-35-4]* **M 213.1, m 122-123°.** Crystd from glacial acetic acid, $CHCl_3$, CCl_4, EtOH aq EtOH or EtOH/benzene, after (optionally) heating with dil HNO_3. Air dried. Fused, and crystd under vacuum.

2,4,6-Trinitrobenzoic acid *[129-66-8]* **M 225.1, m 227-228°.** Crystd from distilled water. Dried in a vacuum desiccator.

2,4,6-Trinitro-*m*-cresol *[602-99-3]* **M 243.1, m 107.0-107.5°.** Crystd successively from H_2O, aq EtOH and benzene/cyclohexane, then dried at 80° for 2h. [Davis and Paabo *J Res Nat Bur Stand* **64A** 533 *1960*].

2,4,7-Trinitro-9-fluorenone *[129-79-3]* **M 315.2, m 176°.** Crystd from nitric acid/water (3:1), washed with water and dried under vacuum over P_2O_5, or recrystd from dry benzene.

2,4,6-Trinitroresorcinol *[82-71-3]* **M 245.1, m 177-178°.** Crystd from water containing HCl.

2,4,6-Trinitrotoluene (TNT) *[118-96-7]* **M 227.1, m 81.0-81.5°.** Crystd from benzene and EtOH. Then fused and allowed to cryst under vacuum. Gey, Dalbey and Van Dolah [*JACS* **78** 1803 *1956*] dissolved TNT in acetone and added cold water (1:2:15), the ppte was filtered, washed free from solvent and stirred with five parts of aq 8% Na_2SO_3 at 50-60° for 10min. It was filtered, washed with cold water until the effluent was colourless, and air dried. The product was dissolved in five parts of hot CCl_4, washed with warm water until the washings were colourless and TNT was recoverd by cooling and filtering. It was recrystd from 95% EtOH and carefully dried over H_2SO_4. The dry solid should not be heated without taking precautions for a possible **EXPLOSION**.

2,4,6-Trinitro-*m*-xylene *[632-92-8]* **M 241.2, m 182.2°.** Crystd from ethyl methyl ketone.

Tri-*n*-octylamine *[1116-76-3]* **M 353.7, b 164-168°/0.7mm, 365-367°/760mm, d 0.813, n 1.450.** It was converted to the amine hydrochloride etherate which was recrystd four times from ethyl ether at -30° (see below). Neutralisation of this salt regenerated the free amine. [Wilson and Wogman *JPC* **66** 1552 *1962*]. Distd at 1-2mm pressure.

Tri-*n*-octylammonium chloride *[1188-95-0]* **M 384.2.** Crystd from ethyl ether, then *n*-hexane (see above).

Tri-*n*-octylammonium perchlorate *[2861-99-6]* **M 454.2.** Crystd from *n*-hexane.

Tri-*n*-octylmethylammonium chloride see **Aliquat 336.**

Tri-*n*-octylphosphine oxide see entry in Chapter 4.

1,3,5-Trioxane *[110-88-3]* **M 90.1, m 64°, b 114.5°/759mm.** Crystd from sodium-dried ethyl ether or water, and dried over $CaCl_2$. Purified by zone refining.

Trioxsalen (2,5,9-trimethyl-7*H*-furo[3,2-*g*][1]benzopyran-7-one) *[3902-71-4]* **M 228.3, m 233-235°, 234.5-235°.** Purified by recrystn from $CHCl_3$. If too impure it is fractionally crystd from $CHCl_3$-pet ether (b 30-60°) using Norit and finally crystd from $CHCl_3$ alone to give colourless prisms, **m** 234.5-235°. It is a photosensitiser so it should be stored in the dark. [UV: Kaufmann *JOC* **26** 117 *1961*; Baeme et al. *JCS* 2976 *1949*].

Tripalmitin *[555-44-2]* **M 807.4, m 66.4°.** Crystd from acetone, ethyl ether or EtOH.

Triphenylamine *[603-34-9]* **M 245.3, m 127.3-127.9°.** Crystd from EtOH or from benzene/abs EtOH, ethyl ether and pet ether. It was sublimed under vacuum and carefully dried in a vacuum line. Stored in the dark under nitrogen.

1,3,5-Triphenylbenzene *[612-71-5]* **M 306.4, m 173-175°.** Purified by chromatography on alumina using benzene or pet ether as eluents.

Triphenyl carbinol see **triphenylmethanol.**

Triphenylene *[58-72-0]* **M 228.3, m 198°.** Purified by zone refining.

1,2,3-Triphenylguanidine *[101-01-9]* **M 287.3, m 144°.** Crystd from EtOH or EtOH/water, and dried under vacuum.

Triphenylmethane *[519-73-3]* **M 244.3, m 92-93°.** Crystd from EtOH or benzene (with one molecule of benzene of crystallisation which is lost on exposure to air or by heating on a water bath). It can also be sublimed under vacuum. It can also be given a preliminary purification by refluxing with tin and glacial acetic acid, then filtered hot through a glass sinter disc, and ppted by addition of cold water.

Triphenylmethanol *[76-84-6]* **M 260.3, m 163°.** Crystd from EtOH, CCl_4 (4ml/g), benzene, hexane or pet ether (b 60-70°). Dried at 90°. [Ohwada et al. *JACS* **108** 3029 *1986*].

Triphenylmethyl chloride (trityl chloride) *[76-83-5]* **M 278.9, m 111-112°.** Crystd from iso-octane. Also crystd from 5 parts of pet ether (b 90-100°) and 1 part of acetyl chloride using 1.8g of solvent per g of chloride. Dried in a desiccator over soda lime and paraffin wax. [*Org Synth* Col Vol III 841 *1955*; Moisel et al. *JACS* **108** 4706 *1986.*]

Triphenyl phosphate, triphenylphosphine, triphenylphosphine oxide and **triphenyl phosphite** see entries in Chapter 4.

Triphenyl silanol see Chapter 4.

2,3,5-Triphenyltetrazolium chloride (TTC) *[298-96-4]* **M 334.8, m 243°(dec).** Crystd from EtOH or $CHCl_3$, and dried at 105°.

Tri-*n*-propylamine *[102-69-2]* **M 143.3, b 156.5°, d 0.757, n 1.419.** Dried with KOH and fractionally distd. Also refluxed with toluene-*p*-sulphonyl chloride and with KOH, then fractionally distd. The distillate, after addn of 2% phenyl isocyanate, was redistd and the residue fractionally distd from sodium. [Takahashi et al. *JOC* **52** 2666 *1987*].

2,2',2''-Tripyridine see **2,2':6',2''-terpyridyl.**

Tripyridyl triazine *[3682-35-7]* **M 312.3, m 245-248°.** Purified by repeated crystn from aq EtOH.

Tris-(2-aminoethyl)amine *[4097-89-6]* **M 146.2, b 114°/15mm, 263°/744mm, d 0.977, n 1.498.** For a separation from a mixture containing 62% TRIEN, see entry under triethylenetetramine. Also purified by conversion to the hydrochloride (see below), recrystn and regeneration of the free base [Xie and Hendrickson *JACS* **109** 6981 *1987*].

Tris-(2-aminoethyl)amine trihydrochloride *[14350-52-8]* **M 255.7, m 300°(dec).** Crystd several times by dissolving in a minimum of hot water and precipitating with excess cold EtOH. The ppte was washed with acetone, then ethyl ether and dried in a vacuum desiccator.

Tris-(2-biphenylyl) phosphate see Chapter 4.

TRIS Buffer see **trishydroxymethylaminomethane.**

Tris(d,d-dicamoholymethanato)europium (III) *[52351-64-1]* **M 108.5, m 220-227.5°, 229-232°, $[\alpha]_D^{25}$ +28.6° (c 5.4, CCl_4; and varies markedly with concentration).** Dissolve in

pentane, filter from any insol material, evaporate to dryness and dry the residue (white powder) at 100°/0.1mm for 36h. The IR has ν 1540cm^{-1}. [McCreary et al. *JACS* **96** 1038 *1974*].

Tris-(1,2-dioxyphenyl)cyclotriphosphazine see Chapter 4.

Tris-(hydroxymethylamino)methane (TRIS) *[77-86-1]* **M 121.1, m 172°.** Tris can ordinarily be obtained in highly pure form suitable for use as an acidimetric standard. If only impure material is available, it should be crystd from 20% EtOH. Dry in a vacuum desiccator over P_2O_5 or $CaCl_2$.
Alternatively, it is dissolved in twice its weight of water at 55-60°, filtered, concd to half its volume and poured slowly, with stirring, into about twice the volume of EtOH. The crystals which separate on cooling to 3-4° are filtered off, washed with a little MeOH, air dried by suction, then finally ground and dried in a vacuum desiccator over P_2O_5. It has also been crystd from water, MeOH or aq MeOH, and vacuum dried at 80° for 2 days.

Tris-(hydroxymethylamino)methane hydrochloride *[1185-53-1]* **M 157.6, m 149-150°(dec).** Crystd from 50% EtOH, then from 70% EtOH. Tris-hydrochloride is also available commercially in a highly pure state. Otherwise, crystd from 50% EtOH, then 70% EtOH, and dried below 40° to avoid risk of decomposition.

1,1,1-Tris-(hydroxymethyl)ethane *[77-85-0]* **M 120.2, m 200°.** Dissolved in hot tetrahydrofuran, filtered and ppted with hexane. It has also been crystd from acetone/water (1:1). Dried in vacuum.

***N*-Tris-(hydroxymethyl)methyl-2-aminomethanesulphonic acid (TES)** *[7365-44-8]* **M 229.3, m 224-226°(dec).** Crystd from hot EtOH containing a little water.

***N*-Tris-(hydroxymethyl)methylglycine (Tricine)** *[5704-04-1]* **M 179.2, m 186-188°(dec).** Crystd from EtOH and water.

Tris-(hydroxymethyl)nitromethane see **2-(hydroxymethyl)-2-nitropropane-1,3-diol.**

Tris-[(3-trifluoromethylhydroxymethylene)-d-camphorato] europium (III) (Eu[tfc]$_3$) *[34830-11-0]* **M 893.6, m 195-299° (dec), ~220°, $[\alpha]_D^{24}$ +152° (c 2, CCl_4; and varies markedly with concentration).** Purified by extraction with pentane, filtered and filtrate evapd and the residual bright yellow amorphous powder is dried at 100°/0.1mm for 36h. A sample purified by fractional molecular distn at 180-200°/0.004mm gave a liquid which solidified and softened at ~130° and melted at ~180° and was analytically pure. IR (CCl_4) ν: 1630-1680cm^{-1} and NMR (CCl_4) δ broad: -1.3 to 0.5, -0.08 (s), 0.41 (s), 1.6-2.3 and 3.39 (s). [McCreary et al. *JACS* **96** 1038 *1974*; ; Goering et al. *JACS* **93** 5913 *1971*].

1,3,5-Trithiane *[291-21-4]* **M 138.3, m 220°(dec).** Crystd from acetic acid.

Tri-*p*-tolyl phosphate and **tri-*o*-tolylphosphine** see entries in Chapter 4.

Trityl chloride see **triphenylmethyl chloride.**

Triuret *[556-99-0]* **M 146.1.** Crystd from aq ammonia.

Tropaeolin 00. Recrystd twice from water.

Tropaeolin 000 (see Orange II Chapter 4). Purified by salting out from hot distilled water using sodium acetate, then three times from distilled water and twice from EtOH.

3-Tropanol (Tropine) *[120-29-6]* **M 141.2, m 63°, b 229°/760mm.** Distd in steam and crystd from ethyl ether. *Hygroscopic.*

***dl*-Tropic acid** *[529-64-6]* **M 166.2, m 118°.** Crystd from water or benzene.

Tropolone *[533-75-5]* **M 122.1, m 49-50°, b 81-84°/0.1mm.** Crystd from hexane or pet ether and sublimed at 40°/4mm.

Tryptamine *[61-54-1]* **M 160.1, m 116°.** Crystd from benzene.

Tryptamine hydrochloride *[343-94-3]* **M 196.7, m 252-253°.** Crystd from EtOH/water.

L-Tryptophan *[73-22-3]* **M 204.3, m 278°, $[\alpha]_D^{20}$ -33.4° (EtOH), $[\alpha]_{546}^{20}$ -36° (c 1, H_2O).** Crystd from water/EtOH, washed with anhydrous ethyl ether and dried at room temperature under vac over P_2O_5.

Tryptophol [3-(2-hydroxyethyl)indole] *[526-55-6]* **M 161.2, m 59°.** Crystd from ethyl ether/pet ether.

(+)-Tubocurarine chloride ($^{-}H_2O$) *[57-94-3]* **M 771.7, m 274-275°, $[\alpha]_{546}^{20}$ +235° (c 0.5, H_2O).** Crystd from water.

D(+)-Turanose *[5349-40-6]* **M 342.3, m 168-170°, $[\alpha]_D^{20}$ +88° (c 4, H_2O).** Crystd from water by addition of EtOH.

Tyramine *[51-67-2]* **M 137.2, m 164-165°.** Crystd from benzene or EtOH.

Tyramine hydrochloride *[60-17-5]* **M 173.6, m 274-276°.** Crystd from EtOH by addition of ethyl ether, or from conc HCl.

Tyrocidine A *[1481-70-5]* **M 1268.8, m 240°(dec), $[\alpha]_D^{25}$ -115° (c 0.91, MeOH).** Crystd as hydrochloride from MeOH or EtOH and HCl. [Paladin and Craig *JACS* **76** 688 *1954*; King and Craig *JACS* **77** 6624 *1955*].

L-Tyrosine *[60-18-4]* **M 181.2, m 290-295°(dec), $[\alpha]_D^{25}$ -10.0° (5M HCl).** Likely impurities are L-cysteine and the ammonium salt. Dissolved in dilute ammonia, then crystd by adding dilute acetic acid to pH 5. Also crystd from water or EtOH/water, and dried at room temperature under vacuum over P_2O_5.

Umbelliferone *[93-35-6]* **M 162.2, m 225-228°.** Crystd from water.

Undecan-1-ol *[112-42-5]* **M 172.3, m 16.5°,**
Undec-10-enoic acid *[112-38-9]* **M 184.3, m 25-25.5°.** Purified by repeated fractional crystn from its melt

Uracil *[26-22-8]* **M 122.1, m 335°(dec),**
Uramil *[118-78-5]* **M 143.1, m >400°(dec).** Crystd from water.

Urea *[57-13-6]* **M 60.1, m 132.7-132.9°.** Crystd twice from conductivity water using centrifugal drainage and keeping the temperature below 60°. The crystals were dried under vacuum at 55° for 6h. Levy and Margouls [*JACS* **84** 1345 *1962*] prepared a 9M soln in conductivity water (keeping the temperature below 25°) and, after filtering through a medium-porosity glass sinter, added an equal volume of absolute EtOH. The mixture was set aside at -27° for 2-3 days and filtered cold. The ppte was washed with a small amount of EtOH and dried in air. Crystn from 70% EtOH between 40° and -9° has also been used. Ionic impurities such as ammonium isocyanate have been removed by treating the conc aqueous soln at 50° with Amberlite MB-1 cation- and anion-exchange resin, and allowing to crystallise. [Benesch, Lardy and Benesch *JBC* **216** 663 *1955*]. Also crystd from MeOH or EtOH, and dried under vacuum at room temperature.

Urea nitrate *[124-47-0]* **M 123.1, m 152°(dec).** Crystd from dilute HNO_3.

Uric acid *[69-93-2]* **M 168.1.** Crystd from hot distilled water.

Uridine *[58-96-8]* **M 244.2, m 165°, $[\alpha]_D^{20}$ +4.0° (H_2O).** Crystd from aqueous 75% MeOH.

Uridylic acid (di-Na salt) *[27821-45-0]* **M 368.2, m 198.5°.** Crystd from MeOH.

Urocanic acid *[104-98-3]* **M 138.1, m 225°.** Crystd from water and dried at 100°.

Ursodeoxycholic acid *[128-13-2]* **M 392.5, m 203°, $[\alpha]_D^{20}$ +60° (c 0.2, EtOH).** Crystd from EtOH.

(+)-Usnic acid *[7562-61-0]* **M 344.3, m 204°, $[\alpha]_{546}^{20}$ +630° (c 0.7, $CHCl_3$).** Crystd from acetone, MeOH or benzene.

Ustilagic acid (ustizeain B) *[8002-36-6]* **M** ~780 **, m 146-147°, $[\alpha]_D^{23}$ +7° (c 1, pyridine).** It is a mixture of partly acetylated di-D-glucosyldihydroxyhexadecanoic acid which crysts from ethyl ether. Also purified from the culture by dissolving in hot MeOH, filtering and concentrating by blowing a current of air until the soln becomes turbid, then heating to 50° and adding 4 vols of H_2O (also at 50°) and allowing to cool very slowly. Filter off the white solid and dry in air. [Lemieux et al. *Canad J Chem* **29** 409, 415 *1951*; *Canad J Biochem Physiol* **33** 289 *1955*].

trans-Vaccenic acid *[693-72-1]* **M 282.5, m 43-44°.** Crystd from acetone.

***n*-Valeraldehyde** *[110-62-3]* **M 86.1, b 103°, d 0.811, n^{25} 1.40233.** Purified *via* the bisulphite derivative. [Birrell and Trotman-Dickinson *JCS* 2059 *1960*].

***n*-Valeramide** *[626-97-1]* **M 101.1, m 115-116°.** Crystd from EtOH.

Valeric acid *[109-52-4]* **M 102.1, b 186.4°, d 0.938, n 1.4080.** Water was removed from the acid by distn using a Vigreux column, until the boiling point reached 183°. A few crystals of $KMnO_4$ were added, and after refluxing, the distn was continued, [Andrews and Keefer *JACS* **83** 3708 *1961*].

δ-Valerolactam (2-piperidone) *[675-20-7]* **M 99.1, m 33-36°, 38.5-39.5°, 39-40°, 40°, b 81-82°/0.1mm, 105°/0.4mm, 128-130°/10mm, 136-137°/15mm.** Purified by repeated fractional distn. It has a pKa of 0.75 in AcOH. [Cowley *JOC* **23** 1330 *1958*; Reppe et al. *A* **596** 198 *1955*; IR: Huisgen et al. *B* **90** 1437 *1957*]. The *hydrochloride* has **m** 183-184° (from isoPrOH or EtOH-Et_2O) [Hurd et al. *JOC* **17** 865 *1952*], and the *oxime* has **m** 122.5° (from pet ether) [Behringer and Meier *A* **607** 67 *1957*].

γ-Valerolactone (tetrahydro-2*H*-pyran-2-one) *[542-28-9]* **M 100.1, m -13°, -12.5°, -12°, b 88°/4mm, 97°/10mm, 124°/24mm, 145-146°/40mm, 226-229°/atm, 229-229.5°/atm, d_4^{20} 1.1081, n_D^{20} 1.4568.** Purified by repeated fractional distn. IR ν: 1750 (CS_2), 1732 ($CHCl_3$), 1748 (CCl_4), 1733 (MeOH) cm^{-1}. [Huisgen and Ott *TET* **6** 253 *1959*; Linstead and Rydon *JCS* 580 *1933*; Jones et al. *Canad J Chem* **37** 2007 *1959*].

γ-Valerolactone (± 4,5-dihydro-5-methyl-2(3*H*)-furanone) *[108-29-2]* **M 100.1, m -37°, 36°, b 82-85°/10mm, 84°/12mm, 97.5°/21mm, 102-103°/28mm, 125.3°/68mm, 136°/100mm, 205.75-206.25°/754mm, d_4^{20} 1.072, n_D^{20} 1.4322.** Purified by repeated fractional distillation [Boorman and Linstead *JCS* 577, 580 *1933*]. IR δ: 1790 (CS_2), 1775 ($CHCl_3$) cm^{-1} [Jones et al. *Canad J Chem* **37** 2007 *1959*]. The *BF_3-complex* distils at 110-111°/20mm [Reppe et al. *A* **596** 179 *1955*]. It is characterised by conversion to γ-hydroxy-*n*-valeramide by treatment with NH_3, **m** 51.5-52° (by slow evapn of a $CHCl_3$ soln).

Valeronitrile *[110-59-8]* **M 83.1, b 142.3°, d 0.799, n^{15} 1.39913, n^{30} 1.39037.** Washed with half its volume of conc HCl (twice), then with saturated aqueous $NaHCO_3$, dried with $MgSO_4$ and fractionally distd from P_2O_5.

L-Valine *[72-18-4]* **M 117.2, m 315°, $[\alpha]_D^{20}$ +266.7° (6M HCl).** Crystd from water by addition of EtOH.

Vanillin *[121-33-5]* **M 152.2, m 83°.** Crystd from water or aqueous EtOH.

Veratraldehyde *[120-14-9]* **M 166.2, m 42-43°.** Crystd from ethyl ether, pet ether, CCl_{34} or toluene.

Veratric acid see **3,4-dimethyoxybenzoic acid.**

Veratrole see ***o*-dimethoxybenzene.**

Variamine Blue RT (salt) *[4477-28-5]* **M 293.3, λ_{max} 377 nm.** Dissolved 10g in 100ml of hot water. Sodium dithionite (0.4g) was added, followed by active carbon (1.5g) and filtered hot. To the colourless or slightly yellow filtrate a soln of saturated NaCl was added and the mixture cooled. The needles were filtered off, washed with cold water, dried at room temperature, and stored in a dark bottle. [Erdey *Chem Analyst* **48** 106 *1959*].

Vicine *[152-93-2]* **M 304.3.** Crystd from water or aqueous 85% EtOH, and dried at 135°.

Vinyl acetate *[108-05-4]* **M 86.1, b 72.3°, d 0.938, n 1.396.** Inhibitors such as hydroquinone, and other impurities are removed by drying with $CaCl_2$ and fractionally distilling under nitrogen, then refluxing briefly with a small amount of benzoyl peroxide and redistilling under nitrogen. Stored in the dark at 0°.

9-Vinylanthracene *[2444-68-0]* **M 204.3, m 65-67°, b 61-66°/10mm.** Purified by vacuum sublimation. Also by chromatography on silica gel with cyclohexane as eluent, and recrystd from EtOH [Werst et al. *JACS* **109** 32 *1987*].

Vinyl butoxyethyl ether *[4223-11-4]* **M 144.2.** Washed with aqueous 1% NaOH, dried with CaH_2, then refluxed with and distd from, sodium.

***N*-Vinylcarbazole** *[484-13-5]* **M 193.3, m 66°.** Crystd repeatedly from MeOH in amber glassware. Vacuum sublimed.

Vinylene carbonate *[872-36-6]* **M 86.1, m 22°.** Purified by zone melting.

1-Vinylnaphthalene *[826-74-4]* **M 154.2, b 124-125°/15mm.** Fractionally distd under reduced pressure on a spinning-band column, dried with CaH_2 and again distd under vacuum. Stored in sealed ampoules in a freezer.

2-Vinylnaphthalene see **naphthylethylene.**

2-Vinylpyridine *[100-69-6]* **M 105.1, b 79-82°/29mm, d 0.974, n 1.550.** Steam distd, then dried with $MgSO_4$ and distd under vacuum.

Vinyl stearate *[111-63-7]* **M 310.5, m 35°, b 166°/1.5mm.** Vacuum distd under nitrogen, then crystd from acetone (3ml/g) or ethyl acetate at 0°.

Vioform see **5-chloro-8-hydroxy-7-iodoquinoline.**

Violanthrene (dibenzanthrene) *[81-31-2]* **M 428.5.** Purified by vacuum sublimation over Cu in a muffle furnace at 450°/25mm in a CO_2 atmosphere [Scholl and Meyer *B* **67** 1229 *1934*].

Viologen (*N,N'*-**dimethyl-4,4'-dipyridyl dihydrochloride**) *[27926-72-3]* **M 229.1, m >300°.** Purified by pptn on adding excess of acetone to a concentrated solution in aqueous MeOH. It has also been recrystd several times from MeOH and dried at 70° under vacuum for 24h [Prasad et al. *JACS* **108** 5135 *1986*], and recrystd three times from MeOH/isopropanol [Stramel and Thomas *JCSFT* **82** 799 *1986*].

Violuric acid see **5-isonitrosobarbituric acid.**

Visnagin *[82-57-5]* **M 230.2, m 142-145°.** Crystd from water.

Vitamin-A acetate see **retinyl acetate** in Chapter 5.

Vitamin-A alcohol see **retinol** in Chapter 5.

Vitamin B_{12} see entry in Chapter 5.

Vitamin D_2 and Vitamin D_3 see entries in Chapter 5.

Vitamin K_1 see entry in Chapter 5.

dl-Warfarin *[81-81-2]* M 308.3, m 161°. Crystd from MeOH.

Xanthatin *[26791-73-1]* M 246.3, m 114.5-115°, $[\alpha]_D$ -20° (EtOH). Crystd from MeOH or EtOH. UV: λ_{max} 213 and 275nm (ε 22800 and 7300).

Xanthene *[92-83-1]* **M 182.2, m 100.5°, b 310-312°/760mm.** Crystd from benzene or EtOH.

9-Xanthenone see **xanthone.**

Xanthine *[69-89-6]* **M 152.1, m >300°(dec).** Ppted by the addition of conc ammonia to its soln in hot 2M HCl (after treatment with charcoal), then crystd from distd water.

Xanthone *[90-47-1]* **M 196.2, m 175.6-175.4°.** Crystd from EtOH (25ml/g) and dried at 100°. It has also been recrystd from *n*-hexane three times and sublimed *in vacuo*. [Saltiel *JACS* **108** 2674 *1986*].

Xanthophyll see **lutein.**

Xanthopterin (H_2O) *[5979-01-1]* **M 197.2, m >410°.** Crystd by acidifying an ammoniacal soln, and collecting by centrifugation followed by washing with EtOH, ether and drying at 100° *in vacuo*.

Xanthorhamnin *[1324-63-6]* **M 770.7, m 195°, $[\alpha]_D^{20}$ +3.75° (EtOH).** Crystd from a mixture of ethyl and isopropyl alcohols, air dried, then dried for several hours at 110°.

Xanthosine ($2H_2O$) *[5968-90-1]* **M 320.3, $[\alpha]_D^{20}$ -53° (c 8, 0.3M NaOH).** Crystd from EtOH or water (as dihydrate).

Xanthydrol *[90-46-0]* **M 198.2, m 123-124°.** Crystd from EtOH and dried at 40-50°.

Xylene *[1330-20-7]* **M 106.1 (mixed isomers).** Usual impurites are ethylbenzene, paraffins, traces of sulphur compounds and water. It is not practicable to separate the *m*-, and *p*-isomers of xylene by fractional

distn, although, with a sufficiently efficient still, *o*-xylene can be fractionally distd from a mixture of isomers. Purified (and dried) by fractional distn from $LiAlH_4$, P_2O_5, CaH_2 or sodium. This treatment can be preceded by shaking successively with conc H_2SO_4, water, aqueous 10% NaOH, water and mercury, and drying with $CaCl_2$ for several days. Xylene can be purified by azeotropic distn with 2-ethoxyethanol or 2-methoxyethanol, the distillate being washed with water to remove the alcohol, then dried and fractionally distilled.

***o*-Xylene** *[95-47-6]* **M 106.2, f.p. -25.2°, b 84°/14mm, 144.4°/760mm, d 0.88020, d^{25} 0.87596, n 1.50543, n^{25} 1.50292.** The general purification methods listed under xylene are applicable [Clarke and Taylor *JACS* **45** 831 *1923*]. *o*-Xylene (4.4Kg) is sulphonated by stirring for 4h with 2.5L of conc H_2SO_4 at 95°. After cooling, and separating the unsulphonated material, the product was diluted with 3L of water and neutralised with 40% NaOH. On cooling, sodium *o*-xylene sulphonate separated and was recrystd from half its weight of water. [A further crop of crystals was obtained by concentrating the mother liquor to one-third of its volume]. The salt was dissolved in the minimum amount of cold water, then mixed with the same amount of cold water, and with the same volume of conc H_2SO_4 and heated to 110°. *o*-Xylene was regenerated and steam distd. It was then dried and redistd.

***m*-Xylene** *[108-38-3]* **M 106, f.p. -47.9°, b 139.1°, d 0.86417, d^{25} 0.85990, n 1.49721, n^{25} 1.49464.** The general purification methods listed under *xylene* are applicable. The *o*- and *p*-isomers can be removed by their selective oxidation when a *m*-xylene sample containing them is boiled with dilute HNO_3 (one part conc acid to three parts water). After washing with water and alkali, the product can be steam distd, then distd and purified by sulphonation. [Clarke and Taylor *JACS* **45** 831 *1923*]. *m*-Xylene is selectively sulphonated when a mixture of xylenes is refluxed with the theoretical amount of 50-70% H_2SO_4 at 85-95° under reduced pressure. By using a still resembling a Dean and Stark apparatus, water in the condensate can be progressively withdrawn while the xylene is returned to the reaction vessel. Subsequently, after cooling, then adding water, unreacted xylenes are distd off under reduced pressure. The *m*-xylenesulphonic acid is subsequently hydrolysed by steam distn up to 140°, the free *m*-xylene being washed, dried with silica gel and again distd. Stored over molecular sieves Linde type 4A.

***p*-Xylene** *[106-42-3]* **M 106.2, f.p.13.3, b 138.3°, d 0.86105, d^{25} 0.85669, n 1.49581, n^{25} 1.49325.** The general purification methods listed for *xylene* are applicable. *p*-Xylene can readily be separated from its isomers by crystn from such solvents as MeOH, EtOH, isopropanol, acetone, butanone, toluene, pentane or pentene. It can be further purified by fractional crystn by partial freezing, and stored over sodium wire or molecular sieves Linde type 4A. [Stokes and French *JCSFT 1* **76** 537 *1980*].

Xylenol see **dimethylphenol.**

Xylenol Orange *[1611-35-4]* **M 758.6, m 210°(dec), ε_{578} 6.09 x 10^4 (pH 14), ε_{435} 2.62 x 10^4 (pH 3.1).** Generally contaminated with starting material (cresol red) and semixylenol orange. Purified by ion-exchange chromatography using DEAE-cellulose, eluting with 0.1M NaCl soln. Cresol Red, semixylenol orange and iminodiacetic acid bands elute first. [Sato, Yokoyama and Momoki *Anal Chim Acta* **94** 317 *1977*].

Xylidine see **dimethylaniline.**

α-D-Xylose *[58-86-6]* **M 150.1, m 146-147°, $[\alpha]_D^{20}$ -18.8° (c 4, H_2O).** Purified by slow crystn from aq 80% EtOH or EtOH, then dried at 60° under vac over P_2O_5. Stored in a vacuum desiccator over $CaSO_4$.

***m*-Xylylene diisocyanate** *[3634-83-1]* **M 188.2, b 88-89°/0.02mm, 130°/2mm, d_4^{20} 1.204, n_D^{20} 1.4531.** Purified by repeated distn through a 2 plate column. [Ferstundig and Scherrer *JACS* **81** 4838 *1959*].

α-Yohimbine *[146-48-5]* **M 354.5, m 278°(dec), $[\alpha]_D^{20}$ +55.6° (c 2, EtOH).** Crystd from EtOH, and dried to remove EtOH of crystn.

γ-Yohimbine see **ajmalicine.**

Zeaxanthin *[144-68-3]* **M 568.9, m 215.5°, λ_{max} 275 (log ε 4.34), 453 (log ε 5.12), 480 (log ε 5.07) in EtOH.** Yellow plates from MeOH.

Zincon see entry in Chapter 4.

CHAPTER 4

PURIFICATION OF INORGANIC AND METAL ORGANIC CHEMICALS

The commonest method of purification of inorganic species is by recrystallisation, usually from water. However, especially with salts of weak acids or of cations other than the alkaline and alkaline earth metals, care must be taken to minimise the effect of hydrolysis. This can be achieved, for example, by recrystallising acetates in the presence of dilute acetic acid. Nevertheless, there are many inorganic chemicals that are too insoluble or are hydrolysed by water so that no general purification method can be given. It is convenient that many inorganic substances have large temperature coefficients for their solubility in water, but in other cases recrystallisation is still possible by partial solvent evaporation.
Organo-metallic compounds, on the other hand, behave very much like organic compounds, e.g. they can be redistilled and may be soluble in organic solvents. A note of **caution** should be made about handling organo-metallic compounds, e.g. arsines, because of their **potential toxicities**, particularly when they are volatile. Generally the suppliers of such compounds provide details about their safe manipulation. These should be read carefully and adhered to closely. If in any doubt always assume that the materials are lethal and treat them with utmost care. The abbreviations are listed in Chapter 1, pp. 1 and 2. The same **safety precautions** about the handling of substances as stated in Chapter 3 should be followed here.

Acetarsol see *N*-Acetyl-4-hydroxy-*m*-arsanilic acid.

Acetonyl triphenyl phosphonium chloride and **acetylmethylene triphenyl phosphorane** see Chapter 3.

3*R*,4*R*,1'*R*-4-Acetoxy-3-[1-(*tert*-butylmethylsilyloxy)ethyl]-2-azetinone *[76855-69-1]* **M 287.4, m 107-108°, $[\alpha]_D^{20}$ +55° (c 0.5, toluene)$[\alpha]_D^{20}$ +53.7° (c 1.04, $CHCl_3$).** Purified by chromatography on silica gel (3 x 14cm) for 50g of ester using 20% EtOAc in *n*-hexane. The eluate is evaporated and the residue recrystd from hexane as white fluffy crystals. [*TET* **39** 2505 *1983*].

Acetylferrocene (ferrocenyl methylketone) *[1271-55-2]* **M 228.1, m 86°, 86-87°.** Orange-red crystals, recrystd from isooctane and sublimed at 100°/1mm. The *oxime* has **m** 167-170° (from Et_2O or aq EtOH). The *semicarbazone* has **m** 198-201° (from EtOH). [*JACS* **77** 2022 3009 *1955*; *JCS* 650 *1958*].

***N*-Acetyl-4-hydroxy-*m*-arsanilic acid** *[97-44-9]* **M 275.1.** Crystd from water.

Alizarin Red S (sodium salt, H_2O) *[130-22-3]* **M 360.3.** Commercial samples contain large amounts of sodium and potassium chlorides and sulphates. It is purified by passing through a Sephadex G-10 column, followed by elution with water, then 50% aq EtOH [King and Pruden *Analyst* **93** 601 *1968*].

Alumina (neutral) *[1344-28-1]* **M 102.0 (anhyd.).** Stirred with hot 2M HNO_3, either on a steam bath for 12h (changing the acid every hour) or three times for 30min, then washed with hot distilled water until the washings had pH 4, followed by three washings with hot MeOH. The product was dried at 270° [Angyal and Young *JACS* **81** 5251 *1959*]. For the preparation of alumina for chromatography see Chapter 1.

Aluminum acetylacetonate *[13963-57-0]* **M 324.3, m 192-194°, 195°.** Crystd several times from

aqueous MeOH, λ_{max} 216 and 286mn. [*JPC* **62** 440 *1958*]. It can be purified by sublimation and has the following solubilities in g per cent: C_6H_6 35.9 (20°), 47.6 (40°), toluene 15.9 (20°), 22.0 (40°) and acetylacetone 6.6 (20°), 10.4 (40°). [*Inorg Synth* **5** 105 *1957*].

Aluminium ammonium sulphate ($10H_2O$) *[7784-26-1]* **M 453.3, m 93°.** Crystd from hot water by cooling in ice.

Aluminium bromide *[7727-15-3]* **M 266.7, m 97°, b 114°/10mm.** Refluxed and then distilled from pure aluminium chips in a stream of nitrogen into a flask containing more of the chips. It was then distd under vacuum into ampoules [Tipper and Walker *JCS* 1352 *1959*]. Anhydrous conditions are essential, and the white to very light brown solid distillate can be broken into lumps in a dry-box (under nitrogen). Fumes in moist air.

Aluminium caesium sulphate ($12H_2O$) *[14284-36-7]* **M 568.2.** Crystd from hot water (3ml/g).

Aluminium chloride (anhydrous) *[7446-70-0]* **M 133.3.** Sublimed several times in an all glass system under nitrogen at 30-50mm pressure. Has also been sublimed in a stream of dry HCl and has been subjected to a preliminary sublimation through a section of granular aluminium metal [for manipulative details see Jensen *JACS* **79** 1226 *1957*]. Fumes in moist air.

Aluminum ethoxide *[555-75-9]* **M 162.2, m 154-159°, 146-151°, b 187-190°/7mm, 210-214°/13mm.** Crystd from CS_2 [**m** 139°, complex: *ZPC* **164** 295 *1933*] and distd in a vacuum. Molecular weight corresponds to $(AlOEt_3)_4$. [*JPC* **39** 1127 *1935*; *JACS* **69** 2605 *1947*].

Aluminium fluoride (anhydrous) *[7784-18-4]* **M 84.0, m 250°.** Technical material may contain up to 15% alumina, with minor impurities such as aluminium sulphate, cryolite, silica and iron oxide. Reagent grade AlF_3 (hydrated) contains only traces of impurities but its water content is very variable (may be up to 40%). It can be dried by calcining at 600-800° in a stream of dry air (some hydrolysis occurs), followed by vacuum distn at low pressure in a graphite system, heated to approximately 925° (condenser at 900°) [Henry and Dreisbach *JACS* **81** 5274 *1959*].

Aluminium isopropoxide *[555-31-7]* **M 204.3, m 119°, b 94°/0.5mm, 135°/10mm.** Distd under vacuum. *Hygroscopic.*

Aluminium nitrate ($9H_2O$) *[7784-27-2]* **M 375.1.** Crystd from dilute HNO_3, and dried by passing dry nitrogen through the crystals for several hours at 40°.

Aluminium potassium sulphate ($12H_2O$, alum) *[7784-24-9]* **M 474.4, m 92°.** Crystd from weak aqueous H_2SO_4 (*ca* 0.5ml/g).

Aluminium rubidium sulphate ($12H_2O$) *[7784-29-4]* **M 496.2.** Crystd from aq H_2SO_4 (*ca* 2.5ml/g).

Aluminium sulphate *[10043-01-3]* **M 342.2, m 765°(dec).** Crystd from hot dilute H_2SO_4 (1 ml/g) by cooling in ice.

Aluminum triethyl (triethyl aluminum) *[97-93-8]* **M 114.2, b 69°/1.5mm, 76°/2.5mm, 129-131°/55mm, d_4^{20} 0.695, n_D^{20} 1.394.** Purified by fractionation in an inert atmosphere under vacuum in a 50cm column containing a heated nichrome spiral, taking the fraction 112-114°/27mm. It is very sensitive to H_2O and should be stored under N_2. It should not contain chloride which can be shown by hydrolysis and testing with $AgNO_3$. [*JACS* **75** 4828 5193*1953*; NMR: *JACS* **81** 3826 *1959*].

Aluminium tri-*tert*-butoxide *[556-91-2]* **M 246.3.** Crystd from benzene and sublimed at 180°.

Aluminium trimethanide (trimethyl aluminium) *[75-24-1]* **M 72.1, m 15.2°, b 11½.5°/488.2mm, 124.5°/atm, d_4^{20} 0.725.** Distd through a 10-20 theoretical plates column under 1 atm of N_2 (better with very slow take-off). Attacks grease (use glass joints). Also vac distd over Al in absence of

grease, into small glass vials and sealed under N_2. Purity is measured by freezing point. Reacts with H_2O, is non-conducting in C_6H_6 and is **HIGHLY FLAMMABLE**. [*JCS* 468*1946*; *JACS* **68** 2204 *1946*].

4-Aminophenylmercuric acetate *[6283-24-51]* **M 371.8, m 168°, 175°(dec), 180°(dec).** Recrystd from hot dilute AcOH and dried in air. [*JICS* **32** 613 *1955; A* **465** 269 *1928*].

Ammonia (gas) *[7664-41-7]* **M 17.0.** Major contaminants are water, oil and non-condensible gases. Most of these impurities are removed by passing the ammonia through a trap at -22° and condensing it at -176° under vacuum. Water is removed by distilling the ammonia into a tube containing a small lump of sodium. Also dried by passage through porous BaO, or over alumina followed by glass wool impregnated with sodium (prepared by soaking the glass wool in a solution of sodium in liquid ammonia, and evaporating off the ammonia). It can be rendered oxygen-free by passage through a soln of potassium in liquid ammonia.
Ammonia (liquid) *[7664-41-7]* **M 17.0, m -77.7°, b -33.4°, d 0.597.** Dried, and stored, with sodium in a steel cylinder, then distd and condensed by means of liquid air, the non-condensable gases being pumped off. In order to obtain liquid NH_3 from a cylinder turn the cylinder up-side-down (i.e. with the valve at the bottom, use a metal stand to secure it in this position) and lead a plastic tube from the tap to a measuring cylinder placed in an efficient fume cupboard which is kept running. Turn the tap on and allow the ammonia to be released. At first, gas and liquid will splatter out (make sure that the plastic tube is secure) but soon the liquid will drip into the measuring cylinder. The high latent heat of evaporation will cool the ammonia so that the liquid will remain cool and not boil vigorously. If the ammonia is required dry the necessary precautions should be taken, i.e. the gas is allowed to flow through tubes packed with coarse CaO pellets.
Ammonia (aqueous) *[7664-41-7]* **M 17.0 + H_2O, d 0.90 (satd, 27% w/v, 14.3 N).** Obtained metal-free by saturating distilled water, in a cooling bath, with ammonia (from tank) gas. Alternatively, can use isothermal distn by placing a dish of conc aq ammonia and a dish of pure water in an empty desiccator and leaving for several days. **AMMONIA (gas, liquid or aq soln) is very irritating and should not be inhaled as it can lead to olfactory paralysis (temporary and partially permanent).**

Ammonium acetate *[631-61-8]* **M 77.1, m 112-114°.** Crystd twice from anhydrous acetic acid, dried under vacuum for 24h at 100° [Proll and Sutcliff *TFS* **57** 1078 *1961*].

Ammonium bisulphate *[7803-63-6]* **M 115.1°.** Crystd from water at room temperature (1ml/g) by adding EtOH and cooling.

Ammonium bromide *[12124-97-9]* **M 98.0, m 450°(sublimes).** Crystd from 95% EtOH.

Ammonium chloride *[12125-02-9]* **M 53.5.** Crystd several times from conductivity water (1.5ml/g) between 90° and 0°. Sublimes.

Ammonium chromate *[7788-98-9]* **M 152.1.** Crystd from weak aqueous ammonia (*ca* 2.5ml/g) by cooling from room temperature.

Ammonium dichromate *[7788-09-5]* **M 252.1, m 170°(dec).** Crystd from weak aq HCl (*ca* 1ml/g).

Ammonium dihydrogen arsenate *[13462-93-6]* **M 159.0.** Crystd from water (1ml/g).

Ammonium dihydrogen orthophosphate *[7722-76-1]* **M 115.0, m 190°.** Crystd from water (0.7ml/g) between 100° and 0°.

Ammonium ferric oxalate ($3H_2O$) *[13268-42-3]* **M 428.1.** Crystd from hot water (0.5ml/g).

Ammonium ferric sulphate ($12H_2O$) *[7783-83-7]* **M 482.2.** Crystd from aqueous ethanol.

Ammonium ferrous sulphate ($6H_2O$) *[7783-85-9]* **M 392.1.** A soln in warm water (1.5ml/g) was cooled rapidly to 0°, and the resulting fine crystals were filtered at the pump, washed with cold distilled water and pressed between sheets of filter paper to dry.

Ammonium fluorosilicate *[16919-19-0]* **M 178.1.** Crystd from water (2ml/g).

Ammonium formate *[540-69-2]* **M 63.1, m 116°, 117.3°, d_4^{45} 1.280.** Heat solid in NH_3 vapour and dry in vacuum till NH_3 odour is faint. Recryst from abs EtOH and then keep in a desiccator over 99% H_2SO_4 *in vacuo*. It is very *hygroscopic*. Exists in two forms, stable needles and less stable plates. Also forms acid salts, i.e. $HCO_2NH_4.3HCO_2H$ and $HCO_2NH_4.HCO_2H$. [*JACS* **43** 1473 *1921*; **63** 3124 *1941*].

Ammonium hexachloroiridate (IV) *[1694-92-4]* **M 641.0.** Ppted several times from aqueous soln by saturation with ammonium chloride. This removes any palladium and rhodium. Then washed with ice-cold water and dried over conc H_2SO_4 in a vacuum desiccator. If osmium or ruthenium is present, it can be removed as the tetroxide by heating with conc HNO_3, followed by conc $HClO_4$, until most of the acid has been driven off. (This treatment is repeated). The near-dry residue is dissolved in a small amount of water and added to excess $NaHCO_3$ soln and bromine water. On boiling, iridic (but not platinic) hydroxide is ppted. It is dissolved in HCl and ppted several times, then dissolved in HBr and treated with HNO_3 and HCl to convert the bromides to chlorides. Saturation with ammonium chloride and cooling precipitates ammonium hexachloroiridate which is filtered off and purified as above [Woo and Yost *JACS* **53** 884 *1931*].

Ammonium hexacyanoferrate II hydrate *[14481-29-9]* **M 284.1.** The pale yellow trihydrate powder can be washed with 10% aq NH_3, filtd, then washed several times with EtOH and Et_2O, and dried at room temp. Decomposes in vacuum above 100° and should be stored away from light and under N_2. In light and air it decomposes by losing NH_3. [*Handbook of Preparative Inorganic Chem, (ed Brauer)* Vol II 1509 *1965*].

Ammonium hexafluorophosphate *[16741-11-0]* **M 163.0, d_4^{18} 2.181.** Crystallises from H_2O in square plates. Decomposes on heating before melting. Soluble in H_2O at 20° (74.8% w/v), also very soluble in Me_2CO, MeOH, EtOH and MeOAc and is decomposed by boiling acids. [*B* **63** 1063 *1930*].

Ammonium hypophosphite *[7803-65-8]* **M 117.1.** Crystd from hot EtOH.

Ammonium iodate *[13446-09-8]* **M 192.9.** Crystd from water (8ml/g) between 100° and 0°.

Ammonium iodide *[12027-06-4]* **M 144.9.** Crystd from EtOH by addition of ethyl iodide. Very *hygroscopic*. Stored in the dark.

Ammonium ionophore I (Nonactin) *[6833-86-7]* **M 736.9, m 147-148°, $[\alpha]_D^{20}$ 0° (c 1.2, $CHCl_3$).** Crystd from MeOH in colourless needles and is dried at 20° in high vac. A selectophore with high sensitivity for NH_4^+ ions. [*HCA* **38** 1445 *1955*, **45** 129 *1962*, **55** 1371 *1972*; *Acta Cryst* **27B** 1680 *1971*].

Ammonium magnesium chloride ($6H_2O$) *[60314-43-4]* **M 256.8.** Crystd from water (6ml/g) by partial evapn in a desiccator over KOH.

Ammonium magnesium sulphate ($6H_2O$) *[20861-69-2]* **M 360.6.** Crystd from water (1ml/g) between 100° and 0°.

Ammonium manganous sulphate ($6H_2O$) *[13566-22-8]* **M 391.3.** Crystd from water (2ml/g) by partial evapn in a desiccator.

Ammonium metavanadate *[7803-55-6]* **M 117.0, m 200°(dec).** Crystd from conductivity water (20ml/g).

Ammonium molybdate *[13106-76-8]* **M 196.0.** Crystd from water (2.5ml/g) by partial evapn in a desiccator.

Ammonium nickel sulphate ($6H_2O$) *[15699-18-0]* **M 395.0.** Crystd from water (3ml/g) between 90° and 0°.

Ammonium nitrate *[6484-52-2]* **M 80.0.** Crystd twice from distilled water (1ml/g) by adding EtOH, or from warm water (0.5ml/g) by cooling in an ice-salt bath. Dried in air, then under vacuum.

Ammonium oxalate (H_2O) *[6009-70-7]* **M 142.1.** Crystd from water (10ml/g) between 50° and 0°.

Ammonium perchlorate *[7790-98-9]* **M 117.5.** Crystd twice from distilled water (2.5ml/g) between 80° and 0°, and dried in a vacuum desiccator over P_2O_5. Drying at 110° might lead to slow decomposition to chloride. **POTENTIALLY EXPLOSIVE.**

Ammonium reineckate *[13573-16-5]* **M 345.5, m 270-273°(dec).** Crystd from water, between 30° and 0°, working by artificial light. Solns of reineckate decompose slowly at room temperature in the dark and more rapidly at higher temperatures or in diffuse sunlight.

Ammonium selenate *[7783-21-3]* **M 179.0.** Crystd from water at room temperature by adding EtOH and cooling.

Ammonium sulphamate *[7773-06-0]* **M 114.1, m 132-135°.** Crystd from water at room temperature (1ml/g) by adding EtOH and cooling.

Ammonium sulphate *[7783-20-2]* **M 132.1, m 230°(dec).** Crystd twice from hot water containing 0.2% EDTA to remove metal ions, then finally from distilled water. Dried in a desiccator for two weeks over $Mg(ClO_4)_2$.

Ammonium tetrafluoroborate *[13826-53-0]* **M 104.8.** Crystd from conductivity water (1ml/g) between 100° and 0°.

Ammonium tetraphenylborate *[14637-34-4]* **M 337.3, m *ca* 220°(dec).** Dissolve in aqueous Me_2CO and allow crystn to proceed slowly otherwise very small crystals are formed. No trace of Me_2CO was left after drying at 120° [*TFS* **53** 19 *1957*]. The salt was ppted from dilute AcOH soln of sodium tetraphenylborane in the presence of NH_4^+ ions. After standing for 5min, the ppte was filtered off onto a sintered porcelain crucible, washed with very dilute AcOH and dried at room temp for at least 24h [*AC* **28** 1001 *1956*]. Alternatively a soln of sodium tetraphenylborane (5% excess) in H_2O is added to NH_4Cl soln. After 5min the ppte is collected, washed several times with H_2O and recryst from aqueous Me_2CO. [*ACA* **19** 342 *1958*].

Ammonium thiocyanate *[1762-95-4]* **M 76.1, m 138°(dec).** Crystd three times from dilute $HClO_4$, to give material optically transparent at wavelengths longer than 270nm. Has also been crystd from absolute MeOH and from acetonitrile.

Ammonium tungstate *[11120-25-5]* **M 283.9.** Crystd from warm water by adding EtOH and cooling.

Ammonium (meta) vanadate *[7803-55-6]* **M 117.0, d_{10}^{20} 2.326.** Wash with H_2O until free from Cl^- and dry in air. It is soluble in H_2O (5.18g/100 at 15°, 10.4g/100 at 32°) but is more soluble in dilute NH_3. When heated at relatively low temperatures it loses H_2O and NH_3 to give vanadium oxide (V_2O_5) and at 210° it forms lower oxides. [*Inorg Synth* **3** 117 *1950*].

***n*-Amylmercuric chloride** *[544-15-0]* **M 307.2, m 110°.** Crystd from EtOH.

9,10-Anthraquinone-2,6-disulphonic acid (disodium salt) *[84-50-4]* **M 412.3, m >325°.** Crystd three times from water, in the dark [Moore et al. *JCSFT1* **82** 745 *1986*].

9,10-Anthraquinone-2-sulphonic acid (sodium salt, H_2O) *[131-08-8]* **M 328.3.** Crystd from water using active charcoal.

Antimony (V) pentafluoride *[7783-70-2]* **M 216.7, m 7.0°, 8.3°, b 141°, 150°, 148-150°, d 2.99.** Purified by vacuum distillation preferably in a quartz apparatus, and stored in quartz or aluminum

bottles. It is a *hygroscopic* viscous liquid which reacts *violently* with H_2O and is hydrolysed by alkalis. *It is* **POISONOUS** *and attacks the skin.* [*JCS* 2200 *1950*; *Handbook of Preparative Inorganic Chemistry (ed Brauer)* Vol I 200 *1965*].

Antimony trichloride *[10025-91-9]* **M 228.1, m 73°, b 283°.** Dried over P_2O_5 or by mixing with toluene or xylene and distilling (water is carried off with the organic solvent), then distd twice under dry nitrogen at 50mm, degassed and sublimed twice in a vacuum into ampoules. Can be crystd from CS_2. Deliquescent. Fumes in moist air.

Antimony trifluoride *[7783-56-4]* **M 178.8, m 292°.** Crystd from MeOH to remove oxide and oxyfluoride, then sublimed under vacuum in an aluminium cup on to a water-cooled copper condenser [Woolf *JCS* 279 *1955*].

Antimony triiodide *[7790-44-5]* **M 502.5, m 167°.** Sublimed under vacuum.

Antimony trioxide *[1309-64-4]* **M 291.5, m 656°.** Dissolved in minimum volume of dilute HCl, filtered, and six volumes of water were added to ppte a basic antimonous chloride (free from Fe and Sb_2O_5). The ppte was redissolved in dilute HCl, and added slowly, with stirring, to a boiling soln (containing a slight excess) of Na_2CO_3. The oxide was filtered off, washed with hot water, then boiled and filtered, the process being repeated until the filtrate gave no test for chloride ions. The product was dried in a vacuum desiccator [Schuhmann *JACS* **46** 52 *1924*].

Argon *[7440-37-1]* **M 39.95, b -185.6°.** Rendered oxygen-free by passage over reduced copper at 450°, or by bubbling through alkaline pyrogallol and H_2SO_4, then dried with $CaSO_4$, $Mg(ClO_4)_2$, or Linde 5A molecular sieves. Other purification steps include passage through Ascarite (asbestos impregnated with sodium hydroxide), through finely divided uranium at about 800° and through a -78° cold trap.
Alternatively the gas is passed over CuO pellets at 300° to remove hydrogen and hydrocarbons, over Ca chips at 600° to remove oxygen and, finally, over titanium chips at 700° to remove nitrogen. Also purified by freeze-pump-thaw cycles and by passage over sputtered sodium [Arnold and Smith *JCSFT 2* **77** 861 *1981*].

***o*-Arsanilic acid** *[2045-00-3]* **M 216.1, m 153°,**
***p*-Arsanilic acid** *[98-50-0]* **M 216.1, m 232°.** Crystd from water or ethanol/ether.

Arsenazo I *[520-10-5]* **M 614.3, ε 2.6 x 10^4 at 500nm, pH 8.0.** A saturated aqueous soln of the free acid was slowly added to an equal volume of conc HCl. The orange ppte was filtered, washed with acetonitrile and dried for 1-2h at 110° [Fritz and Bradford *AC* **30** 1021 *1958*].

Arsenazo III *[1667-00-4]* **M 776.4.** Contaminants include monoazo derivatives, starting materials for synthesis and by-products. Partially purified by pptn of the dye from aqueous alkali by addition of HCl. More thorough purification by taking a 2g sample in 15-25ml of 5% aq NH_3 and filter. Add 10ml HCl (1:1) to the filtrate to ppte the dye. Repeat procedure and dissolve solid dye (0.5g) in 7ml of a 1:1:1 mixture of *n*-propanol:conc NH_3:water at 50°. After cooling, filter soln and treat the filtrate on a cellulose column using 3:1:1 mixture of *n*-propanol:conc NH_3:water as eluent. Collect the blue band and evaporate to 10-15ml below 80°, then add 10ml conc HCl to ppte pure Arsenazo III. Wash with EtOH and air-dry [Borak et al. *Talanta* **17** 215 *1970*]. The purity of the dye can be checked by paper chromatography using M HCl as eluent.

Arsenic *[7440-38-2]* **M 74.9, m 816°.** Heated under vacuum at 350° to sublime oxides, then sealed in a Pyrex tube under vacuum and sublimed at 600°, the arsenic condensing in the cooler parts of the tube. Stored under vacuum [Shih and Peretti *JACS* **75** 608 *1953*].

Arsenic tribromide *[82868-10-8]* **M 394.6, m 89°/11mm, 221°/760mm.** Distd under vacuum.

Arsenic trichloride *[60646-36-8]* **M 181.3, b 130.0°.** Refluxed with arsenic for 4h, then fractionally distd. The middle fraction was stored with sodium wire for two days, then again distd [Lewis and Sowerby *JCS* 336 *1957*].

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Arsenic triiodide *[50288-23-8]* **M 455.6, m 146°.** Crystd from acetone.

Arsenic III oxide *[1327-53-3]* **M 197.8.** Crystd from dil HCl (1:2), washed, dried and sublimed. Analytical reagent grade material is suitable for use as an analytical standard after it has been dried by heating at 105° for 1-2h or has been left in a desiccator for several hours over conc H_2SO_4.

3-(2-Arsenophenylazo)-4,5-dihydroxynaphthalene-2,7-disulphonic acid (trisodium salt) see **Arsenazo.**

Aurothioglucose (gold thioglucose) *[12192-57-3]* **M 139.2.** Purified by dissolving in H_2O (0.05g in 1ml) and ppting by adding EtOH. Yellow cryst with slight mercaptan odour. Decomposes slowly in H_2O, sol in propylene glycol but insol in EtOH and other common organic solvents. [*FEBS LETT* **98** 351 *1970*].

Barium (metal) *[7440-39-3]* **M 137.3.** Cleaned by washing with ethyl ether to remove adhering paraffin, then filed in an argon-filled glove box, washed first with ethanol containing 2% conc HCl, then with dry ethanol. Dried under vacuum and stored under argon [Addison, Coldrey and Halstead *JCS* 3868 *1962*]. Has also been purified by double distn under 10mm argon pressure.

Barium acetate *[543-80-6]* **M 255.4.** Crystd twice from anhydrous acetic acid and dried under vacuum for 24h at 100°.

Barium bromate *[13967-90-3]* **M 265.3.** Crystd from hot water (20ml/g).

Barium bromide ($2H_2O$) *[7791-28-8]* **M 333.2.** Crystd from water (1ml/g) by partial evaporation in a desiccator.

Barium chlorate (H_2O) *[13477-00-4]* **M 322.3.** Crystd from water (1ml/g) between 100° and 0°.

Barium chloride ($2H_2O$) *[10326-27-9]* **M 244.3.** Twice crystd from water (2ml/g) and oven dried to constant weight.

Barium dithionate ($2H_2O$) *[13845-17-5]* **M 333.5.** Crystd from water.

Barium ferrocyanide ($6H_2O$) *[13821-06-2]* **M 594.8.** Crystd from hot water (100ml/g).

Barium fluoride *[7787-32-8]* **M 175.3, m 1353°, b 2260°, d 4.83.** Washed well with distd H_2O and dried in vacuum Sol in H_2O [1.6g (10°), 1.6g (20°) and 1.62g(30°) per L), mineral acids and aq NH_4Cl. May be stored in glass bottles. [*Handbook of Preparative Inorganic Chemistry (ed Brauer)* Vol I 234 *1963*].

Barium formate *[541-43-5]* **M 277.4.** Crystd from warm water (4ml/g) by adding EtOH and cooling.

Barium hydroxide ($8H_2O$) *[12230-71-6]* **M 315.5, m 78°.** Crystd from water (1ml/g).

Barium hypophosphite (H_2O) *[14871-79-5]* **M 285.4.** Ppted from aq soln (3ml/g) by adding EtOH.

Barium iodate (H_2O) *[10567-69-8]* **M 505.2.** Crystd from a large volume of hot water by cooling.

Barium iodide ($2H_2O$) *[7787-33-9]* **M 427.2.** Crystd from water (0.5ml/g) by partial evapn in a desiccator

Barium ionophore I [*N,N,N',N'*-tetracyclohexyloxy-bis-(*o*-phenyleneoxy)diacetamide] *[96476-01-6]* **M 644.9, m 156-158°.** Purified by chromatography on a Kieselgel column and eluted with

CH_2Cl_2-EtOAc (5:1), and recryst from EtOH-Me_2CO as colourless crystals. It is an electrically neutral ionophore with high selectivity for Ba^{++} ions and with high lipophilicity. [*B* **118** 1071 *1985*].

Barium manganate *[7787-35-1]* **M 256.3.** Wash with conductivity H_2O by decantation until the supernatant gives a faint test for Ba^{++}. Remove excess H_2O in vac (IMPORTANT), then heat at 100° and the last traces of H_2O are removed in a vac desiccator over P_2O_5. Store over KOH. It disproportionates in hot H_2O or dil acid to $Ba(MnO_2)_2$ and MnO_2, and is a mild oxidant. [*JACS* **44** 1965 *1924*; *Inorg Synth* **11** 56 *1960*].

Barium nitrate *[10022-31-8]* **M 261.4, m 593°(dec).** Crystd twice from water (4ml/g) and dried overnight at 110°.

Barium nitrite (H_2O) *[7787-38-4]* **M 247.4.** Crystd from water (1ml/g) by cooling in an ice-salt bath.

Barium perchlorate *[13465-95-7]* **M 336.2, m 505°.** Crystd twice from water.

Barium propionate (H_2O) *[5908-77-0]* **M 301.5.** Crystd from warm water (50ml/g) by adding EtOH and cooling.

Barium sulphate *[7722-43-7]* **M 233.4.** Washed five times by decantation with hot distilled water, dialysed against distd water for one week, then freeze-dried and oven dried at 105° for 12h.

Barium tetrathionate *[82203-66-5]* **M 361.6.** Purified by dissolution in a small volume of water and ppted with EtOH below 5°. After drying the salt was stored in the dark at 0°.

Barium thiocyanate (2 H_2O) *[2092-17-3]* **M 289.6.** Crystd from water (2.5ml/g) by partial evaporation in a desiccator.

Barium thiosulphate *[35112-53-9]* **M 249.5.** Very slightly soluble in water. Washed repeatedly with chilled water and dried in air at 40°.

Benzenearsonic acid see **Phenylarsonic acid.**

Benzenechromium tricarbonyl *[12082-08-5]* **M 214.1. m 163-166°.** Purified by sublimation *in vacuo*.

Benzenephosphinic acid *[1779-48-2]* **M 142.1, m** *ca* **70°.** Purified by allowing to stand for several days under ethyl ether, with intermittent shaking and several changes of solvent. After filtration, the excess ether was removed in vacuum.

Benzeneseleninic acid *[6996-92-5]* **M 189.1, m 123-124°.** Recrystd twice from water [Kice and Purkiss *JOC* **52** 3448 *1987*].

Benzenestibonic acid *[535-46-6]* **M 248.9, m >250°(dec).** Crystd from acetic acid, or from EtOH-$CHCl_3$ mixture by addition of water.

Benzyltriphenylphosphonium chloride *[1100-88-5]* **M 388.9, m 280° (sintering), 287-288°.** Wash with Et_2O and crystallise from EtOH (six sided plates). *Hygroscopic* and forms crystals with one mol H_2O. [*A* **229** 320 *1885*; *B* **83** 291 *1950*].

Beryllium acetate (basic) *[543-81-7]* **M 406.3, m 285-286°.** Crystd from chloroform.

Beryllium potassium fluoride *[7787-50-0]* **M 105.1.** Crystd from hot water (25ml/g).

Beryllium sulphate ($4H_2O$) *[7787-56-6]* **M 177.1.** Crystd from weak aqueous H_2SO_4.

Bicyclo[2.2.1]hepta-2,5-diene rhodium (I) chloride dimer (norbornadiene rhodium chloride complex dimer) *[12257-42-0]* **M 462, m 240°(dec).** Recrystd from hot $CHCl_3$-pet ether as fine crystals soluble in $CHCl_3$ and C_6H_6 but almost insoluble in Et_2O or pet ether. [*JCS* 3178 *1959*].

2-Biphenylyl diphenyl phosphate *[132-29-6]* **M 302.4, n^{25}1.5925.** Vacuum distd, then percolated through an alumina column. Passed through a packed column maintained at 150° to remove residual traces of volatile materials by a counter-current stream of nitrogen at reduced pressure. [Dobry and Keller *JPC* **61** 1448 *1957*].

2,2'-Bipyridineruthenous dichloride ($6H_2O$), see **tris(2,2'-bipyridine)ruthenous dichloride.**

2,2'-Bipyridinium chlorochromate *[76899-34-8]* **M 292.6.** Washed with cold conc HCl then H_2O (sintered glass funnel) and dried in vacuum ($CaCl_2$) to a free flowing yellow-brown powder. Stored in the dark. [*S* 691 *1980*; *SC* **10** 951 *1980*).

Bis-(*p-tert*-butylphenyl)phenyl phosphate *[115-87-7]* **M 438.5, b 281°/5mm, n^{25} 1.5412.** Same as for 2-biphenylyl diphenyl phosphate (above).

Bis-(2-chlorophenyl) phenyl phosphate *[597-80-8]* **M 395, b 254°/4mm, n^{25} 1.5767**. Same as for 2-biphenylyl diphenyl phosphate above.

Bis(2,9-dimethyl-1,10-phenanthroline) copper(I) perchlorate *[54816-44-5]* **M 579.6.** Crystd from acetone.

1,1'-Bis-(diphenylphosphino)ferrocene *[12150-46-8]* **M 554.4, m 181-183°, 184-194°.** Wash with distilled H_2O and dry in a vacuum. Dissolve in *ca* 5 parts of hot dioxane and cool to give orange crystals **m** 181-183°. Recrystn from C_6H_6-heptane (1:2) gives product with **m** 183-184°. [*J Organometal Chem* **27** 241 *1971*].

Bis-(2-ethylhexyl) 2-ethylhexyl phosphonate *[25103-23-5]* **M 434.6, n^{25} 1.4473.** Purified by stirring an 0.4M soln in benzene with an equal volume of 6M HCl at *ca* 60° for 8h. The benzene layer was then shaken successively with equal volumes of water (twice), aqueous 5% Na_2CO_3 (three times), and water (eight times), followed by evaporation of the benzene and dissolved water under reduced pressure at room temperature (using a rotating evacuated flask). Stored in dry, dark conditions [Peppard et al. *J Inorg Nuclear Chem* **24** 1387 *1962*]. Vacuum distilled, then percolated through an alumina column before finally passed through a packed column maintained at 150° where residual traces of volatile materials were removed by a counter-current stream of N_2 at reduced pressure [Dobry and Keller *JPC* **61** 1448 *1957*].

Bis-(2-ethylhexyl) phosphoric acid *[298-07-7]* **M 322.4, b 209°/10mm, d 0.965.** See preceding entry and Peppard, Ferraro and Mason [*J Inorg Nuclear Chem* **7** 231 *1958*] or Stewart and Crandall [*JACS* **73** 1377 *1951*].

Bis(ethyl)titanium(IV) chloride *[2247-00-9]* **M 177.0,**
Bis(ethyl)zirconium(IV) chloride *[92212-70-9]* **M 220.3.** Crystd from boiling toluene.

2,4-Bis-(methylthio)-1,3,2λ^5,4λ^5-dithiadiphosphetane-2,4-dithione (Davy's reagent) *[82737-61-9]* **M 284.4, m 160°.** Recrystd from C_6H_6 in yellow plates or from hot trichlorobenzene. The low m observed in the literature (112° with gradual softening at 68-102°) has been attributed to the presence of elemental sulphur in the crystals. [*TET* **40** 2663 *1984*; *JOC* **22** 789 *1957*].

Bismuth *[7440-69-9]* **M 209.0, m 271-273°.** Melted in an atmosphere of dry helium and filtered through dry Pyrex wool to remove any bismuth oxide present [Mayer, Yosim and Topol *JPC* **64** 238 *1960*].

Bismuthiol I, potassium salt *[4628-94-8]* **M 226.4, m 275-276°(dec).** Usually contaminated with disulphide. Purified by crystn from EtOH.

Bismuth trichloride *[7787-60-2]* **M 315.3, m 233.6°.** Sublimed under high vacuum, or dried under a current of HCl gas, followed by fractional distn, once under HCl and once under argon.

Bismuth triphenyl (triphenyl bismuth) *[603-33-8]* **M 440.3, m 75-76°, 77-78°, 78.5°, $d_4^{98.5}$ 1.6427(melt).** Dissolve in EtOH, ppte with H_2O, extract with Et_2O, dry and evaporate when the residue crystallises. It has been recrystd from EtOH and Et_2O-EtOH and is a stable compound. [*JCS* supplement p121 *1949*; *B 37* 4620 *1904*; *JACS* **62** 665 *1940*; UV: *JCP* **22** 1430 *1954*].

Bis-(tetrabutylammonium) dichromate *[56660-19-6]* **M 700.9, m 139-142°.** Wash with water and dry in a vacuum. Crystallises from hexane (**m** 79-80°). [*SC* **10** 75 *1980*].

Bis-[4-(1,1,3,3-tetramethylbutyl)phenyl]phosphate calcium salt (Selectophore) *[40835-97-0]* **M 987.3.** The Ca diester salt is washed with H_2O (x3) and MeOH (x3) alternately and dried in a vacuum oven at 50°. If the Ca salt is contaminated with much Ca salt of the monoester then it (10g) is converted to the free acid by adding 6N HCl (*ca* 10vols) and Et_2O (> 50vols) to it and stirred vigorously to form the free acids. When no white ppte remained (*ca* 5min), the Et_2O is separated, washed with H_2O (2 x > 50 ml) and dried by filtering through a bed of anhydrous Na_2SO_4 (11 x 5 cm) which is then washed with Et_2O (2 x >50 ml). Evapn gives an oil (TLC R_F 0.81 for diester and 0.50 for monoester). The oil is dissolved in benzene (*ca* 25ml) and extracted with ethane-1,2-diol (25ml, 10x). After ten washings, a small sample of the benzene layer is washed twice with H_2O to remove the diol and showed that it is pure bis-[4-(1,1,3,3-tetramethylbutyl)-phenyl)phosphoric acid by TLC, i.e. no monophosphate. To form the Ca salt the oil is dissolved in MeOH and to it is added the equivalent amount of $CaCl_2$ together with aq NaOH to keep the pH >10. The resulting white ppte is collected washed alternately with 3 batches of H_2O and MeOH and dried in a vacuum oven at 50°. [*JINC* **40** 1483 *1978*].

2,4-Bis-(*p*-tolylthio)-1,3,2λ^5,4.λ^5-dithiadiphosphetane-2,4-dithione (Heimgartner's reagent) *[114234-09-2]* **M 436.6, m 175-176°.** Recrystallise from toluene(light yellow solid), wash with Et_2O and dry in a vacuum. [*HCA* **70** 1001 *1987*].

Bis-(trimethylsilyl)acetylene *[14630-40-1]* **M 170.4, m 26°, b 134-136°/atm.** Dissolve in pet ether, wash with ice-cold dilute HCl. The pet ether extract is dried ($MgSO_4$), evaporated and fractionated at atmospheric pressure. [*JOMC* **37** 45 *1972*].

Bis-trimethylsilyl sulphide see **hexamethyldisilthiane.**

Bis-(triphenylphosphine)nickel(II) chloride *[14264-16-5]* **M 654.2.** Wash with glacial AcOH and dry in a vacuum over H_2SO_4 and KOH until AcOH is completely removed. [*JCS* 719 *1958*].

Borax, see **sodium borate.**

Boric acid *[10043-35-3]* **M 61.8.** Crystd three times from H_2O (3ml/g) between 100° and 0°, after filtering through sintered glass. Dried to constant weight over metaboric acid in a desiccator. (pKa^{25} 9.23 in H_2O).

9-Borabicyclo[3.3.1]nonane (9BBN) ***[monomer** 280-64-8] [dimer 70658-61-6] [1:1 in tetrahydrofuran 76422-63-4]* **M 122.0 (monomer), 244.0(dimer), m 141-143°, 150-152°, 154-155°; b 195°/12mm.** Available as the solid dimer or in tetrahydrofuran soln. The solid is relatively stable and can be purified by distn in a vacuum (as dimer) and by recrystn from tetrahydrofuran (solubility at room temp is 9.5%, 0.78M), filter solid under N_2 wash with dry pentane and dry *in vacuo* at *ca* 100°. The solid is a dimer (IR 1567cm^{-1}), stable in air (for *ca* 2 months), and can be heated for 24h at 200° in an inert atmosphere without loss of hydride activity. It is a dimer in tetrahydrofuran soln also (IR 1567cm^{-1}). It is sensitive to H_2O and air (O_2) in soln. Concentration in soln can be determined by reaction with MeOH and measuring the vol of H_2 liberated, or it can be oxidised to *cis*-cyclooctane-1,5-diol (**m** 73.5-74.5°). [IR: *JACS* **90** 5280 *1968*, **96** 7765 *1974*; *JOC* **41** 1778 *1976*, **46** 3978 *1981*].

Borane pyridine complex *[110-51-0]* **M 92.9, m 8-10°, 10-11°, b 86°/7mm, 100-101°/12mm, d_4^{20} 0.785.** Dissolve in Et_2O and wash with H_2O in which it is insol. Evap Et_2O and distil (gives better than 99.8% purity). Its vap pressure is less than 0.1mm at room temp. [*JACS* **77** 1506 *1955*].

Borane triethylamine complex *[1722-26-5]* **M 115.0, b 76°/4mm, 97.0°/12mm, d_4^{20} 0.78.** Distil in a vacuum using a 60cm glass helices packed column. [*JACS* **64** 325 *1942*, **84** 3407 *1962*; *TET LETT* 4703 *1968*].

Borane trimethylamine complex *[75-22-9]* **M 73.0, m 94-94.5°, b 171°/atm.** Sublimed using equipment described in *JACS* **59** 780 *1937*. Its vapour pressure is 86mm at 100°. Colourless hexagonal crystals varying from needles to short lumps, slightly soluble in H_2O (1.48% at 30°), EtOH (1%), hexane (0.74%) but very soluble in Et_2O, C_6H_6 and AcOH. Stable at 125°. [*JACS* **59** 780 *1939*, **104** 325 *1942*].

Borane triphenyl see **triphenyl borane.**

Boron trichloride *[10294-34-5]* **M 117.2, b 0°/476mm.** Purified (from chlorine) by passage through two mercury-filled bubblers, then fractionally distd under vacuum. In a more extensive purification the nitrobenzene addition compound is formed by passage of the gas over nitrobenzene in a vacuum system at 10°. Volatile impurities are removed from the crystalline yellow solid by pumping at -20°, and the BCl_3 is recovered by warming the addition compound at 50°. Passage through a trap at -78° removes entrained nitrobenzene; the BCl_3 finally condensing in a trap at -112° [Brown and Holmes *JACS* **78** 2173 *1956*]. Also purified by condensing into a trap cooled in acetone/Dry-ice, where it was pumped for 15min to remove volatile impurities. It was then warmed, recondensed and again pumped.

Boron trifluoride *[7637-07-2]* **M 67.8, b 111.8°/300mm.** The usual impurities - bromine, BF_5, HF and non-volatile fluorides - are readily separated by distn. Brown and Johannesen [*JACS* **72** 2934 *1950*] passed BF_3 into benzonitrile at 0° until the latter was satd. Evacuation to 10^{-5}mm then removed all traces of SiF_4 and other gaseous impurities. [A small amount of the BF_3-benzonitrile addition compound sublimed and was collected in a U-tube cooled to -80°]. Pressure was raised to 20mm by admitting dry air, and the flask containing the BF_3 addition compound was warmed with hot water. The BF_3 evolved was passed through a -80° trap (to condense any benzonitrile) into a tube cooled in liquid air. The addition compound with anisole can also be used. For drying, BF_3 can be passed through H_2SO_4 saturated with boric oxide. Fumes in moist air.

Boron trifluoride diethyl etherate *[109-63-7]* **M 141.9, b 67°/43mm, b 126°/760mm, d 1.154, n 1.340.** Treated with a small quantity of ethyl ether (to remove an excess of this component), and then distd under reduced pressure, from CaH_2. Fumes in moist air. **TOXIC.**

Bromine *[7726-95-6]* **M 159.8, b 59°, d 3.102, n 1.661.** Refluxed with solid KBr and distd, dried by shaking with an equal volume of conc H_2SO_4, then distd. The H_2SO_4 treatment can be replaced by direct distn from BaO or P_2O_5 A more extensive purification [Hildenbrand et al. *JACS* **80** 4129 *1958*] is to reflux *ca* 1L of bromine for 1h with a mixture of 16g of CrO_3 in 200ml of conc H_2SO_4 (to remove organic material). The bromine is distd into a clean, dry, glass-stoppered bottle, and chlorine is removed by dissolving *ca* 25g of freshly fused CsBr in 500ml of the bromine and standing overnight. To remove HBr and water, the bromine was then distd back and forth through a train containing alternate tubes of MgO and P_2O_5. **HIGHLY TOXIC.**

Bromine pentafluoride *[7789-30-2]* **M.174.9, m -60.5°, b 41.3°, d^{25} 2.466.** Purified *via* its KF complex, as described for chlorine trifluoride. **HIGHLY TOXIC.**

2-Bromoallyltrimethylsilane *[81790-10-5]* **M 193.2, b 64-66°/10mm, 82-85°/58-60mm, d_4^{20} 1.13.** Fractionally distd through an efficient column. *It is* **flammable.** [*JACS* **104** 3733 6879 *1982*].

2-Bromo-1,3,2-benzodioxaborole *[51901-85-0]* **M 198.8, m 47°, 51-53°, b 76°/9mm.** Keep at 20°/15mm for some time and then fractionally distil. [*JCS* 1529 *1959*].

Bromopyrogallol Red *[16574-43-9]* **M 576.2, ε 5.45 x 10^4 at 538nm (water pH 5.6-7.5).** Recrystd from aqueous alkaline soln (Na_2CO_3 or NaOH) by pptn on acidification [Suk *Coll Czech Chem Commun* **31** 3127 *1966*].

Bromosulfalein (disodium phenoltetrabromophthalein 3',3'-disulphonate) see Chapter 3.

Bromo trimethyl silane (trimethyl bromosilane) *[2857-97-8]* **M 153.1, m -43.5° to -43.2°; b 40.5°/200mm, 77.3°/735mm, 79°/744mm, 79.8-79.9°/754mm, d_4^{20} 1.1805, d_4^{20} 1.190, n_D^{20} 1.422.** Purified by repeated fractional distillation and stored in sealed ampoules in the dark. [*JACS* **75** 1583 *1953*]. Also fractionally distd through a 15 plate column (0.8 x 32cm packed with 1/16in single turn helices from Pt-Ir wire). [*JACS* **68** 1161 *1946;* **70** 433 *1948*].

***n*-Butylmercuric chloride** *[543-63-5]* **M 293.1, m 130°.** Crystd from EtOH.

***n*-Butylphenyl *n*-butylphosphonate** *[36411-99-1]* **M 270.3.** Crystd three times from hexane as its compound with uranyl nitrate. See *tri-n-butyl phosphate* below.

***p-tert*-Butylphenyl diphenyl phosphate** *[981-40-8]* **M 382.4, b 261°/6mm, n^{25} 1.5522.** Purified by vacuum distn, and percolation through an alumina column, followed by passage through a packed column maintained at 150° to remove residual traces of volatile materials in a counter-current stream of N_2 at reduced pressure [Dobry and Keller *JPC* **61** 1448 *1957*].

Butyl phosphate see **tri-*n*-butyl phosphate** below.

***n*-Butylstannoic acid [PhSn(OH)$_3$]** *[22719-01-3]* **M 208.8.** Purified by adding excess KOH in $CHCl_3$ to remove *n*-BuSn(OH)Cl_2 and *n*-BuSn(OH)$_2$Cl, and isolated by acidification [Holmes et al. *JACS* **109** 1408 *1987*].

***tert*-Butyldimethylsilyl chloride** *[18162-48-6]* **M 150.7, m 87-89°, 92.5°, b 125°/760mm.** Fractionally distd at atmospheric pressure. [*JACS* **76** 1030 *1954*; **94** 6190 *1972*].

Cacodylic acid

[75-60-5] **M 138.0, m 195-196°.** Crystd from warm EtOH (3ml/g) by cooling and filtering. Dried in vacuum desiccator over $CaCl_2$. Has also been twice recrystd from propan-2-ol. [Koller and Hawkridge *JACS* **107** 7412 *1985*].

Cadion [1-(4-nitrophenyl)-3-(4-phenylazophenyl)-triazene] *[5392-67-6]* **M 346, m 198°.** Commercial cadion is purified by recrystn from 95% EtOH and dried. It is stable in 0.2 N KOH (in 20% aqueous EtOH) at 25°. It is a sensitive reagent for Cd, and the Cd complex has λmax (EtOH) 475nm. [*Australian Chem Inst J Proc* **4** 26 *1937* ; *ACA* **19** 377 *1958*].

Cadmium *[7440-43-9]* **M 112.4.** Oxide has been removed by filtering the molten metal, under vacuum through quartz wool.

Cadmium acetate *[543-90-8]* **M 230.5.** Crystd twice from anhydrous acetic acid and dried under vacuum for 24h at 100°.

Cadmium bromide ($4H_2O$) *[7789-42-6]* **M 344.2.** Crystd from water (0.6ml/g) between 100° and 0°, and dried at 110°.

Cadmium chloride *[10108-64-2]* **M 183.3, m 568°.** Crystd from water (1ml/g) by addition of EtOH and cooling.

Cadmium fluoride *[7790-79-6]* **M 150.4, m >1000°.** Crystd by dissolving in water at room temperature (25ml/g) and heating to 60°.

Cadmium iodide *[7790-80-9]* **M 366.2, m 388°.** Crystd from ethanol (2ml/g) by partial evaporation.

Cadmium ionophore I [*N,N,N',N'*-tetramethyl-3,6-dioxooctanedi-(thioamide)] *[73487-00-0]* **M 432.7, m 35-36°.** Wash well with pet ether, then several times with 2N HCl (if it has a slight odour of pyridine) then H_2O and dry in a vacuum over H_2SO_4. It is a polar selectrophore for Cd. [*HCA* **63** 217 *1980*].

Cadmium lactate *[16039-55-7]* **M 290.6.** Crystd from water (10ml/g) by partial evapn in a desiccator.

Cadmium nitrate ($4H_2O$) *[10022-68-1]* **M 308.5.** Crystd from water (0.5ml/g) by cooling in ice-salt.

Cadmium potassium iodide *[13601-63-3]* **M 532.2.** Crystd from ethanol by partial evapn.

Cadmium salicylate *[19010-79-8]* **M 248.5,**
Cadmium sulphate *[10124-36-4]* **M 769.5.** Crystd from distd water by partial evapn in a desiccator.

Caesium compounds see **cesium compounds**.

Calcein [2',7'-bis-{*N,N*-di(carboxymethyl)aminomethyl}fluorescein] sodium salt *[1461-15-0]* **M 666.5.** Dissolve in distilled H_2O and acidify with dilute HCl to pH 3.5. Filter off the solid acid and wash well with H_2O. Redissolve *ca* 10g in 300ml H_2O containing 12g of NaOAc. Ppte again by adding HCl, filter and wash with H_2O. Add the solid to 200ml of EtOH stir for 1h and filter. Repeat the EtOH wash and dry the bright yellow solid in a vacuum. This acid decomposes on heating at *ca* 180°. See below for the prepn of the Na salt. [*AC* **28** 882 *1956*].
Dissolve in H_2O and acidify with 3N HCl to pH 3.5. Collect the solid and wash with H_2O. The air-dried ppte is extracted with 70% aqueous EtOH, filtered hot and cooled slowly. Fine yellow needles of the acid crystallise out, are filtered and dissolved in the minimum quantity of 0.01N NaOH and reppted with N HCl to pH 3.5. It is then recrystd from 70% aqueous EtOH (3x). The final product (acid) is dried at 80° in a vacuum for 24h, **m** >300°dec. It contains one mol of water per mol of acid ($C_{30}H_{36}N_4O_{13}.H_2O$). The product is pure as revealed by electrophoresis at pH 5.6 and 8.6, and by TLC in isoBuOH-isoPrOH-AcOH-H_2O (60:60:5:5 by vol) or isoPrOH or pH 8.0 borate buffer. [*AC* **31** 456 *1959*].
The Na salt is prepared by dissolving in H_2O containing 2 mols of NaOH per mol of acid reagent and lyophilizing.

Calcium *[7440-70-2]* **M 40.1, m 845°.** Cleaned by washing with ether to remove adhering paraffin, filed in an argon-filled glove box, and washed with ethanol containing 2% of conc HCl. Then washed with dry ethanol, dried in a vacuum and stored under pure argon [Addison, Coldrey and Halstead, *JCS* 3868 *1962*].

Calcium acetate *[62-54-4]* **M 158.2.** Crystd from water (3ml/g) by partial evapn in a desiccator.

Calcium benzoate ($3H_2O$) *[2090-05-3]* **M 336.4.** Crystd from water (10m/g) between 90° and 0°.

Calcium bromide (H_2O) *[62648-72-0]* **M 217.9.** Crystd from ethanol or acetone.

Calcium butyrate *[5743-36-2]* **M 248.2.** Crystd from water (5ml/g) by partial evapn in a desiccator.

Calcium carbamate *[543-88-4]* **M 160.1.** Crystd from aqueous ethanol.

Calcium chloride (anhydrous) *[10043-52-4]* **M 111.0, m 772°, b >1600°, d_4^{15} 2.15.** Available as fused granules or cubic crystals. It is very *hygroscopic*. Very soluble in H_2O (exothermic), and EtOH. Loses H_2O at 200° so it can be dried at high temperatures to dehydrate. Store in a tightly closed container.

Calcium chloride ($2H_2O$) *[22691-02-7]* **M 147.0.** Crystd from ethanol.

Calcium dithionite *[13812-88-9]* **M 168.2.** Crystd from water, or water followed by acetone and dried in air at room temperature.

Calcium D-gluconate monohydrate *[299-28-5]* **M 448.4, $[\alpha]_{546}^{20}$ +11.0°, $[\alpha]_{D}^{20}$ +9.0° (c 1.2, H_2O).** It is sol in H_2O (3.5g in 100g at 25°). Dissolve in H_2O, filter and ppte by adding MeOH. Filter off solid and dry in a vacuum at 85°. Alternatively, dissolve in H_2O, filter (from insol inorganic Ca) and evaporate to dryness under vacuum at 85°. [*J.Amer.Pharm.Assoc* **41** 366 *1952*].

Calcium D-heptagluconate dihydrate *[17140-60-2]* **M 526.4, $[\alpha]_{546}^{20}$ +5.2°, $[\alpha]_{D}^{20}$ +4.4° (c 5, H_2O).** Purified same as calcium D-gluconate.

Calcium formate *[544-17-2]* **M 130.1.** Crystd from water (5ml/g) by partial evaporation in a desiccator.

Calcium hexacyanoferrate (II) ($11H_2O$) *[13821-08-4]* **M 490.3.** Recrystd three times from conductivity H_2O and air dried to constant weight over partially dehydrated salt. [*TFS* **45** 855 *1949*]. Alternatively the Ca salt can be purified by pptn with absolute EtOH in the cold (to avoid oxidation) from an air-free saturated aqueous soln. The pure lemon yellow crystals are centrifuged, dried in a vacuum desiccator first over dry charcoal for 24h, then over partly dehydrated salt and stored in a dark glass stoppered bottle. No deterioration occurred after 18 months. No trace of Na, K or NH_4 ions could be detected in the salt from the residue after decomposition of the salt with conc H_2SO_4. Analyses indicate 11mols of H_2O per mol of salt. The solubility in H_2O is 36.45g (24.9°) and 64.7g(44.72°) per 100g of solution. [*JCS* 50 *1926*].

Calcium hydroxide *[1305-62-0]* **M 74.1.** Heat analytical grade calcium carbonate at 1000° during 1h. Allow the resulting oxide to cool and add slowly to water. Heat the suspension to boiling, cool and filter through a sintered glass funnel of medium porosity (to remove soluble alkaline impurities). Dry the solid at 110° and crush to a uniformly fine powder.

Calcium iodate *[7789-80-2]* **M 389.9.** Crystd from water (100ml/g).

Calcium iodide (H_2O) *[71626-98-7]* **M 293.9.** Dissolved in acetone, which was then diluted and evaporated. This drying process was repeated twice, then the CaI_2 was crystd from acetone-ethyl ether and stored over P_2O_5. Very *hygroscopic* when anhydrous [Cremlyn et al. *JCS* 528 *1958*].

Calcium ionophore I (ETH 1001) *[58801-34-6]* **M 685.0.** This is a neutral Ca selectophore. It can be purified by thick layer (2mm) chromatography (Kieselgel F_{245}) and eluted with Me_2CO-$CHCl_3$ (2:1). [*HCA* **56** 1780 *1973*].

Calcium ionophore II (ETH 129) *[74267-27-9]* **M 460.7, m 153-154°.** Recrystd from Me_2CO. It forms 1:2 and 1:3 metal/ligand complexes with Mg^{++} and Ca^{++} ions respectively, and induces selectivity in membranes for Ca^{++} over Mg^{++} by a factor of *ca* 10^4. [*HCA* **63** 191 *1980*].

Calcium ionophore III [A23187 calcimycin] *[52665-69-7]* **M 523.6, m 181-182°, $[\alpha]_{D}^{25}$ -56.0° (c 1, $CHCl_3$).** Recrystallises from Me_2CO as colourless needles. Protect from light and moisture, store in a refrigerator. Soluble in Me_2SO or EtOH and can be stored for 3 months without loss of activity. Mg and Ca salts are soluble in organic solvents and cross biological membranes. It has a pKa of 6.9 in 90% Me_2SO. The Ca complex cryst from 50% EtOH as colourless prisms. *Highly* **TOXIC** [*Annual Reviews of Biochemistry* **45** 501 *1976*; *JACS* **96** 1932 *1974*, *J Antibiotics* **29** 424 *1976*].

Calcium isobutyrate *[533-90-4]* **M 248.2.** Crystd from water (3ml/g) by partial evapn in a desiccator.

Calcium lactate ($5H_2O$) *[814-80-2]* **M308.3.** Crystd from warm water (10ml/g) by cooling to 0°.

Calcium nitrate ($4H_2O$) *[13477-34-4]* **M 236.1, m 45°.** Crystd four times from water (0.4ml/g) by cooling in a $CaCl_2$-ice freezing mixture. The tetrahydrate was dried over conc H_2SO_4 and stored over P_2O_5, to give the anhydrous salt.

Calcium nitrite ($2H_2O$) *[13780-06-8]* **M 150.1.** Crystd from hot water (1.4ml/g) by adding ethanol and cooling.

(+)-Calcium pantothenate (H_2O) *[63409-48-3]* **M 476.5, $[\alpha]_{546}^{20}$ +26.5° (c 5, H_2O).** Crystd from methanol.

Calcium permanganate ($4H_2O$) *[10118-76-0]* **M 350.0.** Crystd from water (3.3ml/g) by partial evapn in a desiccator.

Calcium propionate *[4075-81-4]* **M 186.2.** Crystd from water (2ml/g) by partial evapn in a desiccator.

Calcium salicylate ($2H_2O$) *[824-35-1]* **M 350.4.** Crystd from water (3ml/g) between 90° and 0°.

Calcium sulphate dihydrate *[10101-41-4]* **M 172.1, d 2.32.** Loses only part of its H_2O at 100-150°. Soluble in H_2O and very slowly soluble in glycerol. Insoluble in most organic solvents.

Calcium sulphate hemihydrate *[10034-76-1]* **M 145.2.** Sol in H_2O (0.2 parts/100 at 18.75°). Completely dehydrated >650°. Dry below 300° to give a solid with estimated pore size *ca* 38% of vol. Anhydrous $CaSO_4$ has high affinity for H_2O and will absorb 6.6% of its weight of H_2O to form the hemihydrate (gypsum). It sets to a hard mass with H_2O, hence should be kept in a tightly sealed container.

Calcium thiosulphate M 152.2. Recrystd from water below 60° in a N_2 atmosphere, followed by drying with EtOH and Et_2O. Stored in a refrigerator. [Pethybridge and Taba *JCSFT 1* **78** 1331 *1982*].

(4-Carbamylphenylarsylenedithio)diacetic acid *[531-72-6]* **M 345.1.** Crystd from MeOH or EtOH.

Carbonate ionophore I [ETH 6010] (heptyl-4-trifluoroacetylbenzoate) *[129476-47-7]* **M 316.3, b 170°/0.02 Torr, d 0.909.** Purified by flash chromatography (2g of reagent with 30g of Silica Gel 60) and eluted with EtOAc/hexane (1:19). The fractions that absorbed at 260nm were pooled, evapd and dried at room temp (10.3 Torr). The oily residue was distd in a bubbled-tube apparatus (170°/0.02 Torr). Its IR ($CHCl_3$) had peaks at 1720, 1280, 940cm^{-1} and its sol in tetrahydrofuran is 50mg/0.5ml. It is a lipophilic neutral ionophore selective for carbonate as well as being an optical humidity sensor. [*ACA* **233** 41 *1990*].

Carbon dioxide *[124-38-9]* **M 44.0, sublimes at -78.5°.** Passed over CuO wire at 800° to oxidise CO and other reducing impurities (such as H_2), then over copper dispersed on Kieselguhr at 180° to remove oxygen. Drying at -78° removed water vapour. Final purification was by vacuum distn at liquid nitrogen temperature to remove non-condensable gases [Anderson, Best and Dominey *JCS* 3498 *1962*].
Sulphur dioxide can be removed at 450° using silver wool combined with a plug of platinized quartz wool. Halogens are removed by using Mg, Zn or Cu, heated to 450°.

Carbon disulphide, see entry in Chapter 3.

Carbon monoxide *[630-08-0]* **M 28.0, b -191.5°.** Iron carbonyl is a likely impurity in CO stored under pressure in steel tanks. It can be decomposed by passage of the gas through a hot porcelain tube at 350-400°. Passage through alkaline pyrogallol soln removes oxygen (and CO_2). Removal of CO_2 and water are effected by passage through soda-lime followed by $Mg(ClO_4)_2$. Carbon monoxide can be condensed and distd at -195°. **HIGHY POISONOUS gas.**

Carbon tetrachloride, see entry in Chapter 3.

Carbonyl bromide *[593-95-3]* **M 187.8.** Purified by distn from Hg and from powdered Sb to remove free bromine, then vacuum distd to remove volatile SO_2 (the major impurity) [Carpenter et al. *JCSFT 2* 384 *1977*].

Carbonyl sulphide *[463-58-1]* **M 60.1.** Purified by scrubbing through three consecutive fritted washing flasks containing conc NaOH at 0°. Then freeze-pumped repeatedly and distd through a trap packed with glass wool and cooled to -130° (using an *n*-pentane slurry).

Celite 545 (diatomaceous earth) *[12279-49-1]*. Stood overnight in conc HCl after stirring well, then washed with distilled water until neutral and free of chloride ions. Washed with methanol and dried at 50°.

Ceric ammonium nitrate *[16774-21-3]* **M 548.2.** Ceric ammonium nitrate (125g) is warmed with 100ml of dilute HNO_3 (1:3 v/v) and 40g of NH_4NO_3 until dissolved, and filtered off on a sintered-glass funnel. The solid which separates on cooling in ice is filtered off on a sintered funnel (at the pump) and air is sucked through the solid for 1-2 h to remove most of the nitric acid. Finally, the solid is dried at 80-85°.

Cerous acetate *[537-00-8]* **M 317.3.** Crystd twice from anhydrous acetic acid, then pumped dry under vacuum at 100° for 8h.

Cesium bromide *[7787-69-1]* **M 212.8, m 636°, b *ca* 1300°, d 4.44.** Very soluble in H_2O, soluble in EtOH but insoluble in Me_2CO. Dissolve in the minimum volume of H_2O, filter and ppte by adding Me_2CO. Filter solid and dry at 100°. Also recrystd from water (0.8ml/g) by partial evaporation in a desiccator.

Cesium carbonate *[534-17-8]* **M 325.8.** Crystd from ethanol (10ml/g) by partial evaporation.

Cesium chloride *[7647-17-8]* **M 168.4, m 645°, b 1303°, d 3.99.** Soluble in H_2O but can be purified by crystn from H_2O [sol in g per cent: 162.3(0.7°), 182.2(16.2°) and 290(at bp 119.4°)] and dried in high vac. Sol in EtOH and is deliquescent, keep in a tightly closed container. [*Handbook of Preparative Inorganic Chemistry (ed Brauer)* Vol I 951 *1963*]. For further purification of CsCl, a conc aqueous soln of the practically pure reagent is treated with an equivalent weight if I_2 and Cl_2 bubbled into the soln until pptn of $CsCl_2I$ ceased. Recrystn yields a salt which is free from other alkali metals. It is then decomposed to pure CsCl on heating. [*JACS* **52** 3886 *1930*]. Also rerystd from acetone-water, or from water (0.5ml/g) by cooling in $CaCl_2$/ice. Dried at 78° under vacuum.

Cesium chromate *[13454-78-9]* **M 381.8.** Crystd from water (1.4ml/g) by partial evapn in a desiccator.

Cesium fluoride *[13400-13-0]* **M 151.9.** Crystd from aqueous soln by adding ethanol.

Cesium iodide *[7789-17-5]* **M 259.8.** Crystd from warm water (1ml/g) by cooling to -5°.

Cesium nitrate *[7789-18-6]* **M 194.9.** Crystd from water (0.6ml/g) between 100° and 0°.

Cesium oleate *[31642-12-3]* **M 414.4.** Crystd from ethyl acetate, dried in an oven at 40° and stored over P_2O_5.

Cesium perchlorate *[13454-84-7* **M 232.4.** Crystd from water (4ml/g) between 100° and 0°.

Cesium perfluoro-octanoate *[17125-60-9]* **M 546.0.** Recrystd from a butanol-petroleum ether mixture, dried in an oven at 40° and stored over P_2O_5 under vacuum.

Cesium sulphate *[10294-54-9]* **M 361.9.** Crystd from water (0.5ml/g) by adding ethanol and cooling.

Chloramine-T *[127-65-1]* **M 227.6, m 168-170°.** Crystd from hot water (2ml/g). Dried in a desiccator over $CaCl_2$ (protect from sunlight).

Chlorine *[7782-50-5]* **M 70.9.** Passed in succession through aqueous $KMnO_4$, dilute H_2SO_4, conc H_2SO_4, and a drying tower containing $Mg(ClO_4)_2$. Or, washed with water, dried over P_2O_5 and distd from bulb to bulb. **HIGHLY TOXIC.**

Chlorine trifluoride *[7790-91-2]* **M 92.5, b 12.1°.** Impurities include chloryl fluoride, chlorine dioxide and hydrogen fluoride. Passed first through two U-tubes containing NaF to remove HF, then through a series of traps in which the liquid is fractionally distd. Can be purified *via* the KF complex, $KClF_4$, formed by adding excess ClF_3 to solid KF in a stainless steel cylinder in a dry-box and shaking overnight. After pumping out the volatile materials, pure ClF_3 is obtained by heating the bomb to 100-150° and condensing the evolved gas in a -196° trap [Schack, Dubb and Quaglino *Chemistry and Industry (London)*) 545 *1967*]. **HIGHLY TOXIC.**

2-Chloro-1,3,2-benzodioxaphosphole-2-oxide see **1,2-phenylenephosphorochloridate.**

Chloro diisopropyl silane see **diisopropyl chlorosilane.**

4-Chloromercuribenzoic acid *[59-85-8]* **M 357.2, m >300°.** Its suspension in water is stirred with enough 1M NaOH to dissolve most of it: a small amount of insoluble matter is removed by centrifugation. The chloromercuribenzoic acid is then ppted by adding 1M HCl and centrifuged off. The pptn is repeated twice. Finally, the ppte is washed three times with distilled water (by centrifuging), then dried in a thin layer under vacuum over P_2O_5 [Boyer *JACS* **76** 4331 *1954*].

Chloromethylphosphonic acid dichloride *[1983-26-2]* **M 167.4, b 50°/0.5mm, 52-53(59)°/2mm, 63-65°/3mm, 78-79°/10mm, 87-88°/15mm, 102-103°/30mm, d_4^{20} 1.638, n_D^{20} 1.4971.** Fractionally distd using a short Claisen column and redistd. The *aniline salt* has **m** 199-201°. The ^{31}P NMR has a line at -38±2 ppm from 85% H_3PO_4. [Kinnear and Perren *JCS* 3437 *1952*; NMR: *JACS* **78** 5715 *1956*; *JOC* **22** 462 *1957*].

2-Chloro-2-oxo-1,3,2-dioxaphospholane *[6609-64-9]* **M 142.5, m 12-14°, b 89-91°/0.8mm, d_4^{20}1.549, n_D^{20} 1.448.** Should be distd at high vacuum as some polymerisation occurs on distn. It has IR bands at 3012, 2933, 1477, 1366, 1325, 1040, 924 and 858 cm^{-1}. In H_2O at 100° it is hydrolysed to $HOCH_2CH_2OPO_3H_2$ in 30min [IR: Cox and Westheimer *JACS* **80** 5441 *1958*].

2-Chlorophenyl diphenyl phosphate *[115-85-5]* **M 360.7, b 236°/4mm, n^{25} 1.5707.** Purified by vacuum distn, percolated through a column of alumina, then passed through a packed column maintained by a countercurrent stream of nitrogen at reduced pressure [Dobry and Keller *JPC* **61** 1448 *1957*].

Chlorosulphonic acid *[7790-94-5]* **M 116.5, b 151-152°/750mm, d_4 1.753, n 1.4929.** Distd in an all-glass apparatus, taking the fraction boiling at 156-158°. Reacts **EXPLOSIVELY** with water.

Chloro-(2,2':6',2'-terpyridine)platinum (II) chloride ($2H_2O$) *[60819-00-3]* **M 535.3.** Recrystd from hot dilute HCl and cooling to give the red dihydrate. The trihydrate crysts slowly from a cold aq soln and is air dried. The red dihydrate can be obtained from the trihydrate by desiccation over conc H_2SO_4, by washing with EtOH or by precipitating from a warm aq soln with HCl. The dihydrate is also formed by decomposing the black trihydrate form by heating in water (slowly), or more rapidly with hot 2N HCl. [*JCS* 1498 *1934*].

Chloro-tri-isopropyl titanium *[20717-86-6]* **M 260.6, m 45-50°, b 61-65°/0.1mm.** Distd under vacuum and sets slowly to a solid on standing. Stock reagents are made by dissolving the warm liquid in pentane, toluene, Et_2O, THF, CH_2Cl_2,, and can be stored in pure state or in soln under dry N_2 for several months. The reagent is *hygroscopic* and is hydrolysed by H_2O. [*B* **118** 1421 *1985*].

Chloro trimethyl silane see **trimethyl chlorosilane.**

Chloro triphenyl silane (triphenyl chlorosilane) *[76-86-8]* **M 294.9, m 90-92°, 91-93°, 94-95°, 97-99°, b 156°/1mm, 161°/0.6mm.** Likely impurities are tetraphenylsilane, small amounts of hexaphenyldisiloxane and traces of triphenylsilanol. Purified by distn at 2mm, then crystd from EtOH-free $CHCl_3$, and from pet ether (b 30-60°) or hexane by cooling in a Dry-ice/acetone bath. [*JCS* 3671 *1957*; *JACS* **72** 4471 *1958*, **77** 6395 *1955*, **79** 1843 *1957*].

Chromazurol S *[1667-99-8]* **M 605.3.** Purified by paper chromatography using *n*-butanol, acetic acid and water (7:3:1). First and second spots extracted.

Chromic chloride (anhydrous) *[10025-73-7]* **M 158.4.** Sublimed in a stream of dry HCl. Alternatively, the impure chromic chloride (100g) was added to 1L of 10% aq $K_2Cr_2O_7$ and several millilitres of conc HCl, and the mixture was brought to a gentle boil with constant stirring for 10 min. (This removed a reducing impurity.) The solid was separated, and washed by boiling with successive 1L lots of distilled water until the wash water no longer gave a test for chloride ion, then dried at 110° [Poulsen and Garner *JACS* **81** 2615 *1959*].

Chromionophore I [ETH 5294] [9-diethylamino-5-octadecanoyl-imino-5-*H*-benzo[a]phenoxazine] *[125829-24-5]* **M 583.9.** Purified by flash chromatography (Silica Gel) and eluted with EtOAc. The coloured fractions are pooled, evaporated and recrystd from EtOAc. It is a lipohilic chromionophore and is a selectophore for K and Ca ions. [*AC* **62** 738 *1990*].

Chromium (III) acetylacetonate *[21679-31-2]* **M 349.3, m 212-216°, 216°.** Purified by dissolving 6g in hot C_6H_6 (20ml) and adding 75ml of pet ether slowly. Cool to room temp then chill on ice, filter off and dry in air to give 2.9g. Sol in heptane, C_6H_6 , toluene and pentane-2,4-dione at 20-40°. It forms a 1:2 complex with $CHCl_3$. [*Inorg Synth* **5** 130 *1957*; *JACS* **80** 1839 *1958*].

Chromium ammonium sulphate ($12H_2O$) *[34275-72-4]* **M 478.4.** Crystd from a saturated aqueous soln at 55° by cooling slowly with rapid mechanical stirring. The resulting fine crystals were filtered on a Büchner funnel, partly dried on a porous plate, then equilibrated for several months in a vacuum desiccator over crude chromium ammonium sulphate (partially dehydrated by heating at 100° for several hours before use)[Johnson, Hu and Horton *JACS* **75** 3922 *1953*].

Chromium (II) Chloride (anhydrous) *[10049-05-5]* **M 122.9, m 824°, d_4^{14} 2.75.** Obtained from the dihydrate by heating *in vacuo* at 180°. It is a very *hygroscopic* white powder which dissolves in H_2O to give a sky blue solution. Stable in dry air but oxidises rapidly in moist air and should be stored in air tight containers. It sublimes at 800° in a current of HCl gas and cooled in the presence of HCl gas. Alternatively it can be washed with air-free Et_2O and dried at 110-120°. [*Inorg Synth* **3** 150 *1950*].

Chromium hexacarbonyl *[13007-92-6]* **M 220.1, d 1.77.** Wash with cold EtOH then Et_2O and allow to dry in air. Alternatively recrystallise from dry Et_2O. This is best accomplished by placing the hexacarbonyl in a Soxhlet extractor and extracting exhaustively with dry Et_2O. Pure $Cr(CO)_6$ is filtered off and dried in air. Completely colourless refracting crystals are obtained by sublimation at 40-50°/<0.5mm in an apparatus where the collecting finger is cooled by Dry Ice and in which there is a wide short bore between the hot and cold sections to prevent clogging by the crystals. Loss of product in the crystn and sublimation is slight. It is important not to overdo the drying as the solid is appreciably volatile and **TOXIC** [vapour pressure is 0.04(8°), 1.0(48°) and 66.5(100°) mm]. Also do not allow the Et_2O solns to stand too long as a brown deposit is formed which is sensitive to light, and to avoid the possibility of violent decomposition. It sinters at 90°, dec at 130°, and **EXPLODES** at 210°. [*Inorg Synth* **3** 156 *1950*; *JACS* **83** 2057 *1961*].

Chromium potassium sulphate ($12H_2O$) *[7788-99-0]* **M 499.4.** Crystd from hot water (2ml/g) by cooling.

Chromium trioxide *[1333-82-0]* **M 100.0.** Crystd from water (0.5ml/g) between 100° and -5°, or from water/conc HNO_3 (1:5). Dried in a vacuum desiccator over NaOH pellets.

Chromium (III) tris-2,4-pentanedionate *[21679-31-2]* **M 349.3, m 210°.** Crystd three times from aqueous ethanol.

Chromomycin A_3 *[7059-24-7]* **M 1183.3, m 185°dec, $[\alpha]_D^{23}$ -57° (c 1, EtOH).** Dissolve reagent (10g) in EtOAc and add to a column of Silica Gel (Merck 0.05-0.2microns, 4x70cm) in EtOAc containing 1% oxalic acid. Elute with EtOAc+1% oxalic acid and check fractions by TLC. Pool fractions, wash with H_2O

thoroughly, dry and evaporate. Recryst from EtOAc. The *hepta-acetate* has **m** 214°, $[\alpha]_D^{23}$ -20° (c 1,EtOH). [*TET* **23** 421 *1967*; *JACS* **91** 5896 *1969*].

Chromyl chloride *[14977-61-8]* **M 154.9, b 115.7°, d 1.911.** Purified by distn under reduced pressure. **TOXIC.**

Cisplatin see ***cis*-diamminedichloroplatinum(II).**

Claisen alkali (alkali Claisen). Prepared from KOH (35g) in H_2O (25ml) and diluted to 100ml with MeOH.

Cobalt (II) *meso*-5.10,15,20-tetraphenylporphine complex *[14172-90-8]* **M 671.7.** Brown crystals from Et_2O or $CHCl_3$-MeOH (*cf iron chloride complex*). Recrystd by extraction (Soxhlet) with C_6H_6. Sol in most organic solvents except MeOH and pet ether. [UV, IR: *JACS* **70** 1808 *1948*; **81** 5111 *1959*].

Cobaltous acetate ($4H_2O$) *[6147-53-1]* **M 249.1.** Crystd several times as the tetrahydrate from 50% aqueous acetic acid. Converted to the anhydrous salt by drying at 80°/1mm for 60h.

Cobaltous acetylacetonate *[14024-48-7]* **M 257.2, m 172°.** Crystd from acetone.

Cobaltous ammonium sulphate ($6H_2O$) *[13596-46-8]* **M 395.5.** Crystd from boiling water (2ml/g) by cooling. Washed with ethanol.

Cobaltous bromide ($6H_2O$) *[7789-43-7]* **M 326.9.** Crystd from water (1ml/g) by partial evaporation in a desiccator.

Cobaltous chloride ($6H_2O$) *[7791-13-7]* **M 237.9.** A saturated aqueous soln at room temperture was fractionally crystd by standing overnight. The first half of the material that crystd in this way was used in the next crystn. The process was repeated several times, water being removed in a dry-box using air filtered through glass wool and dried over $CaCl_2$ [Hutchinson *JACS* **76** 1022 *1954*]. Has also been crystd from dilute aq HCl.

Cobaltous nitrate ($6H_2O$) *[10026-22-9]* **M 291.0.** Crystd from water (1ml/g), or ethanol (1ml/g), by partial evapn.

Cobaltous perchlorate ($6H_2O$) *[13455-31-7]* **M 365.9.** Crystd from warm water (0.7ml/g) by cooling.

Cobaltous potassium sulphate [*13596-22-0*] **M 329.4.** Crystd from water (1ml/g) between 50° and 0°.

Cobaltous sulphate ($7H_2O$) *[10124-43-3]* **M 281.1.** Crystd three times from conductivity water (1.3ml/g) between 100° and 0°.

Copper (I) thiophenolate *[1192-40-1]* **M 172.7, m *ca* 280°.** The Cu salt can be extracted from a thimble (Soxhlet) with boiling MeOH. It is a green-brown powder which gives a yellow-green soln in pyridine. Wash with EtOH and dry in a vacuum. It can be ppted from a pyridine soln by addition of H_2O, collect ppte, wash with EtOH and dry in a vacuum. [*S* 662 *1974*; *JACS* **79** 170 *1957*; *B* **90** 425 *1957*].

12-Crown-4 (lithium ionophore V, 1,4,7,10-tetraoxacyclododecane) *[294-93-9]* **M 176.2, m 17°.** The distilled crude product had to be crystd from pentane at -20° to remove acyclic material. It is then dried over P_2O_5. [*Acta Chem Scand* **27** 3395 *1973*].

Cupferon (*N*-nitroso-*N*-phenylhydroxylamine) ammonium salt *[135-20-6]* **M 155.2, m 150-155°(dec), 162.5-163.5°, 163-164°.** Recrystd twice from EtOH after treatment with Norite and finally once with EtOH. The dried crystals are stored in the dark over solid ammonium carbonate. A standard soln (*ca* 0.05M prepared in air-free H_2O) is prepared daily from this material for analytical work and is essentially 100% pure. [*AC* **26** 1747 *1954*]. It can also be washed with Et_2O, dried and stored as stated. In a sealed, dark

container it can be stored for at least 12 months without deterioration. λmax 260nm ($CHCl_3$). [*Org Synth* Col Vol 1 177 *1948*; *JACS* **78** 4206 *1956*]. *Possible* **CARCINOGEN.**

Cupric acetate (H_2O) *[6046-93-1]* **M 199.7.** Crystd twice from warm dilute acetic acid solns (5ml/g) by cooling.

Cupric ammonium chloride ($2H_2O$) *[10534-87-9]* **M 277.5.** Crystd from weak aqueous HCl (1ml/g).

Cupric benzoate *[533-01-7]* **M 305.8.** Crystd from hot water.

Cupric bromide *[7789-45-9]* **M 223.4.** Crystd twice by dissolving in water (140ml/g), filtering to remove any Cu_2Br_2, and concentrating under vac at 30° until crystals appeared. The cupric bromide was then allowed to crystallise by leaving the soln in a vac desiccator containing P_2O_5 [Hope, Otter and Prue *JCS* 5226 *1960*].

Cupric chloride *[7447-39-4]* **M 134.4.** Crystd from hot dilute aqueous HCl (0.6ml/g) by cooling in a $CaCl_2$-ice bath. Dehydrated by heating on a steam-bath under vacuum.

Cupric lactate (H_2O) *[814-81-3]* **M 295.7.** Crystd as the monohydrate from boiling water (3ml/g) by cooling.

Cupric nitrate ($3H_2O$) *[19004-19-4]* **M 241.6.** Crystd from weak aqueous HNO_3 (0.5ml/g) by cooling from room temperature. The anhydrous salt can be prepared by dissolving copper metal in a 1:1 mixture of liquid NO_2 and ethyl acetate and purified by sublimation [Evans et al. *JCSFT I* **75** 1023 *1979*].

Cupric oleate *[1120-44-1]* **M 626.5.** Crystd from ethyl ether.

Cupric perchlorate ($6H_2O$) *[13770-18-8]* **M 370.5.** Crystd from distilled water.

Cupric phthalocyanine *[147-14-8]* **M 576.1.** Precipitated twice from conc H_2SO_4 by slow dilution with water. Also purified by two or three sublimations in an argon flow at 300-400Pa.

Cupric sulphate *[7758-98-7]* **M 159.6.** After adding 0.02g of KOH to a litre of nearly saturated aq soln, it was left for two weeks, then the ppte was filtered on to a fibreglass filter with pore diameter of 5-15 microns. The filtrate was heated to 90° and allowed to evaporate until some $CuSO_4.5H_2O$ had crystd. The soln was then filtered hot and cooled rapidly to give crystals which were freed from mother liquor by filtering under suction [Geballe and Giauque *JACS* **74** 3513 *1952*]. Alternatively crystd from water (0.6ml/g) between 100° and 0°.

Cupric trifluoromethylsulphonate (copper II triflate) *[34946-82-2]* **M 361.7.** Dissolve in MeCN, add dry Et_2O until cloudy and cool at -20° in a freezer. The light blue ppte is collected and dried in a vacuum oven at 130°/20mm for 8h. It has λmax 737nm (ε 22.4$M^{-1}cm^{-1}$) in AcOH. [*JACS* **95** 330 *1973*]. It has also been dried in a vessel at 0.1Torr by heating with a Fischer burner [*JOC* **43** 3422 *1978*]. It has been dried at 110-120°/5mm for 1h before use and forms a benzene complex which should be handled in a dry box because it is air sensitive [*Chem Pharm Bull Japan* **28** 262 *1980*; *JACS* **95** 330 *1973*].

Cuprous bromide *[7787-70-4]* **M 286.9.** Purified as for cuprous iodide but using aqueous NaBr.

Cuprous bromide dimethylsulphide complex *[54678-23-8]* **M 205.6, m *ca* 135°(dec).** Purified by recrystn in the presence of Me_2S. A soln of the complex (1.02g) in M_2S (5ml) is slowly diluted with hexane (20ml) and the pure colourless prisms of the complex (0.96g) separate and are collected and dried, **m** 124-129°dec. The complex is insoluble in hexane, Et_2O, Me_2CO, $CHCl_3$ and CCl_4. It dissolves in DMF and DMSO but the soln becomes hot and green indicating dec. It dissolves in C_6H_6, Et_2O, MeOH and $CHCl_3$ if excess of Me_2S is added a colourless soln is obtained. [*JOC* **40** 1460 *1975*]. Prior to use, the complex was dissolved in Me_2S and evaporated to dryness in the weighed reaction flask [*J Organomet Chem* **228** 321 *1982*].

Cuprous chloride *[7758-89-6]* **M 99.0.** Dissolved in strong HCl, ppted by dilution with water and filtered off. Washed with ethanol and ethyl ether, then dried and stored in a vacuum desiccator [Österlöf *Acta Chem Scand* **4** 375 *1950*]. Alternatively, to an aq. soln of $CuCl_2.2H_2O$ was added, with stirring, an aqueous soln of anhydrous sodium sulphite. The colourless product was dried at 80° for 30min and stored under N_2. $CuCl_2$ can be purified by zone-refining [Hall et al. *JCSFT I* **79** 243 *1983*].

Cuprous cyanide *[544-92-3]* **M 89.6.** Wash thoroughly with boiling H_2O, then with EtOH. Dry at 100° to a fine soft powder. [*JCS* 79 *1943*].

Cuprous iodide *[7681-65-4]* **M 190.5, m 605°, b 1336°, d_4^{25} 5.63.** It can be freshly prepared by dissolving an appropriate quantity of CuI in boiling saturated aqueous NaI over 30min. Pure CuI is obtained by cooling and diluting the soln with water, followed by filtering and washing sequentially with H_2O, EtOH, EtOAc and Et_2O, pentane, then drying *in vacuo* for 24h [Dieter, *JACS* **107** 4679 *1985*]. Alternatively wash with H_2O then EtOH and finally with Et_2O containing a little iodine. Traces of H_2O are best removed first by heating at 110° and then at 400°. Exess of I_2 is removed completely at 400°. It dissolves in Et_2O if an amine is present to form the amine complex. [*Chemistry and Industry (London)* 1180 *1957*].

Cuprous iodide trimethylphosphite *[34836-53-8]* **M 314.5, m 175-177°, 192-193°.** Cuprous iodide dissolves in a C_6H_6 soln containing trimethylphosphite to form the complex. The complex crystallises from C_6H_6 or pet ether. [*B* **38** 1171 *1905*; *Bull Chem Soc Japan* **34** 1177 *1961*].

Cuprous thiocyanate *[18223-42-2]* **M 121.6.** Purified as for cuprous iodide but using aq NaSCN.

Cyanamide *[420-04-2]* **M 42.0, m 43°, 45°, 46°, b 85-87°/0.5mm.** Purified by placing *ca* 15g in a Soxhlet thimble and extracting exhaustively (2-3h) with two successive portions of Et_2O (400ml, saturated with H_2O by shaking before use) containing two drops of N-acetic acid. Two successive portions of Et_2O are used so that the NH_2CN is not heated for too long. Each extract is dried over Na_2SO_4(30g), then combined and evaporated under reduced pressure. The NH_2CN may be kept unchanged at 0° in Et_2O soln in the presence of a trace of AcOH. Extracts from several runs may be combined and evaporated together. The residue from evaporation of an Et_2O soln is a colourless viscous oil which sets to a solid, and can be recrystd from a mixture of 2 parts of C_6H_6 and 1 part of Et_2O. Concentrating an aqueous soln of NH_2CN at high temps causes **EXPLOSIVE** polymerisation. It has a pKa^{29} of 1.1 in H_2O. [*Org Synth* Col Vol IV 645 *1963*; *Inorg Synth* **3** 39 *1950*; *JOC* **23** 613 *1958*].

Cyanogen bromide *[506-68-3]* **M 105.9, m 49-51°, b 60-62°/atm.** *All operations with this substance should be performed in a very efficient fume cupboard - it is very* **POISONOUS** *and should be handled in small amounts. Fresh commercial material is satisfactory for nearly all purposes and does not need to be purified. It is a white crystalline solid with a strong cyanide odour. If it is reddish in colour and partly liquid or paste-like then it is too far gone to be purified, and fresh material should be sought.* It can be purified by distn using small amounts at a time, and using a short wide-bore condenser because it readily solidifies to a crystalline white solid and may clog the condenser. *An appropriate gas mask should be used when transferring the molten solid from one container to another and the operation should be done in an efficient fume cupboard.* The melting point (**m** 49-51°) should be measured in a sealed tube. [*Org Synth* Col Vol II, 150 *1948*].

Cyanogen iodide *[506-78-5]* **M 152.9, m 146-147°.** *This compound is* **POISONOUS** *and the precautions for cyanogen bromide (above) apply here.* The reagent (*ca* 5.9g) is dissolved in boiling $CHCl_3$ (15ml), filtered through a plug of glass wool into a 25ml Erlenmeyer flask. Cool to room temperature for 15min, then place in an ice-salt bath and cool to -10° . This cooling causes a small aqueous layer to separate as ice. The ice is filtered with the CNI, but melts on the filter and is also removed with the $CHCl_3$ used as washing liquid. The CNI which is collected on a sintered glass funnel is washed 3x with $CHCl_3$ (1.5ml at 0°) and freed from last traces of solvent by being placed on a watch glass and exposed to the atmosphere in a good fume cupboard at room temp for 1h to give colourless needles (*ca* 4.5g), **m** 146-147° (sealed capillary totally immersed in the oil bath). The yield depends slightly on the rapidity of the operation, in this way loss by sublimation can be minimised. If desired, it can be sublimed under reduced pressure at temps at which CNI is

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only slowly decomposed into I_2 and $(CN)_2$. The vacuum will need to be renewed constantly due to the volatility of CNI. [*Org Synth* **32** 29 *1952*].

Decaborane *[17702-41-9]* **M 122.2, m 99.7-100°.** Purified by vacuum sublimation at 80°/0.1mm, followed by crystn from methylcyclohexane, methylene chloride, or dry olefin-free-*n*-pentane, the solvent being subsequently removed by storing the crystals in a vacuum desiccator containing $CaCl_2$.

Deuterium *[7782-39-0]* **M 4.** Passed over activated charcoal at -195° [MacIver and Tobin *JPC* **64** 451 *1960*]. Purified by diffusion through nickel [Pratt and Rogers, *JCSFT I* **92** 1589 *1976*].

Deuterium oxide *[7789-20-0]* **M 20, fp 3.8°/760mm, b 101.4°/760mm, d 1.105.** Distd from alkaline $KMnO_4$ [de Giovanni and Zamenhof *BJ* **92** 79 *1963*]. **NOTE that D_2O invariably contains tritiated water and will therefore be RADIOACTIVE; always check the radioactivity of D_2O in a scintillation counter before using.**

***cis*-Diamminedichloroplatinum(II)** *[15663-27-1]* **M 300.1.** Recrystd from dimethylformamide and the purity checked by IR and UV-VIS spectroscopy. [Raudaschl et al. *Inorg Chim Acta* **78** 143 *1983*].

Diammonium hydrogen orthophosphate *[7783-28-0]* **M 132.1.** Crystd from water (1ml/g) between 70° and 0°.

Di-*n*-amyl *n*-amylphosphonate *[6418-56-0]* **M 292.4.** Purified by three crystns of its compound with uranyl nitrate from hexane. For method see *tributyl phosphate*.

6,6-Dibenzyl-14-crown-4, (lithium ionophore VI; 6,6-dibenzyl-1,4,8,11-tetra-oxa-cyclotetradecane) *[106868-21-7]* **M 384.5, m 102-103°.** Dissolve in $CHCl_3$, wash with saturated aqueous NaCl, dry with $MgSO_4$, evaporate and purify by chromatography on silica gel and gradient elution with C_6H_6-MeOH followed by preparative reverse phase HPLC on an octadecyl silanised silica (ODS) column and eluting with MeOH. It can be crystd from MeOH (ν_{KBr} 1120 cm^{-1}, C-O-C). [*JCS Perk I* 1945 *1986*].

Di-*n*-butyl boron triflate (di-*n*-butylboryl trifluorosulphonate) *[60669-69-4]* **M 274.1, b 37°/0.12mm, 60°/2mm.** Distil in vacuum under argon and store under argon. Should be used within 2 weeks of purchase or after redistn. Use a short path distn system. It has IR bands in CCl_4 at ν 1405, 1380, 1320, 1200 and 1550cm^{-1}; and ^{13}C NMR($CDCl_3$) with δ at 118.1, 25.1, 21.5 and 13.6ppm. [*Org Synth* **68** 83 *1990*; *JACS* **103**, 3099 *1981*].

Di-*n*-butyl cyclohexylphosphonate *[1085-92-3]* **M 245.4.** The compound with uranyl nitrate was crystd three times from hexane. For method see *tributyl phosphate*.

Di-*ter*-butyl dichlorosilane ($DTBCl_2$) *[18395-90-0]* **M 213.2, m -15°, b 190°/729mm, 195-197°/atm, d 1.01.** Purified by fractional distn. It is a colourless liquid with a pleasant odour and does not fume in moist air, but does not titrate quantitatively with excess of dil alkali. [*JACS* **70** 2877 *1948*].

Di-*n*-butyl *n*-butylphosphonate *[78-46-6]* **M 250.3, b 150-151°/10mm, 160-162°/20mm, n^{25} 1.4302.** Purified by three recrystallisations of its compound with uranyl nitrate, from hexane. For method, see *tributyl phosphate*.

Di-*ter*-butyl silyl bis(trifluoromethanesulphonate) *[85272-31-7]* **M 440.5, b 73.5-74.5°/0.35mm, d 1.36.** Purified by fractional distillation. It is a pale yellow liquid which should be stored under argon. It is less reactive than the diisopropyl analogue. The presence of the intermediate monochloro compound can be detected by ^1H NMR, ($CHCl_3$): t-$Bu_2Si(OTf)_2$ [δ 1.25s]; t-$Bu_2Si(H)OTf$ [δ 1.12s] and t-$Bu_2HSi(Cl)OTf$ [δ 1.19s]. [*TET LETT* **23** 487 *1982*].

Dichlorodimethylsilane *[75-78-5]* **M 129.1, m -76°, b 70°, d 1.064, n 1.404.** Purified by fractional distillation. *Irritant and* **TOXIC**.

Dichloro methyl phenylsilane see **methylphenyl dichlorosilane.**

Dichloro methylsilane see **methyl dichlorosilane.**

Dichloro methyl vinyl silane see **methylvinyldichlorosilane.**

Dicobalt octacarbonyl *[15226-74-1]* **M 341.9, m 51°.** Orange-brown crystals by recrystn from *n*-hexane under a carbon monoxide atmosphere [Ojima et al. *JACS* **109** 7714 *1987*; see also Hileman in *Preparative Inorganic Reactions*, Jolly ed, **vol 1** 101 1987].

Diethyl aluminium chloride *[96-10-6]* **M 120.6, m -75.5°, b 106.5-108°/24.5mm, d 0.96.** Distd from excess dry NaCl (to remove ethyl aluminium dichloride) in a 50-cm column containing a heated nichrome spiral.

***O,O*-Diethyl-*S*-2-diethylaminoethyl phosphorothiolate** *[78-53-5]* **M 269.3, m 98-99°.** Crystd from isopropanol/ethyl ether.

Di-(2-ethylhexyl)phosphoric acid ('diisooctyl' phosphate) *[27215-10-7] [298-07-7]* **M 322.4.** Contaminants of commercial samples include the monoester, polyphosphates, pyrophosphate, 2-ethylhexanol and metal impurities. Dissolved in *n*-hexane to give an 0.8M soln. Washed with an equal volume of M HNO_3, then with saturated $(NH_4)_2CO_3$ soln, with 3M HNO_3, and twice with water [Petrow and Allen *AC* **33** 1303 *1961*]. Similarly, the impure sodium salt, after scrubbing with pet ether, has been acidified with HCl and the free organic acid has been extracted into pet ether and purified as above. For purification *via* the copper salt see McDowell et al. [*JINC* **38** 2127 *1976*].

Diethyl methylsilane *[760-32-7]* **M 102.3, b 78.4°/760mm, 77.2-77.6°/atm, d 0.71.** Fractionally distilled through a *ca* 20 plate column and the fraction boiling within a range of less than 0.5° is collected. [*Izv Akad SSSR Otd Chim* 1416 *1957*; *JACS* **69** 2600 *1947*].

Diethyl trimethylsilyl phosphite *[13716-45-5]* **M 210.3, b 61°/10mm, 66°/15mm, d 0.9476, n 1.4113.** Fractionated under reduced pressure and has δ_P -128 ±0.5 ppm relative to H_3PO_4. [*JOC* **46** 2097 *1981*; *J Gen Chem USSR (Eng edn)* **45** 231 *1975*].

***N,N*-Diethyltrimethyl silylamine** *[996-50-9]* **M 145.3, b 33°/26mm, 126.8-127.1°/738mm, 126.1-126.4°, d 0.763, n 1.411.** Fractionated through a 2ft vac-jacketed column containing Helipak packing with a reflux ratio of 10:1. [*JACS* **68** 241 *1946*; *JOC* **23** 50 *1958*; *J prakt Chem* **9** 315 *1959*].

***N,N'*-Diheptyl-*N,N'*-5,5-tetramethyl-3,7-dioxanonanediamide, [lithium ionophore I (ETH 149)** *[58821-96-8]* **M 442.7.** Purified by chromatography on Kieselgel using $CHCl_3$ as eluent (IR ν 1640cm^{-1}). [*HCA* **60** 2326 *1977*].

Dihexadecyl phosphate *[2197-63-9]* **M 546.9, m 75°.** Crystd from MeOH [Lukac *JACS* **106** 4387 *1984*].

1,2-Dihydroxybenzene-3,5-disulphonic acid, disodium salt (TIRON) *[149-45-1]* **M 332.2, ε 6.9 x 10^4 at 260nm, pH 10.8.** Recrystd from water [Hamaguchi et al. *Anal Chim Acta* **9** 563 *1962*].

Diiron nonacarbonyl see **Iron ennecarbonyl.**

Diisooctyl phenylphosphonate *[49637-59-4]* **M 378.5, n^{25} 1.4780.** Vacuum distilled, percolated through a column of alumina, then passed through a packed column maintained at 150° to remove residual

traces of volatile materials in a countercurrent stream of N_2 at reduced pressure [Dobry and Keller *JPC* **61** 1448 *1957*].

'Diisooctyl' phosphate see **di-(2-ethylhexyl)phosphoric acid.**

Diisopropyl chlorosilane (chlorodiisopropylsilane) *[2227-29-4]* **M 150.7, b 59°/8mm, 80°/10mm, 200°/738mm, d 0.9008, n, 1.4518.** Impurities can be readily detected by ^1H NMR. Purified by fractional distn [*JACS* **69** 1499 *1947*; *JCS* 3668 *1957*; *J Organometal Chem* **282** 175 *1985*].

Dilongifolyl borane *[77882-24-7]* **M 422.6, m 169-172°.** Wash with dry Et_2O and dry in a vacuum under N_2. It has **m** 160-161° in a sealed evacuated capillary. It is sparingly soluble in pentane, THF, CCl_4, CH_2Cl_2, and $CHCl_3$, but the suspended material is capable of causing asymmetric hydroboration. Disappearance of solid indicates that the reaction has proceeded. [*JOC* **46** 2988 *1981*].

Dimethyl carbonate *[616-38-6]* **M 90.1, b 89.5°/755mm, 90.2°/atm, d 1.0446, n 1.3687.** If the reagent has broad intense bands at 3300cm^{-1} and above (i.e. OH streching) then it should be purified further. Wash successively with 10% Na_2CO_3 soln, saturated $CaCl_2$, H_2O and dried by shaking mechanically for 1h with anhydrous $CaCl_2$, and fractionated. [*JCS* 78 *1939*, 1847 *1948*].

Dimethyl dicarbonate (dimethyl pyrocarbonate) *[4525-33-1]* **M 134.1, m 15.2°, b 45-46°/5mm, d 1.2585, n 1.3950.** Dissolve in Et_2O, shake with a small vol of 0.1N HCl, dry Et_2O with Na_2SO_4 and distil in vac below 100° to give a clear liquid. It dec to CO_2 and dimethyl carbonate on heating at 123-149°. It is readily hydrolysed by H_2O. [*J Gen Chem USSR* **22** 1546 *1952*; see also *B* **71** 1797 *1938*].

Dimethyl dichlorosilane *[75-78-5]* **M 129.1, m -75.5°, b 68.5-68.7°/750mm, 70.5°/760mm, d 1.0885, n 1.4108.** Other impurities are chlorinated silanes and methylsilanes. Fractionated through a 3/8in diameter 7ft Stedman column rated at 100 theoretical plates at almost total reflux. See purification of $MeSiCl_2$. [*JACS* **70** 3590 *1948*].

2,6-Dimethyl-1,10-phenanthrolinedisulphonic acid, disodium salt (H_2O) *[52698-84-7]* **M 564.5.** Inorganic salts and some coloured species can be removed by dissolving the crude material in the minimum volume of water and precipitating by adding EtOH. Purified reagent can be obtained by careful evapn of the filtrate.

Dinitrogen tetroxide, N_2O_4 *[10544-72-6]* **M 92.0 m -11.2°, b 21.1°.** Purified by oxidation at 0° in a stream of oxygen until the blue colour changed to red-brown. Distd from P_2O_5, then solidified on cooling in a deep-freeze (giving nearly colourless crystals). Oxygen can be removed by alternate freezing and melting.

***N,N*-Dioctadecyl methylamine** see **hydrogen ionophore III**

Dioctyl phenylphosphonate *[1754-47-8]* **M 378.8, d 1.485, n^{25} 1.4780.** Purified as described under diisooctyl phenylphosphonate.

Diphenyl hydrogen phosphate *[838-85-7]* **M 250.2, m 99.5°.** Crystd from $CHCl_3$/pet ether.

Diphenylmercury *[587-85-9]* **M 354.8, m 125.5-126°.** Sublimed, then crystd from nitromethane or ethanol. If phenylmercuric halides are present they can be converted to phenylmercuric hydroxide which, being much more soluble, remains in the alcohol or benzene used for crystn. Thus, crude material (10g) is dissolved in warm ethanol (*ca* 150ml) and shaken with moist Ag_2O (*ca* 10g) for 30min, then heated under reflux for 30min and filtered hot. Concentration of the filtrate by evaporation gives diphenylmercury, which is recrystd from benzene [Blair, Bryce-Smith and Pengilly *JCS* 3174 *1959*]. **TOXIC.**

4,7-Diphenyl-1,10-phenanthrolinedisulphonic acid, disodium salt *[52746-49-3]* **M 536.5.** Dissolve crude sample in the minimum volume of water and add EtOH to ppte the contaminants. Carefully evaporate the filtrate to obtain pure material.

Diphenylphosphinic acid *[1707-03-5]* **M 218.2, m 194-195°.** Recrystd from 95% EtOH and dried under vacuum at room temperature. [see entries in Kosolapoff *Organophosphorus Compounds* J Wiley, NY, *1950*; Kosolapoff and Maier *Organic Phosphorus Compounds* Wiley-Interscience, NY, *1972-1976*].

Diphenylsilane *[775-12-2]* **M 184.3, b 75-76°/0.5mm, 113-114°/9mm, 124-126°/11mm, 134-135°/16mm, d 1.0027, n 1.5802, 1.5756.** Dissolve in Et_2O, mix slowly with ice-cold 10% AcOH. The Et_2O layer is then shaken with H_2O until the washings are neutral to litmus. Dry over Na_2SO_4, evaporate the Et_2O and distil the residual oil under reduced pressure using a Claisen flask with the take-off head modified into a short column. Ph_2SiH_2 boils at 257°/760mm but it cannot be distd at this temp because exposure to air leads to flashing, decomposition and formation of silica. It is a colourless, odourless oil, miscible with organic solvents but not H_2O. A possible impurity is Ph_3SiH which has **m** 43-45° and would be found in the residue. [*JOC* **18** 303 *1953* ; *JACS* **74** 648*1952*, **81** 5925 *1959*].

Diphenylsilanediol *[947-42-2]* **M 216.3, m 148°(dec).** Crystd from $CHCl_3$-methyl ethyl ketone.

Disodium anthraquinone-2,6-disulphonate *[853-693-9]* **M 412.3.** Crystd from water.

Disodium calcium ethylenediaminetetraacetate *[62-33-9]* **M 374.3.** Dissolved in a small amount of water, filtered and ppted with excess EtOH. Dried at 80°.

Disodium dihydrogen ethylenediaminetetraacetic acid ($2H_2O$) *[6381-92-6]* **M 372.2, m 248°(dec).** Analytical reagent grade material can be used as primary standard after drying at 80°. Commercial grade material can be purified by crystn from water or by preparing a 10% aqueous soln at room temperature, then adding ethanol slowly until a slight permanent ppte is formed, filtering, and adding an equal volume of ethanol. The ppte is filtered off on a sintered-glass funnel, is washed with acetone, followed by ethyl ether, and dried in air overnight to give the dihydrate. Drying at 80° for at least 24h converts it to the anhydrous form.

Disodium 1,8-dihydroxynaphthalene-3,6-disulphonate ($2H_2O$) *[2808-22-0]* **M 400.3, m >300°.** Crystd from water.

Disodium ethylenebis[dithiocarbamate] *[142-59-6]* **M 436.5.** Crystd (as hexahydrate) from aqueous ethanol.

Disodium-ß-glycerophosphate *[819-83-0]* **M 216.0, m 102-104°.** Crystd from water.

Disodium hydrogen orthophosphate (anhydrous) *[7558-79-4]* **M 142.0.** Crystd twice from warm water, by cooling. Air dried, then oven dried overnight at 130°. *Hygroscopic*: should be dried before use.

Disodium magnesium ethylenediaminetetraacetate *[14402-88-1]* **M 358.5.** Dissolved in a small amount of water, filtered and ppted with an excess of methanol. Dried at 80°.

Disodium naphthalene-1,5-disulphonate *[1655-29-4]* **M 332.3.** Recrystd from aqueous acetone [Okahata et al. *JACS* **108** 2863 *1986*].

Disodium 4-nitrophenylphosphate ($6H_2O$) *[4264-83-9]* **M 371.1** Dissolve in hot aqueous MeOH, filter and ppte by adding Me_2CO. Wash the solid with Me_2CO and repeat the purification. Aq MeOH and Et_2O can also be used as solvents. The white fibrous crystals contain less than 1% of free 4-nitrophenol [assay: *JBC* **167** 57 *1947*].

Disodium phenylphosphate ($2H_2O$) *[3279-54-7]* **M 254.1.** Dissolved in a minimum amount of methanol, filtering off an insoluble residue of inorganic phosphate, then ppted by adding an equal volume of ethyl ether. Washed with ethyl ether and dried [Tsuboi *Biochim Biophys Acta* **8** 173 *1952*].

Disodium succinate *[150-90-3]* **M 162.1.** Crystd twice from water. Freed from other metal ions by passage of an 0.1M soln through a column of Dowex ion-exchange resin A-1, sodium form.

Disodium 4-nitrophenylphosphate $6H_2O$ *[4264-83-9]* **M 371.1** Dissolve in hot aqueous MeOH, filter and ppte by adding Me_2CO. Wash the solid with Me_2CO and repeat the purification. Aqueous MeOH and Et_2O can also be used as solvents. The white fibrous crystals contain less than 1% of free 4-nitrophenol [assay: *JBC* **167** 57 *1947*].

Di-*p*-tolylmercury *[50696-65-6]* **M 382.8, m 244-246°.** Crystd from xylene.

Di-*p*-tolyl phenylphosphonate *[94548-75-1]* **M 388.3, n^{25} 1.5758.** Purified as described under diisooctyl phenylphosphonate.

1,3-Divinyl-1,1,3,3-tetramethyldisiloxane *[2627-95-4]* **M 186.4, m -99.7°; b 128-129°/atm, 139°/760mm, d 0.811, n 1.4122.** Dissolve in Et_2O, wash with H_2O, dry over $CaCl_2$ and distil. [*JACS* **77** 1685 *1955*; *Coll Czech Chem Comm* **24** 3758 *1959*].

Eosin (as disodium salt) *[548-26-5]* M 624.1.

Dissolved in water and ppted by addition of dilute HCl. The ppte was washed with water, crystd from ethanol, then dissolved in the minimum amount of dilute NaOH soln and evaporated to dryness on a water-bath. The purified disodium salt was then crystd twice from ethanol [Parker and Hatchard *TFS* **57** 1894 *1961*].

Ethylarsonic acid *[507-32-4]* **M 154.0, m 99.5°.** Crystd from ethanol.

Ethylmercuric chloride *[107-27-7]* **M 265.1, m 193-194°.** Mercuric chloride can be removed by suspending ethylmercuric chloride in hot distilled water, filtering with suction in a sintered-glass crucible and drying. Then crystd from ethanol and sublimed under reduced pressure. It can also be crystd from water.

Ethylmercuric iodide *[2440-42-8]* **M 356.6, m 186°.** Crystd once from water (50ml/g).

Ethyl trimethylsilylacetate *[4071-88-9]* **M 160.3, b 74.5°/41mm, 75.5°/42mm, (157°/730mm), d 0.8762, n 1.4149.** Purified by distilling *ca* 10g of reagent through a 15cm, Vigreux column and then redistilling through a 21cm glass helices-packed column [*JACS* **75** 994 *1953*]. Alternatively, dissolve in Et_2O, wash with H_2O, dilute Na_2CO_3, dry over Na_2CO_3, evaporate Et_2O, and distil through a column of 15 theoretical plates [*JACS* **70** 2874 *1948*].

Ethyl 3-(trimethylsilyl)propionate *[17728-88-0]* **M 174.3, b 93°/40mm, 178°-180°/atm, d 0.8763, n 1.4198.** Dissolve in Et_2O, wash with H_2O, dilute Na_2CO_3, dry over Na_2SO_4, evaporate Et_2O and fractionally distil. [*JACS* **72** 1935 *1950*].

Ethynyl tributylstannane *[994-81-8]* **M 315.1, b 76°/0.2mm, 130-135°/0.7mm, 200°/2mm, d 1.1113, n 1.4770.** Purified by dissolving the reagent (*ca* 50g) in heptane (250ml), washing with H_2O (100ml), drying ($MgSO_4$), evaporating and distilling in a vacuum. It has IR ν 3280 (≡C–H) , 2950, 2850, 2005 (C≡C), 1455, 1065 and 865cm^{-1}. [*JOC* **46** 5221 *1981*; *JACS* **109** 2138 *1987*; *J Gen Chem USSR (Engl Edn)* **37** 1469 *1967*].

Ethynyl trimethylsilane *[1066-54-2]* **M 98.2, b 53°/atm, 52.5°/atm, d 0.71, n 1.3871.** Distil through an efficient column. The IR has bands at 2041 (C≡C) and 3289 (≡C-H) cm^{-1}. [*B* **92** 30 *1959*].

Ethyl triphenylphosphonium bromide *[1530-32-1]* **M 371.3, m 203-205°.** Recrystd from H_2O and dried in high vacuum at 100°. IR has bands at 6.90, 6.99 and 10.03μ. [*A* **606** 1 *1957*; *JOC* **23** 1245 *1958*].

Europium (III) acetate ($2H_2O$) *[101953-41-7]* **M 383.1.** Recrystd several times from water [Ganapathy et al. *JACS* **108** 3159 *1986*].

Europium shift reagents see **lanthanide shift reagents** in Chapter 3.

Ferric acetonylacetonate *[14024-18-1]* **M 353.2, m 181.3-182.3°.** Recrystd twice from benzene-pet ether **m** 181.3-182.3° corr [*JCS* 1256 *1938*]. Recrystd from EtOH or Et_2O, **m** 179° [*A* **323** 13 *1902*]. Recrystd from absolute EtOH, **m** 159.5° [*B* **67** 286 *1934*].

Ferric acetylacetonate *[14024-18-1]* **M 353.2, m 179°.** Crystd from 95% EtOH and dried for 1h at 120°.

Ferric chloride (anhydrous) *[7705-08-0]* **M 162.2, m >300°(dec).** Sublimed at 200° in an atmosphere of chlorine. Stored in a weighing bottle inside a desiccator.

Ferric chloride ($6H_2O$) *[10025-77-1]* **M 270.3.** An aqueous soln, saturated at room temperature, was cooled to -20° for several hours. Pptn was slow, even with scratching and seeding, and it was generally necessary to stir overnight. The presence of free HCl retards the pptn [Linke *JPC* **60** 91 *1956*].

Ferric nitrate ($9H_2O$) *[7782-61-8]* **M 404.0.** Cryst from aqueous solutions of moderately strong HNO_3 as the violet nonahydrate. With more concentrated aqueous solns (containing some HNO_3), the hexahydrate crysts out. The anhydrous salt is slightly deliquescent and decomposes at 47°.

Ferric perchlorate ($9H_2O$) *[13537-24-1]* **M 516.3.** Crystd twice from conc $HClO_4$, the first time in the presence of a small amount of H_2O_2 to ensure that the iron is fully oxidised [Sullivan *JACS* **84** 4256 *1962*]. Extreme care should be taken with this preparation because it is potentially **DANGEROUS**.

Ferric sulphate (xH_2O) *[10028-22-5]* **M 399.9 + xH_2O.** Dissolve in the minimum volume of dilute aqueous H_2SO_4 and allow to evaporate at room temp until crystals start to form. Do not concentrate by boiling off the H_2O as basic salts will be formed. Various *hydrates* are formed the common ones are the *dodeca* and *nona hydrates* which are violet in colour. The anhydrous salt is colourless and very *hygroscopic* but dissolves in H_2O slowly unless ferrous sulphate is added.

Ferrocene *[102-54-5]* **M 186.0, m 173-174°.** Purified by crystn from pentane or cyclohexane (also C_6H_6 or MeOH can be used). Moderately soluble in Et_2O. Sublimes readily above 100°. Crystallisation from EtOH gave **m** 172.5-173°. [*Org Synth* Col Vol IV 473 *1963*; *JCS* 632 *1952*]. Also crystd from methanol and sublimed *in vacuo*. [Saltiel et al. *JACS* **109** 1209 *1987*].

Ferrocene carboxaldehyde *[12093-10-6]* **M 214.1, m 117-120°, 118-120°, 121°, 124.5°.** Red crystals from EtOH or pet ether and sublimed at 70°/1mm. *Semicarbazone* **m** 217-219°(dec) cryst from aqueous EtOH. *O-Acetyloxime* **m** 80-81° cryst from hexane [*JOC* **22** 355 *1957*]. *2,4-Dinitrophenylhydrazone* **m** 248°(dec). [*Beilstein* 16 *IV* 1798; *JACS* **79** 3416 *1957*; *JCS* 650 *1958*].

Ferrocene carboxylic acid *[1271-42-7]* **M 230.1, m 210°(dec), 225-230°(dec).** Yellow crystals from pet ether. Also crystd from aqueous ethanol. [Matsue et al. *JACS* **107** 3411 *1985*]. *Acid chloride* **m** 49° crystallises from pentane, λmax 458nm [*JOC* **24** 280 *1959*]. *Methyl ester* crystallises from aq MeOH **m** 70-71°. *Anhydride* **m** 143-145° from pet ether [*JOC* **24** 1487 *1959*]. *Amide* **m** 168-170° from $CHCl_3$-Et_2O or **m** 167-169° from C_6H_6-MeOH. [*JACS* **77** 6295 *1955*; **76** 4025 *1954*].

Ferrocene-1,1'-dicarboxylic acid *[1293-87-4]* **M 274.1, m >250°(dec), >300°.** Orange-yellow crystals from AcOH. Sublimes above 230°. *Monomethyl ester* **m** 147-149° [*Dokl Acad Nauk USSSR* **115**, 518 *1957*]. *Dimethyl ester* **m** 114-115° [*JACS* **74**, 3458 *1958*]. *Diacid chloride* **m** 92-93° from pet ether. [*Dokl Acad Nauk USSSR* **120** 1267 1958; **127** 333 *1959*].

Ferrocene-1,1,-dimethanol *[1291-48-1]* **M 246.1, m 107-108°.** Obtained from the diacid with $LiAlH_4$ reduction and recrystd from Et_2O-pet ether. [*JACS* **82** 4111 *1960*

Ferrous bromide *[20049-65-4]* **M 215.7 + xH_2O, m 684°, d^{25} 4.63.** Crystn from air-free H_2O provides the *hexahydrate* as pale green to bluish-green rhombic prisms. On heating at 49° H_2O is lost and the *tetrahydrate* is formed. Further heating at 83° more H_2O is lost and the *dihydrate* is formed as a light yellow to dark brown *hygroscopic* powder. The ferrous iron in the aqueous solns of these salts readily oxidises to ferric iron. The salts should be stored over H_2SO_4 under N_2 in tightly closed containiners. They have some solubility in EtOH. [*B* **38** 236 *1904*].

Ferrous chloride ($4H_2O$) *[13478-10-9]* **M 198.8.** A 550ml round-bottomed Pyrex flask was connected, *via* a glass tube fitted with a medium porosity sintered-glass disc, to a similar flask. To 240g of $FeCl_2.4H_2O$ in the first flask was added conductivity water (200ml), 38% HCl (10ml), and pure electrolytic iron (8-10g). A stream of purified N_2 was passed through the assembly, escaping through a mercury trap. The salt was dissolved by heating which was continued until complete reduction had occurred. By inverting the apparatus and filtering (under N_2 pressure) through the sintered glass disc, unreacted iron was removed. After cooling and crystn, the unit was again inverted and the crystals of ferrous chloride were filtered free from mother liquor by applied N_2 pressure. Partial drying by overnight evacuation at room temperature gave a mixed hydrate which, on further evacuation on a water bath at 80°, lost water of hydration and its absorbed HCl (with vigorous effervescence) to give a white powder, $FeCl_2.2H_2O$ [Gayer and Wootner *JACS* **78** 3944 *1956*].

Ferrous chloride *[7758-94-3]* **M 126.8, m 674°, b 1023°, d^{25} 3.16.** Sublimes in a stream of HCl at *ca* 700°, or in H_2 below 300°. Its vapour pressure at 700° is 12mm. Anhydrous $FeBr_2$ can be obtained by carefully dehydrating the *tetrahydrate* in a stream of HBr and N_2, and it can be sublimed under N_2. White *hygroscopic* rhombohedral crystals with a green tint. They oxidise in air to $FeCl_3 + Fe_2O_3$. Sol in H_2O, EtOH Me_2CO but insol in Et_2O. The *tetrahydrate* is pale green to pale blue in colour and loses $2H_2O$ at 105-115°. The *dihydrate* loses H_2O at 120°. The ferrous iron in the aqueous solns of these salts readily oxidises to ferric iron. [*Inorg Synth* **6** 172 *1960*; *Handbook of Preparative Inorganic Chemistry (Ed Brauer)* Vol II 1491 *1965*].

Ferrous perchlorate ($6H_2O$) *[13933-23-8]* **M 362.9.** Crystd from $HClO_4$.

Ferrous sulphate ($7H_2O$) *[7782-63-0]* **M 278.0.** Crystd from 0.4M H_2SO_4.

Flophemesyl chloride see **pentafluorophenyl dimethylchlorosilane.**

Fluorine *[7782-41-4]* **M 38.0, b -129.2°.** Passed through a bed of NaF at 100° to remove HF and SiF_4. [For description of stills used in fractional distn, see Greenberg et al. *JPC* **65** 1168 *1961*; Stein, Rudzitis and Settle *Purification of Fluorine by Distillation, Argonne National Laboratory,* ANL-6364 1961 (from Office of Technical Services, US Dept of Commerce, Washington 25)]. **HIGHLY TOXIC.**

Fluoroboric acid *[16872-11-0]* **M 87.8.** Crystd several times from conductivity water.

Gallium *[7440-55-3]* **M 69.7, m 29.8°.** Dissolved in dilute HCl and extracted into Et_2O. Pptn with H_2S removed many metals, and a second extraction with Et_2O freed Ga more completely, except for Mo, Th(III) and Fe which were largely removed by pptn with NaOH. The soln was then electrolysed in 10% NaOH with a Pt anode and cathode (2-5A at 4-5V) to deposit Ga, In, Zn and Pb, from which Ga was obtained by fractional crystn of the melt [Hoffman *J Res Nat Bur Stand* **13** 665 *1934*]. Also purified by heating to boiling in 0.5-1M HCl, then heating to 40° in water and pouring the molten Ga with water under vacuum onto a glass filter (30-50 μ pore size), to remove any unmelted metals or oxide film. The Ga was then fractionally crystd from the melt under water.

Gallium (III) Chloride *[13450-90-3]* **M 176.1, m 77.8°; b 133°/100mm, 197.7°/700mm, d 2.47.** Pure compound can be obtained by redistn in a stream of Cl_2 or Cl_2/N_2 followed by vacuum sublimation or zone refining. Colourless needles which give *gallium dichloride* [$Ga(GaCl_4)$, **m** 172.4°] on heating. Dissolves in H_2O with liberation of heat. Soluble in Et_2O. [*Handbook of Preparative Inorganic Chemistry (Ed Brauer)* Vol I 846 *1963*].

Gallium (III) nitrate ($9H_2O$) *[63462-65-7]* **M 417.9, m *ca* 65°.** Recrystd from H_2O (sol: 295g/100ml at 20°). White deliquescent colourless powder soluble in H_2O, absolute EtOH and Et_2O. Loses HNO_3 upon heating at 40°. Addition of Et_2O to a warm ethanolic soln (40-50°) of $Ga(NO_3)_3$ $9H_2O$ precipitates $Ga(OH)_2NO_3.Ga(OH)_3.2H_2O$. If the salt has partly hydrolysed, dissolve in conc HNO_3, reflux, dilute with H_2O and concentrate on a sand bath. Wash several times by adding H_2O and evaporate until there is no odour of acid. Dilute the residue to a Ga concentration of 26g/100ml. At this concentration, spongy $Ga(NO_3)_3.xH_2O$ separates from the viscous soln. After standing for several days the crystals are collected and dried in a stream of dry air first at room temp then at 40°. Dehydration is complete after 2 days. Recrystallise from H_2O and dry on a water pump at room temperature. [*Z Naturforsch* **20B** 71 *1965*; *Handbook of Preparative Inorganic Chemistry (ed Brauer)* Vol I 856*1963*].

Gallium (III) sulphate *[34781-33-4]* **M 427.6.** Recrystn from H_2O gives the 16-$18H_2O$ hydrate (sol at 20° is 170g/100ml). Alternatively dissolve in 50% H_2SO_4 and evaporate (60-70°), cool and ppte by adding $EtOH/Et_2O$. On heating at 165° it provides the *anhydrous* salt which is a white *hygroscopic* solid. [*Z Naturforsch* **20B** 71 *1965*].

Germanium *[7440-56-4]* **M 72.6.** Copper contamination on the surface and in the bulk of single crystals of Ge can be removed by immersion in molten alkali cyanide under N_2. The Ge was placed in dry cyanide powder in a graphite holder in a quartz or porcelain boat. The boat was then inserted into a heated furnace which, after a suitable time, was left to cool to room temperature. At 750°, a 1mm thickness requires about 1min, whereas 0.5cm needs about half hour. The boat was removed and the samples were taken out with plastic-coated tweezers, carefully rinsed in hot water and dried in air [Wang *JPC* **60** 45 *1956*].

Germanium (IV) oxide *[1310-53-8]* **M 104.6, m 1080°(soluble form), d^{25} 6.239; m 1116°(insoluble form) d^{25} 4.228.** The oxide is usually prepared by hydrolysing redistd $GeCl_4$ and igniting in order to remove H_2O and chloride. It can be further purified by dissolving in hot H_2O (sol: 4g/L cold) evaporating and drying the residual crystalline solid. When the *soluble* form (which is produced in H_2O at 355°) is heated for 100h it is converted to the *insoluble* form. This form is stable at temperatures up to 1033°, and fusion at 1080° for 4h causes complete devitrification and it reverts to the *soluble* form. [*JACS* **46** 2358 *1924*, **47** 1945 *1925*, **54** 2303 *1032*].

Germanium tetrachloride *[10038-98-9]* **M 214.4, m -49.5° (α), -52.0° (β), b 83.1°/760mm, 86.5°/760mm corr, d_4^{20} 1.84.** Traces of Cl_2 and HCl can be removed from the liquid by blowing dry air through it for a few hours at room temperature or shake it with Hg or Hg_2Cl_2 and then fractionally distil in a vacuum. It decomposes on heating at 950°. It has a sharp penetrating odour and fumes in moist air to give a chalky coat of GeO_2. It is slowly hydrolysed by H_2O to give GeO_2. [*JACS* **44** 306 *1922*].

Germanium tetraethoxide *[14165-55-0]* **M 252.8, m -72°; b 54.5°/5mm, 71-72°/11mm, 188-190°/722mm, d^{25} 1.1288.** Distil through a 10cm Vigreux column under reduced pressure. Alternatively distil through a Fensche glass helices column fitted with a total condensation variable take-off stillhead. Fractionate under reduced pressure using a reflux ratio of 10:1. [*JACS* **75** 718 *1953*; *JCS* 4916 *1956*].

Glass powder (100-300 mesh). Washed with 10% HNO_3, water and dried.

Gold (III) bromide (gold tribromide) *[10294-28-7]* **M 436.7, m 150°(dec).** Purified by adding pure Br_2 to the dark powder, securely stopper the container, warm a little and shake while keeping away from light for *ca* 48h. Remove the stopper and place over NaOH until free Br_2 is no longer in the apparatus (48-60h). The bright yellow needles of the tribromide are stable over NaOH in the dark. It is sol in H_2O and in EtOH where it is slowly reduced. Keep in a cooled closed container and protect from light as decomposition

causes gold to be formed. *Aurobromic acid* can be obtained by adding the calculated amount of conc HBr to $AuBr_3$ (actually Au_2Br_6) until all dissolves, whereby the acid crystallises out as $HAuBr_4.5H_2O$, deliquescent solid soluble in EtOH with **m** *ca* 27°, and store as above. [*JCS* 2410 *1931*, 217, 219 *1935*].

Gold (III) chloride (hydrate) *[16903-35-8]* **M 339.8 + xH_2O, m 229°, b 354°dec, d 3.9.** Obtained as a dark red crystalline mass by dissolving Au in aqua regia and evaporating. When sublimed at 180° the crystals are ruby red. The anhydrous salt is *hygroscopic* sol in H_2 but sparingly soluble in EtOH and Et_2O. *Aurochloric acid* is formed when $AuCl_3$ is dissolved in HCl. [*JACS* **35** 553 *1913; Handbook of Preparative Inorganic Chemistry (ed Brauer)* Vol II 1056 *1965*].

Gold (I) cyanide *[506-65-0]* **M 223.0.** The lemon yellow powder is sparingly soluble in H_2O and EtOH but soluble in aqueous NH_3. It is obtained by heating $H[Au(CN)_2]$ at 110°. Wash well with H_2O and EtOH and dry at 110°. It has an IR band at ν 2239cm^{-1} typical fo C≡N stretching vibration. [*Handbook of Preparative Inorg anic Chemistry (ed Brauer)* Vol II 1064 *1965*].

Gold (I) iodide *[13453-24-2]* **M 577.7.** It has been prepared by heating gold and iodine in a tube at 120° for 4 months. Since it decomposes to Au and I_2 in the presence of UV light and heat then the main impurity is Au. The salt is therefore purified by heating at 120° with I_2 for several weeks. The crystals should be kept dry and in a cool place in the dark. [*Z Naturforsch* **11B** 604 *1956*].

Gold (III) oxide hydrate *[1303-58-8]* **M 441.9 + xH_2O.** Most probable impurities are Cl^- ions. Dissolve in strong boiling KOH soln (*ca* 5M) and precipitate (**care**) with excess of 3N H_2SO_4. Then shake and centrifuge, resuspend in H_2O and repeat wash several times until free from SO_4 and Cl ions. This gives a *wet* oxide which is dried in air. It is best to keep it wet as it decomposes on drying (analyse wet sample). Store away from light in the presence of H_2O vapour. It evolves O_2 at 110°. It is insoluble in H_2O but soluble in HCl and conc HNO_3. [*JACS* **49** 1221 *1927*].

Graphite *[7782-42-5]*. Treated with hot 1:1 HCl. Filtered, washed, dried, powdered and heated in an evacuated quartz tube at 1000° until a high vacuum was obtained. Cooled and stored in an atmosphere of helium [Craig, Van Voorhis and Bartell *JPC* **60** 1225 *1956*].

Haematoporphyrin IX *[14459-29-1]* M 598.7. Recrystd from MeOH.

Helium *[7440-59-7]* **M 4.0.** Dried by passage through a column of Linde 5A molecular sieves and $CaSO_4$, then passed through an activated-charcoal trap cooled in liquid N_2, to adsorb N_2, argon, xenon and krypton. Passed over CuO pellets at 300° to remove hydrogen and hydrocarbons, over Ca chips at 600° to remove oxygen, and then over titanium chips at 700° to remove N_2 [Arnold and Smith *JCSFT 2* **77** 861 *1981*].

Heptyl-4-trifluoroacetylbenzoate see **carbonate ionophore I.**

Hexachlorocyclotriphosphazene *[940-71-6]* **M 354.0, m 113-114°, 113-115°.** Purified by sublimation and twice crystd from hexane [Meirovitch et al. *JPC* **88** 1522, *1984*; Alcock et al. *JACS* **106** 5561 *1984*; Winter and van de Grampel *JCSDT* 1269 *1986*].

2,2,4,4,6,6-Hexamethylcyclotrisiloxane *[1009-93-4]* **M 219.5, m -10°; 81-82°/19mm, 111-112°/85mm, 188°/756mm, d 0.9196, n 1.448.** Purified by fractional distillation at atmospheric pressure until the temperature reaches 200° The residue in the flask is mostly octamethylcyclotetrasilazane. [*JACS* **70** 3888 *1948*].

Hexamethyldisilane *[1450-14-2]* **M 164.4, m 9-12°, 113.1°/750mm, d 0.7272, n 1.4229.** Most likely impurity is trimethylchlorosilane (*cf* boiling point). Wash with H_2O, cold conc H_2SO_4, H_2O again then aqueous $NaHCO_3$, dry over $CaSO_4$ and fractionate at atmospheric pressure. [*JCS* 2811 *1958*].

Grossly impure sample (25% impurities) was purified by repeated spinning band distn. This lowered the impurity level to 500 ppm. The main impurity was identified as 1-hydroxypentamethyldisilane.

Hexamethyldisilazane *[999-97-3]* **M 161.4, b 125-125.6°/atm, 126°/760mm, d 0.7747, n 1.407.** Possible impurity is Me_3SiCl. Wash well with pet ether and fractionate through a vacuum jacketed column packed with Helipac using a reflux ratio of 10:1. [*JOC* **23** 50 *1958*].

Hexaethyldisiloxane *[924-49-0]* **M 246.5, b 114-115°/16mm, 235.5°/760mm, d 0.8443, n 1.4330.** Distil in a vacuum, but can be distilled at atmospheric pressure without decomposition. It is characterised by completely dissolving in conc H_2SO_4. [*JCS* 3077 *1950*].

Hexamethyldisiloxane *[107-46-0]* **M 162.4, b 99.4°/760mm, 100.4°/764mm, d 0.7633, n 1.3777.** Fractionally distilled through a column packed with glass helices with *ca* 15 theoretical plates. [*JACS* **76** 2672 *1954*; *J Gen Chem USSR (Engl ed)* **25** 469 *1955*].

Hexamethyldisilthiane (bis-trimethylsilyl sulphide) *[3385-94-2]* **M 178.5, b 65-67°/16mm, 162.5-163.5°/750mm corr, 164°/760mm, d 0.85, n 1.4598.** Dissolve in pet ether (b *ca* 40°), remove solvent and distilled. Redistilled under atmospheric pressure of dry N_2. It is collected as a colourless liquid which solidifies to a white solid in Dry-ice. On standing for several days it turns yellow possibly due to liberation of sulphur. Store below 4° under dry N_2. [*JCS* 3077 *1950*].

Hexamethyl ditin (hexamethyldistannane) *[661-69-8]* **M 327.6, m 23.5°, b 85-88°/45mm, 182°/756mm, d^{25} 1.57.** Wash with H_2O and extract with C_6H_6, dry by filtering through powdered Na_2SO_4, remove C_6H_6 on a rotary evaporator and fractionally dist the oily residue under vacuum (b 85-88°/45mm). *It boils at ca 182° at atmospheric press but it cannot be distilled in air because the hot vapours flash in the condenser.* [*JACS* **47** 2361 *1925*, **63** 2509 *1941*; *TFS* **53** 1612 *1957*].

Hexamethylphosphoric triamide (HMPT) *[680-31-9]* **M 179.2, f.p. 7.2°, b 68-70°/1mm, 235°/760mm, d 1.024, n 1.460.** The industrial synthesis is usually by treatment of $POCl_3$ with excess of dimethylamine in isopropyl ether. Impurities are water, dimethylamine and its hydrochloride. It is purified by refluxing over BaO or CaO at about 4mm pressure in an atmosphere of nitrogen for several hours, then distd from sodium at the same pressure. The middle fraction (**b** *ca* 90°) is collected, refluxed over sodium under reduced pressure under nitrogen and distd. It is kept in the dark under nitrogen, and stored in solid CO_2. Can also be stored over 4A molecular sieves.
Alternatively, it is distd under vacuum from CaH_2 at 60° and crystd twice in a cold room at 0°, seeding the liquid with crystals obtained by cooling in liquid nitrogen. After about two-thirds frozen, the remaining liquid is drained off [Fujinaga, Izutsu and Sakara *PAC* **44** 117 *1975*]. For tests of purity see Fujinaga et al. in *Purification of Solvents*, ed Coetzee, Pergamon Press, Oxford, 1982. For efficiency of desiccants in drying HMPT see Burfield and Smithers [*JOC* **43** 3966 *1978*; Sammes et al. *JCSFT 1* 281 *1986*]. **CARCINOGEN.**

Hexamminecobalt(III) chloride *[10534-89-1]* **M 267.5.** Crystd from warm water (8ml/g) by cooling.

Hexammineruthenium(III) chloride *[14282-91-8]* **M 309.6.** Crystd twice from 1M HCl.

Hexarhodium hexadecacarbonyl *[28407-51-4]* **M 1065.6, m 220°(dec, in air), d 2.87.** Slowly loses CO when heated in air; may be regenerated by heating at 80-200° in the presence of CO at 200atm pressure for 15h, preferably in the presence of Cu. Forms black crystals which are insoluble in hexane. It has bands at 2073, 2026 and 1800cm^{-1} in the IR. [*Z Anorg Allgem Chem* **251** 96 *1963*; *JACS* **85** 1202 *1963*; *TET LETT* **22** 1783 *1981*].

Hydrazine (anhydrous) *[302-01-2]* **M 32.1, fp 1.5-2.0°, b 113-113.5°, n 1.470, d 1.91.** Hydrazine hydrate is dried by refluxing with an equal weight of NaOH pellets for 3h, then distilled from fresh NaOH or BaO in a current of dry N_2.

Hydrazine dihydrochloride *[5341-61-7]* **M 105.0.** Crystd from aqueous EtOH and dried under vacuum over $CaSO_4$.

Hydrazine monohydrochloride *[2644-70-4]* **M 68.5, m 89°.** Prepared by dropwise addition of cold conc HCl to cold liquid hydrazine in equimolar amounts. The crystals were harvested from water and were twice recrystd from absolute MeOH and dried under vacuum. [Kovack et al. *JACS* **107** 7360 *1985*].

Hydriodic acid *[10034-85-2]* **M 127.9, b 127°, d 1.701.** Iodine can be removed from aqueous HI, probably as the amine hydrogen triiodide, by three successive extractions using a 4% soln of Amberlite LA-2 (a long-chain aliphatic amine) in CCl_4, toluene or pet ether (10ml per 100ml of acid). [Davidson and Jameson *Chemistry & Industry (London)* 1686 *1963*]. Extraction with tributyl phosphate in $CHCl_3$ or other organic solvents is also suitable. Alternatively, a De-acidite FF anion-exchange resin column in the OH^--form using 2M NaOH, then into its I^--form by passing dilute KI soln, can be used. Passage of an HI solution under CO_2 through such a column removes polyiodide. The column can be regenerated with NaOH. [Irving and Wilson *Chemistry & Industry (London)* 653 *1964*]. The earlier method was to reflux with red phosphorus and distil in a stream of N_2. The colourless product was stored in ampoules in the dark [Bradbury *JACS* **74** 2709 *1952*]. Fumes in moist air.

Hydrobromic acid *[10035-10-6]* **M 80.9.** A soln of aqueous HBr *ca* 48% (w/w, constant boiling) was distilled twice with a little red phosphorus, and the middle half of the distillate was taken. (The azeotrope at 760mm contains 47.8% (w/w) HBr.) [Hetzer, Robinson and Bates *JPC* **66** 1423 *1962*]. Free bromine can be removed by Irvine and Wilson's method for HI (see above), except that the column is regenerated by washing with an ethanolic solution of aniline or styrene. Hydrobromic acid can also be purified by aerating with H_2S distilling and collecting the fraction boiling at 125-127°.

Hydrochloric acid *[7647-01-0]* **M 36.5, d 1.20.** Readily purified by fractional distillation as constant boiling point acid, following dilution with H_2O. The constant-boiling fraction contains 1 mole of HCl in the following weights of distillate at the stated pressures: 179.555g (730mm), 179,766g (740mm), 179,979 (750mm), 180.193 (760mm), 180.407 (770mm) [Foulk and Hollingsworth *JACS* **45** 1220 *1923*].

Hydrofluoric acid *[7664-36-3]* **M 20.0, d 1.150.** Freed from lead (Pb *ca* 0.002ppm) by co-precipitation with SrF_2, by addition of 10ml of 10% $SrCl_2$ soln per kilogram of the conc acid. After the ppte has settled, the supernatant is decanted through a filter in a hard-rubber or paraffined-glass vessel [Rosenqvist *Amer J Sci* **240** 358 *1942*. Pure aqueous HF solutions (up to 25M) can be prepared by isothermal distn in polyethylene, polypropylene or platinum apparatus [Kwestroo and Visser *Analyst* **90** 297 *1965*]. **HIGHLY TOXIC.**

Hydrogen *[1333-75-0]* **M 2.0, m -259.1°, -252.9°.** Usually purified by passage through suitable absorption train. Carbon dioxide is removed with KOH pellets, soda-lime or NaOH pellets. Oxygen is removed with a "De-oxo" unit or by passage over Cu heated to 450-500°, Cu on Kieselguhr at 250°. Passage over a mixture of MnO_2 and CuO (Hopcalite) oxidises any CO to CO_2 (which is removed as above). Hydrogen can be dried by passage through dried silica-alumina at -195°, through a dry-ice trap followed by a liquid-N_2 trap packed with glass wool, through $CaCl_2$ tubes, or through $Mg(ClO_4)_2$ or P_2O_5. Other purification steps include passage through a hot palladium thimble [Masson *JACS* **74** 4731 *1952*], through an activated-charcoal trap at -195°, and through non-absorbent cotton-wool filter or small glass spheres coated with a thin layer of silicone grease. *Potentially* **EXPLOSIVE** *in air.*

Hydrogen bromide (anhydrous) *[10035-10-6]* **M 80.9.** Dried by passage through $Mg(ClO_4)_2$ towers. This procedure is **hazardous**, see Stoss and Zimmermann [*Ind Eng Chem* **17** 70 *1939*]. Shaken with mercury, distd through a -78° trap and condensed at -195°/10^{-5}mm. Fumes in moist air.

Hydrogen chloride *[7647-01-0]* **M 36.5.** Passed through conc H_2SO_4, then over activated charcoal and silica gel. Fumes in moist air. Hydrogen chloride in gas cylinder include ethylene, 1,1-dichloroethane and ethyl chloride. The latter two may be removed by fractionating the HCl through a trap cooled to -112°. Ethylene is difficult to remove. Fumes in moist air.

Hydrogen cyanide (anhydrous) *[74-90-8]* **M 27.0, b 25.7°.** Prepared from NaCN and H_2SO_4, and dried by passage through H_2SO_4 and over $CaCl_2$, then distilled in a vacuum system and degassed at 77°K before use [Arnold and Smith *JCSFT 2* **77** 861 *1981*]. Cylinder HCN may contain stabilisers against explosive polymerisation, together with small amounts of H_3PO_4, H_2SO_4, SO_2, and water. It can be purified by distn over P_2O_5, then frozen in Pyrex bottles at Dry-ice temperature for storage. It has a pKa^{25} of 9.22 in water. **HIGHLY POISONOUS.**

Hydrogen fluoride (anhydrous) *[7664-39-3]* **M 20.0, b 19.4°.** Can be purified by trap-to-trap distn, followed by drying over CoF_2 at room temperature and further distn. Alternatively, it can be absorbed on NaF to form $NaHF_2$ which is then heated under vacuum at 150° to remove volatile impurities. The HF is regenerated by heating at 300° and stored with CoF_3 in a nickel vessel, being distilled as required. (Water content *ca* 0.01%.) To avoid contact with base metal, use can be made of nickel, polychlorotrifluoroethylene and gold-lined fittings [Hyman, Kilpatrick and Katz *JACS* **79** 3668 *1957*]. **HIGHLY TOXIC.**

Hydrogen iodide (anhydrous) *[10034-85-2]* **M 127.9, b -35.5°.** After removal of free iodine from aqueous HI (q.v.), the solution is frozen, then covered with P_2O_5 and allowed to melt under vacuum. The gas evolved is dried by passage through P_2O_5 on glass wool. It can be freed from iodine contamination by repeated fractional distillation at low temperatures. Fumes in moist air.

Hydrogen ionophore II (ETH 1907) (4-nonadecylpyridine - Proton ionophore) *[70268-36-9]* **M 345.6, b 180°/0.07mm.** Dissolve the waxy solid (*ca* 60g) in $CHCl_3$ (200ml), wash with H_2O (3 X 200ml), dry and evaporate to dryness then distil in vacuum. A waxy solid is formed on cooling the distillate. UV, 257nm (ε 1.86 x 10^3 $M^{-1}cm^{-1}$), 308nm (ε 1.7 x 10^2 $M^{-1}cm^{-1}$). [IR, NMR UV: *Inorg Chem* **18** 2160 *1979*].

Hydrogen ionophore III (*N,N*-dioctadecyl methylamine) *[4088-22-6]* **M 536.0, m 40°, 44-46°, 48-49°, b 252-259°.** It can be distd at high vacuum; but dissolving in C_6H_6, filtering and evaporating gives a waxy solid suitable for electrode use. It recrystallises from Me_2CO. [*B* **69** 60 *1936*; *Talanta* **34** 435 *1987*].

Hydrogen ionophore IV ETH 1778 (octadecyl isonicotinate) *[103225-02-1]* **M 375.6, m 57.5°.** Dissolve in Et_2O and wash 3 times with H_2O. Dry, evaporate, and recrystallise the residue from EtOAc/hexane (4:1). The pKa of the short chain homologue methyl isonicotinate is 3.6. [*AC* **58** 2285 *1986*].

Hydrogen peroxide *[7722-84-1]* **M 34.0, d 1.110.** The 30% material has been steam distilled using distilled water. Gross and Taylor [*JACS* **72** 2075 *1950*] made 90% H_2O_2 approximately 0.001M in NaOH and then distilled under its own vapour pressure, keeping the temperature below 40°, the receiver being cooled with a Dry-ice/isopropyl alcohol mush. The 98% material has been rendered anhydrous by repeated fractional crystn in all-quartz vessels. **EXPLOSIVE IN CONTACT WITH ORGANIC MATERIAL.**

Hydrogen sulphide *[7783-06-4]* **M 34.1, b -59.6°.** Washed, then passed through a train of flasks containing saturatedd $Ba(OH)_2$ (two), water (two), and dilute HCl [Goates et al. *JACS* **73** 707 *1951*]. **HIGHLY POISONOUS.**

Hydroxylamine *[7803-49-8]* **M 33.0, m 33.1°, b 56.5°/22mm.** Crystd from *n*-butanol at -10°, collected by vacuum filtration and washed with cold ethyl ether.

Hydroxylamine hydrochloride *[5470-11-1]* **M 69.5, m 151°.** Crystallised from aqueous 75% ethanol or boiling methanol, and dried under vacuum over $CaSO_4$ or P_2O_5. Has also been dissolved in a minimum of water and saturated with HCl; after three such crystns it was dried under vacuum over $CaCl_2$ and NaOH.

Hydroxylamine sulphate *[10039-54-0]* **M 164.1, m 170°(dec).** Crystallised from boiling water (1.6ml/g) by cooling to 0°.

Hydroxynaphthol Blue, disodium salt, M 620.5. Crude material was treated with hot EtOH to remove soluble impurities, then dissolved in 20% aqueous MeOH and chromatographed on a cellulose powder column with propanol:EtOH:water (5:5:4) as eluent. The upper of three zones was eluted to give the pure dye which was ppted as the monosodium salt trihydrate by adding conc HCl to the concentrated eluate [Ito and Ueno *Analyst* **95** 583 *1970*].

4-Hydroxy-3-nitrobenzenearsonic acid *[121-19-7]* **M 263.0.** Crystd from water.

Hydroxyurea *[127-07-1]* **M 76.1, m 133-136°, 140°dec, 139-141°(dec).** Recrystallise from absolute EtOH (10g in 150ml). Note that the rate of solution in boiling EtOH is slow (15-30 min). It should be stored in a cool dry place but some decomposition could occur after several weeks. (*Org Synth* Col Vol V 645 *1973*]. It is very soluble in H_2O and can be crystd from Et_2O. It has a pKa of 10.6. [*Acta Chem Scand* **10** 256 *1956*].

Hypophosphorous acid (Phosphinic acid) *[6303-21-5]* **M 66.0, m 26.5°, d_4^{30} 1.217, 1.13 and 1.04 for 50, 30-32, and 10% aq solns resp.** Phosphorous acid is a common contaminant of commercial 50% hypophosphorous acid. Jenkins and Jones [*JACS* **74** 1353 *1952*] purified this material by evaporating about 600ml in a 1L flask at 40°, under reduced pressure (in N_2), to a volume of about 300ml. After the soln was cooled, it was transferred to a wide-mouthed Erlenmeyer flask which was stoppered and left in a Dry-ice/acetone bath for several hours to freeze (if necessary, with scratching of the wall). When the flask was then left at *ca* 5° for 12h, about 30-40% of it liquefied, and again filtered. This process was repeated, then the solid was stored over $Mg(ClO_4)_2$ in a vacuum desiccator in the cold. Subsequent crystns from *n*-butanol by dissolving it at room temperature and then cooling in an ice-salt bath at -20° did not appear to purify it further. The free acid forms deliquescent crystals m 26.5°, and is soluble in H_2O and EtOH. It has a pKa of 1.1, and the NaH_2PO_3 salt can be purified through an anion exchange resin [*Z Anorg Allgem Chem* **260** 267 *1949*].

Hydroxylamine-*O*-sulphonic acid *[2950-43-8]* **M 113.1, m 210-211°, 215°(dec).** Stir the solid vigorously with anhydrous Et_2O and filter off using large volumes of dry Et_2O. Drain dry at the pump for 5min and then for 12-14h in a vacuum. Store in a vacuum desiccator/conc H_2SO_4. Determine the purity by oxidation of iodide to I_2. Must be stored in a dry atmosphere at 0-4°. It decompose slowly in H_2O at 25° and more rapidly above this temperature. [*Inorg Synth* **5** 122 *1957*].

Indium

[7440-74-6] **M 114.8.** Before use, the metal surface can be cleaned with dilute HNO_3, followed by a thorough washing with water and an alcohol rinse.

Indium (III) chloride *[10025-82-8]* **M 211.2, m 586°, d 4.0.** The anhydrous salt forms yellow deliquescent crystals which can be sublimed at 600° in the presence of Cl_2/N_2 (1:1) {does not melt}. It is resublimed in the presence of Cl_2/N_2 (1:10) and finally heated to 150° to expel excess Cl_2. It is soluble in H_2O and should be stored in a tightly closed container. [*JACS* **55** 1943 *1933*].

Indium (III) oxide *[1313-43-2]* **M 277.6, d 7.18.** Wash with H_2O and dry below 850°. Volatilises at 850° and dissolves in hot mineral acids to form salts. Store away from light because it darkens due to formation of In.

Indium sulphate *[13464-82-9]* **M 517.8.** Crystd from dilute aqueous H_2SO_4.

Indium (III) sulphate ($5H_2O$) *[17069-79-3]* **M 607.9, d 3.44.** Dissolve in strong H_2SO_4 and slowly evaporate at *ca* 50°. Wash crystals with glacial AcOH and then heat in a furnace at a temperature of 450-500° for 6h. Sol in H_2O is 5%. The pentahydrate is converted to an anhydrous *hygroscopic* powder on heating at 500° for 6h; but heating above this temperature over N_2 yields the oxide sulphate. Evaporation of neutral aqueous solutions provides basic sulphates. [*JACS* **55** 1943 *1933*, **58** 2126 *1936*].

Iodic acid *[7782-68-5]* **M 175.9, m 118°(dec), d 4.628.** Dissolve in the minimum volume of hot dilute HNO_3, filter and evaporate in a vacuum desiccator until crystals are formed. Collect crystals and wash with a little cold H_2O and dry in air in the dark. Soluble in H_2O: 269g/100ml at 20° and 295g/100ml at 40°. Soluble in dilute EtOH and darkens on exposure to light. It is converted to $HIO_3.I_2O_5$ on heating at 70°, but at 220° complete conversion to HIO_3 occurs. [*JACS* **42** 1636 *1920*, **53** 44 *1931*].

Iodine *[7553-56-2]* **M 253.8, m 113.6°.** Usually purified by vacuum sublimation. Preliminary purifications include grinding with 25% by weight of KI, blending with 10% BaO and subliming; subliming with CaO; grinding to a powder and treating with successive portions of H_2O to remove dissolved salts, then drying; and crystn from benzene. Barrer and Wasilewski [*TFS* **57** 1140 *1961*] dissolved I_2 in conc KI and distilled it, then steam distilled three times, washing with distilled H_2O. Organic material was removed by sublimation in a current of O_2 over platinum at about 700°, the iodine being finally sublimed under vacuum.

Iodine monobromide *[7789-33-5]* **M 206.8, m 42°,**
Iodine monochloride *[7790-99-0]* **M 162.4, m 27.2°.** Purified by repeated fractional crystallisation from its melt.

Iodine pentafluoride *[7783-66-6]* **M 221.9, m -8.0°, b 97°.** Rogers et al. [*JACS* **76** 4843 *1954*] removed dissolved iodine from IF_5 by agitating with a mixture of dry air and ClF_3 in a fluorothene beaker using a magnetic stirrer. The mixture was transferred to a still and the more volatile impurities were pumped off as the pressure was reduced below 40mm. The still was gradually heated (kept at 40mm) to remove the ClF_3 before IF_5 distilled. Stevens [*JOC* **26** 3451 *1961*] pumped IF_5 under vacuum from its cylinder, trapping it at -78°, then allowing it to melt in a stream of dry N_2.

Iodine trichloride *[22520-96-3]* **M 233.3, m 33°, b 77°(dec).** Purified by sublimation at room temperature.

Iodomethyl trimethylsilane *[4206-67-1]* **M 214.1, b 139.5°/744mm, d 1.44, n_D^{25} 1.4917.** If slightly violet in colour wash with aqueous 1% sodium metabisulphite, H_2O, dry over Na_2SO_4 and fractionally distil at atmospheric pressure. [*JACS* **68** 481 *1946*].

Iodotrimethylsilane *[16029-98-4]* **M 200.1, b 106.8°/742mm, 107.5°/760mm, d 1.470.** Add a little antimony powder and fractionate with this powder in the still. Stabilise with 1% wt of Cu powder. [*JCS* 3077 *1950*].

Iridium *[7439-88-5]* **M 192.2, m 2450°, b ~4500°, d 22.65.** It is a silver white hard solid which oxidises superficially in air. Scrape the outer tarnished layer until silver clear and store under paraffin. Stable to acids but dissolves in aqua regia. [*Chem Reviews* **32** 277 *1943*].

Iridium (IV) chloride hydrate (hexachloroiridic acid) *[16941-92-7]* **M 515.1.** If it contains nitrogen then repeatedly concentrate a conc HCl solution until free from nitrogen, and dry free from HCl in a vacuum over CaO until crystals are formed. The solid is very *hygroscopic*. [*JACS* **53** 884 *1931*; *Handbook of Preparative Inorganic Chemistry (ed Brauer)* Vol II 1592 *1965*].

Iron (wire) *[7439-89-6]* **M 55.9, m 1535°.** Cleaned in conc HCl, rinsed in de-ionised water, then reagent grade acetone and dried under vacuum.

Iron ennecarbonyl (di-iron nonacarbonyl) *[15321-51-4]* **M 363.7, m 100°(dec).** Wash with EtOH and Et_2O and dry in air. Sublimes at 35° at high vacuum. Dark yellow plates stable for several days when kept in small amounts. Large amounts, especially when placed in a desiccator spontaneously ***ignite*** in a period of one day. It decomposes in moist air. It is insoluble in hydrocarbon solvents but forms complexes with several organic compounds. [*JACS* **72** 1107 *1950*; *B* 60 1424 *1424*].

Iron (III) ***meso*-5,10,15,20-tetraphenylporphine chloride complex** *[16456-81-8]* **M 704.0.** Crystallise by extraction from a thimble (Soxhlet) with $CHCl_3$. Concentrate the extract to *ca* 10ml and add *ca*

80ml of hot MeOH. Dark blue crystals separate on cooling. It can be recrystallised several times from $CHCl_3$-MeOH. Avoid prolonged heating. It is quite soluble in organic solvents but insoluble in pet ether. [*JACS* **70 1808** *1948*; UV: **73** 4315 *1951*].

Iron pentacarbonyl *[13463-40-6]* **M 195.9, b 102.5°, n 1.520, d 1.490.** Distilled under vacuum, the middle cut being redistd twice and stored in a bulb protected from light (*photosensitive*).

Isopentyloxy trimethylsilane *[1833-53-0]* **M 130.3, b 93-95°, d 0.786.** Can contain up to 5% of hexamethyldisiloxane (b 99-101°) but is generally non-reactive and need not be removed. It can be removed by efficient fractional distillation at atmospheric pressure.

Isopropenyloxy trimethylsilane *[1833-53-0]* **M 130.3, b 93-95°/atm, d 0.786.** Purified by fractional distillation using a very efficient column at atmospheric pressure. Usually contains 5% of hexamethyldisiloxalane which boils at 99-101°, but is generally non-reactive and need not be removed. [*JACS* **71** 5091 *1952*]. It has been distilled under N_2 through a 15cm column filled with glass helices. Fraction **b** 99-104° is further purified by gas chromatography through a Carbowax column (Autoprep A 700) at a column temperature of 87°, retention time is 9.5min. [*J Organometal Chem* **1** 476 *1963-4*].

Isopropyl dimethyl chlorosilane *[3634-56-8]* **M 140.7, b 109.8-110.0°/738mm, d 0.88, n 1.4158.** Probable impurity is Me_3SiCl (b 56.9°/783mm) which can be removed by efficient fractional distillation. [*JACS* **76** 801 *1954*].

Lanthanide shift reagents see Chapter 3.

Lanthanum *[7439-91-0]* **M 138.9, m 920°, b 3470°, d 6.16.** White metal that slowly tarnishes in air due to oxidation. Slowly decomposed by H_2O in the cold and more rapidly on heating to form the hydroxide. The metal is cleaned by scraping off the tarnished areas until the shiny metal is revealed and stored under oil or paraffin. It burns in air at 450°.

Lanthanum triacetate *[917-70-4]* **M 316.0 xH_2O.** Boil with redistilled Ac_2O for 10min (does not dissolve and is a white solid). Cool, filter, wash with Ac_2O and keep in a vacuum desiccator (NaOH) till free from solvent. [*JICS* **33** 877 *1956*].

Lead [11] acetate *[301-04-2]* **M 325.3, m 280°.** Crystallised twice from anhydrous acetic acid and dried under vacuum for 24h at 100°.

Lead (II) bromide *[10031-22-8]* **M 367.0, m 373°.** Crystallised from water containing a few drops of HBr (25ml of water per gram $PbBr_2$) between 100° and 0°. A neutral solution was evaporated at 110° and the crystals that separated were collected by rapid filtration at 70°, and dried at 105° (to give the *monohydrate*). To prepare the anhydrous bromide, the hydrate is heated for several hours at 170° and then in a Pt boat at 200° in a stream of HBr and H_2. Finally fused [Clayton et al. *JCSFT 1* **76** 2362 *1980*].

Lead (II) chloride *[7758-95-4]* **M 278.1, m 501°.** Crystallised from distilled water at 100° (33ml/g) after filtering through sintered-glass and adding a few drops of HCl, by cooling. After three crystns the solid was dried under vacuum or under anhydrous HCl vapour by heating slowly to 400°.

Lead diethyldithiocarbamate *[17549-30-3]* **M 503.7.** Wash with H_2O and dry at 60-70°, or dissolve in the min vol of $CHCl_3$ and add the same vol of EtOH. Collect the solid that separates and dry as before. Alternatively, recryst by slow evaporation of a $CHCl_3$ soln at 70-80°. Filter the crystals, wash with H_2O until all Pb^{++} ions are eluted (check by adding chromate) and then dry at 60-70° for at least 10h. [*A* **49** 1146 *1977*].

Lead (II) formate *[811-54-4]* **M 297.3.** Crystd from aqueous formic acid.

Lead (II) iodide *[10101-63-0]* **M 461.0, m 402°.** Crystd from a large volume of water.

Lead monoxide *[1317-36-8]* **M 223.2, m 886°.** Higher oxides were removed by heating under vacuum at 550° with subsequent cooling under vacuum. [Ray and Ogg *JACS* **78** 5994 *1956*].

Lead nitrate *[10099-74-8]* **M 331.2.** Ppted twice from hot (60°) conc aqueous soln by adding HNO_3. The ppte was sucked dry in a sintered-glass funnel, then transferred to a crystallising dish which was covered by a clock glass and left in an electric oven at 110° for several hours [Beck, Singh and Wynne-Jones *TFS* **55** 331 *1959*].

Lead (biscyclopentadienyl) *[1294-74-2]* **M 337.4.** Purified by vacuum sublimation. Handled and stored under N_2.

Lead tetraacetate *[546-67-8]* **M 443.4.** Dissolved in hot glacial acetic acid, any lead oxide being removed by filtration. White crystals of lead tetraacetate separated on cooling. Stored in a vacuum desiccator over P_2O_5 and KOH for 24h before use.

Lissapol C (mainly sodium salt of cetyl oleyl alcohol sulphate) *[2425-51-6]*, **Lissapol LS (mainly sodium salt of anisidine sulphate)** *[28903-20-0]*. Refluxed with 95% EtOH, then filtered to remove insoluble inorganic electrolytes. The alcohol solution was then concentrated and the residue was poured into dry acetone. The ppte was filtered off, washed in acetone and dried under vacuum. [Biswas and Mukerji *JPC* **64** 1 *1960*].

Lithium (metal) *[7439-93-2]* **M 6.9.** After washing with pet ether to remove storage oil, lithium was fused at 400° and then forced through a 10-micron stainless-steel filter with argon pressure. It was again melted in a dry-box, skimmed, and poured into an iron distillation pot. After heating under vacuum to 500°, cooling and returning to the dry-box for a further cleaning of its surface, the lithium was distilled at 600° using an all-iron distillation apparatus [Gunn and Green *JACS* **80** 4782 *1958*].

Lithium acetate ($2H_2O$) *[6108-17-4]* **M 102.0, m 54-56°.** Crystallised from EtOH (5ml/g) by partial evaporation.

Lithium aluminium hydride *[16853-85-3]* **M 37.9, m 125°(dec).** Extracted with Et_2O, and, after filtering, the solvent was removed under vacuum. The residue was dried at 60° for 3h, under high vacuum [Ruff *JACS* **83** 1788 *1961*]. **Ignites in the presence of a small amount of water.**

Lithium amide *[7782-89-0]* **M 23.0, m 380-400°, $d^{17.5}$ 1.178.** Purified by heating at 400° while NH_3 is passed over it in the upper of two crucibles (the upper crucible is perforated). The $LiNH_2$ will drip into the lower crucible through the holes in the upper crucible. The product is cooled in a stream of NH_3. Protect it from air and moisture, store under N_2 in a clear glass bottle sealed with paraffin. Store small quantities so that all material is used once the bottle is opened. If the colour of the amide is yellow it should be destroyed as it is likely to have oxidised and to **EXPLODE.** On heating above 450° it is decomposed to Li_2NH which is stable up to 750-800°. [*Handbook of Preparative Inorganic Chemistry (ed Brauer)* Vol I 463 *1963*; *Inorg Synth* **2** 135 *1953*].

Lithium benzoate *[553-54-8]* **M 128.1.** Crystd from EtOH (13ml/g) by partial evaporation.

Lithium borohydride *[16949-15-8]* **M 21.8.** Crystd from Et_2O, and pumped free of ether at 90-100° during 2h [Schaeffer, Roscoe and Stewart *JACS* **78** 729 *1956*].

Lithium bromide *[7550-35-8]* **M 86.8, m 550°.** Crystd several times from water or EtOH, then dried under high vacuum for 2 days at room temperature, followed by drying at 100°.

Lithium carbonate *[554-13-2]* **M 73.9, m 618°.** Crystd from water. Its solubility decreases as the temperature is raised

Lithium chloride *[7447-47-8]* **M 42.4, m 600°.** Crystd from water (1ml/g) or MeOH and dried for several hours at 130°. Other metal ions can be removed by preliminary crystallisation from hot aqueous 0.01M disodium EDTA. Has also been crystallised from conc HCl, fused in an atmosphere of dry HCl gas, cooled under dry N_2 and pulverised in a dry-box. Kolthoff and Bruckenstein [*JACS* **74** 2529 *1952*] ppted with ammonium carbonate, washed with Li_2CO_3 five times by decantation and finally with suction, then dissolved in HCl. The LiCl solution was evaporated slowly with continuous stirring in a large evaporating dish, the dry powder being stored (while still hot) in a desiccator over $CaCl_2$.

Lithium diisopropylamide *[4111-54-0]* **M 107.1, b 82-84°/atm, 84°/atm, d^{22} 0.722, flash point -6°.** It is purified by refluxing over Na wire or NaH for 30min and then distilled into a receiver under N_2. Because of the low boiling point of the amine a dispersion of NaH in mineral oil can be used directly in this purification without prior removal of the oil. It is *highly* ***flammable***, and is decomposed by air and moisture. [*Org Synth* **50** 67 *1970*].

Lithium dodecylsulphate *[2044-56-6]* **M 272.3.** Recrystd twice from absolute EtOH and dried under vacuum.

Lithium fluoride *[7789-24-4]* **M 25.9, m 842°, 848°, b 1676°, 1681°, d 2.640.** Possible impurities are $LiCO_3$, H_2O and HF. These can be removed by calcining at red heat, then pulverised with a Pt pestle and stored in a paraffin bottle. Solubility in H_2O is 0.27% at 18°. It volatilises between 1100-1200°. [*Handbook of Preparative Inorganic Chemistry (ed Brauer)* Vol I 235 *1963*].

Lithium formate (H_2O) *[556-63-8]* **M 70.0.** Crystd from hot water (0.5ml/g) by chilling.

Lithium hydride. *[7580-67-8]* **M 7.95, m 680°, d 0.76-0.77.** It should be a white powder otherwise replace it. It darkens rapidly on exposure to air and is decomposed by H_2O to give H_2 and LiOH, and reacts with lower alcohols. One gram in H_2O liberates 2.8L of H_2.

Lithium hydroxide (H_2O) *[1310-66-3]* **M 42.0.** Crystd from hot water (3ml/g) as the monohydrate. Dehydrated at 150° in a stream of CO_2-free air.

Lithium iodate *[13765-03-2]* **M 181.9.** Crystd from water and dried in a vacuum oven at 60°.

Lithium iodide *[10377-51-2]* **M 133.8.** Crystd from hot water (0.5ml/g) by cooling in $CaCl_2$-ice, or from acetone. Dried under vacuum over P_2O_5 for 1h at 60° and then at 120°.

Lithium ionophore I (ETH 149) see ***N,N'*-diheptyl-*N,N'*-5,5-tetramethyl-3,7-dioxanonanediamide.**

Lithium ionophore V see **12-crown-4, (1,4,7,10-tetraoxacyclododecane).**

Lithium ionophore VI see **6,6-dibenzyl-14-crown-4, (6,6-dibenzyl-1,4,8,11-tetraoxacyclotetradecane).**

Lithium methylate (lithium methoxide) *[865-34-9]* **M 38.0.** Most probable impurity is LiOH due to hydrolysis by moisture. It is important to keep the sample dry. It can be dried by keeping in a vacuum at 60-80° under dry N_2 using an oil pump for a few hours. Store under N_2 in the cold. It should not have bands above 3000cm^{-1}; IR has ν_{KBr} 1078, 2790, 2840 and 2930cm^{-1}. [*JOC* **21** 156 *1956*].

Lithium nitrate *[7790-69-4]* **M 68.9.** Crystd from water or EtOH. Dried at 180° for several days by repeated melting under vacuum. If it is crystallised from water keeping the temperature above 70°, formation of trihydrate is avoided. The anhydrous salt is dried at 120° and stored in a vacuum desiccator over $CaSO_4$.

Lithium nitrite (H_2O) *[13568-33-7]* **M 71.0.** Crystd from water by cooling from room temperature.

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Lithium picrate *[18390-55-1]* **M 221.0.** Recrystd three times from EtOH and dried under vacuum at 45° for 48h [D'Aprano and Sesta *JPC* **91** 2415 *1987*]. The necessary precautions should be taken in case of **EXPLOSION**.

Lithium perchlorate *[7791-03-9]* **M 106.4.** Crystd from water or 50% aq MeOH. Rendered anhydrous by heating the trihydrate at 170-180° in an air oven. It can then be recrystd twice from acetonitrile and again dried under vacuum [Mohammad and Kosower *JACS* **93** 2713 *1971*].

Lithium salicylate *[552-38-5]* **M 144.1.** Crystd from EtOH (2ml/g) by partial evaporation.

Lithium sulphate (anhydrous) *[10377-48-7]* **M 109.9.** Crystd from H_2O (4ml/g) by partial evaporation.

Lithium tetrafluoroborate *[14283-07-9]* **M 93.7.** Dissolve in THF just below its solubility, filter from insol material and evap to dryness in a vacuum below 50°. Wash the residue with dry Et_2O, and pass dry N_2 gas over the solid and finally heat in an oven at 80-90°. Solubility in Et_2O: 1.9 (1.3)g in 100ml at 25°, in THF: 71g in 100ml at 25°. It is *hygroscopic* and is an **irritant.** [*JACS* **74** 5211 *1952*, **75** 1753 *1953*].

Lithium thiocyanate (lithium rhodanide) *[556-65-0]* **M 65.0.** It crystallises from H_2O as the dihydrate but on drying at 38-42° it gives the monohydrate. It can be purified by allowing an aqueous soln to crystallise in a vac over P_2O_5. The crystals are collected, dried out in vacuum at 80°/P_2O_5 in a stream of pure N_2 at 110°. [*JCS* 1245 *1936*].

Lithium trimethylsilanolate (trimethylsilanol Li salt) *[2004-14-0]* **M 96.1, m 120°(dec in air).** Wash with Et_2O and pet ether. Sublimes at 180°/1mm as fine transparent needles. [*JOC* **17** 1555 *1952*].

Magnesium

[7439-95-4] **M 24.3, m 651°, b 1100°, d 1.739.** Slowly oxidises in moist air and tarnishes. If dark in colour do not use. Shiny solid should be degreased by washing with dry Et_2O, dry and keep in a N_2 atmosphere. It can be activated by adding a crystal of I_2 in the Et_2O before drying and storing.

Magnesium acetate *[16674-78-5]* **M 214.5, m 80°.** Crystd from anhydrous acetic acid, then dried under vacuum for 24h at 100°

Magnesium benzoate ($3H_2O$) *[553-70-8]* **M 320.6.** Crystd from water (6ml/g) between 100° and 0°.

Magnesium bromide (anhydrous) *[7789-84-6]* **M 184.1.** Crystd from EtOH.

Magnesium chloride ($6H_2O$) *[7791-18-6]* **M 203.3.** Crystd from hot water (0.3ml/g) by cooling.

Magnesium dodecylsulphate *[3097-08-3]* **M 555.1.** Recrystd three times from EtOH and dried in a vacuum.

Magnesium ethylate (magnesium ethoxide) *[2414-98-4]* **M 114.4.** Dissolve *ca* 1g of solid in 12.8ml of absolute EtOH and 20ml of dry xylene and relux in a dry atmosphere (use $CaCl_2$ in a drying tube at the top of the condenser). Add 10ml of absolute EtOH and cool. Filter solid under dry N_2 and dry in a vacuum. Alternatively dissolve in absolute EtOH and pass through molecular sieves (40 mesh) under N_2, evap under N_2, and store in a tightly stoppered container. [*JACS* **68** 889 *1964*].

Magnesium D-gluconate *[3632-91-5]* **M 414.6, $[\alpha]_{546}^{20}$ +13.5°, $[\alpha]_{D}^{20}$ +11.3° (c 1, H_2O).** Cryst from dilute EtOH to give *ca* trihydrate, and then dry at 98° in high vacuum. Insol in EtOH and solubility in H_2O is 16% at 25°.

Magnesium iodate ($4H_2O$) *[7790-32-1]* **M 446.2.** Crystd from water (5ml/g) between 100° and 0°.

Magnesium iodide *[10377-58-9]* **M 278.1.** Crystd from water (1.2ml/g) by partial evapn in a desiccator.

Magnesium ionophore I (ETH 1117), (*N,N'*-diheptyl-*N,N'*-dimethyl-1,4-butanediamide) *[75513-72-3]* **M 340.6.** Purified by flash chromatography (at 40 kPa) on silica and eluting with EtOH-hexane (4:1). IR has ν($CHCl_3$) 1630cm^{-1}. [*HCA* **63** 2271 *1980*]. It is a good magnesium selectophore compared with Na, K and Ca [*AC* **52** 2400 *1980*].

Magnesium ionophore II (ETH 5214), [*N,N''*-octamethylene-bis(*N'*-heptyl-*N''*-methyl methylmalonamide)] *[119110-38-8]* **M 538.8.** Reagent (*ca* 700mg) can be purified by flash chromatography on Silica Gel 60 (30g) and eluting with CH_2Cl_2-Me_2CO (4:1). [*AC* **61** 574 *1989*].

Magnesium lactate *[18917-93-6]* **M 113.4.** Crystd from water (6ml/g) between 100° to 0°.

Magnesium nitrate ($6H_2O$) *[13446-18-9]* **M 256.4.** Crystd from water (2.5ml/g) by partial evapn in a desiccator.

Magnesium perchlorate ($2H_2O$) *[10034-81-8]* **M 259.2.** Crystd from water. Coll, Nauman and West [*JACS* **81** 1284 *1959*] removed traces of unspecified contaminants by washing with small portions of Et_2O. **EXPLOSIVE** *in contact with organic materials.*

Magnesium succinate *[556-32-1]* **M 141.4.** Crystd from water (0.5ml/g) between 100° and 0°.

Magnesium sulphate (anhydrous) *[7487-88-9]* **M 120.4.** Crystd from warm water (1ml/g) by cooling.

Magnesium trifluoromethanesulphonate *[60871-83-2]* **M 322.4, m >300°.** Wash with CH_2Cl_2 and dry at 125°/2h and 3mmHg. [*TET LETT* **24** 169 *1983*].

Magon [3-hydroxy-4-(hydroxyphenylazo)-2-naphthoyl2,4-dimethylanilide; Xylidyl Blue II] *[523-67-1]* **M 411.5, m 246-247°.** Suspend in H_2O and add aqueous NaOH until it dissolves, filter and acidify with dil HCl. Collect the dye, dissolve in hot EtOH (sol is 100mg/L at *ca* 25°) concentrate to a small volume and allow to cool. Sol in H_2O of the Na salt is 0.4mg/ml. [*ACA* **16** 155 *1957*; *AC* **28** 202 *1956*].

Manganese (III) acetate ($2H_2O$) *[19513-05-4]* **M 268.1.** Wash the acetate with AcOH then thoroughly with Et_2O and dry in air to obtain the dihydrate. The *anhydrous* salt can be made by stirring vigorously a mixt of the hydrated acetate (*ca* 6g) and Ac_2O (22.5ml) and heat carefully (if necessary) until the mixture is clear. It is set aside overnight for the material to crystallise. Filter the solid, wash with Ac_2O and dry over P_2O_5. The dihydrate can also be obtained from the *di-* and *tetra- hydrate* mixture of the divalent acetate by adding 500ml of Ac_2O and 48g of the hydrated acetate and refluxing for 20min, then add slowly 8.0g of $KMnO_4$. After refluxing for an additional 30min, the mixture was cooled to room temperature and 85ml of H_2O added. It should be noted that larger amounts of H_2O change the yield and nature of the manganese acetate and the yields of reactions that use this reagent, e.g. formation of lactones from olefines. The $Mn(OAc)_3.2H_2O$ is then filtered off after 16h, washed with cold AcOH and air dried. [*JACS* **90** 5903, 5905 *1968*, **91** 138 *1969*].

Manganese (II) acetylacetone *[14024-58-9]* **M 253.2, m ~250°.** Purify by stirring 16g of reagent for a few min with 100ml absolute EtOH and filter by suction as rapidly as possible through coarse filter paper. Sufficient EtOH is added to the filtrate to make up for the loss of EtOH and to redissolve any solid that separates. Water (15ml) is added to the filtrate and the solution is evaporated with a stream of N_2 until reduced to half its vol. Cool for a few min and filter off the yellow crystals, dry under a stream of N_2, then in a

vacuum at room temp for 6-8h. These conditions are important for obtaining the *dihydrate*. A vacuum to several mm of Hg or much lower pressure for several days produces the anhydrous complex. The degree of hydration can be established by determining the loss in weight of 100g of sample after heating for 4h at 100° and <20mmHg. The theoretical loss in weight for $2H_2O$ is 12.5%. Material sublimes at 200°/2mm. It is soluble in heptane, MeOH, EtOH or C_6H_6 at 30°. [*Inorg Synth* **6** 164 *1960*, **5** 105 *1957*].

Manganese decacarbonyl $Mn_2(CO)_{10}$ *[10170-69-1]* **M 390.0, m 151-152°, 154-155°(sealed tube), d^{25} 1.75.** Golden yellow crystals which in the absence of CO begin to decompose at 110°. and on further heating yield a metallic mirror. In the presence of 3000psi of CO it does not decompose on heating to 250°. It is soluble in common organic solvents, insoluble in H_2O, not very stable in air, to heat or UV light. Dissolves in a lot of C_6H_6 and can be crystallised from it. It distils with steam at 92-100°. It can be purified by sublimation under reduced pressure (<0.5mm) at room temperature to give well formed golden yellow crystals. If the sample is orange coloured this sublimation leads to a mixture of golden-yellow and dark red crystals of the carbonyl and carbonyliodide respectively which can be separated by hand picking under a microscope. Separate resublimations provide the pure compounds. **(POISONOUS)** [*JACS 76* 3831 *1954*, **80** 6167 *1958*, **82** 1325 *1960*].

Manganous acetate ($4H_2O$) *[6156-78-1]* **M 245.1.** Crystd from water acidified with acetic acid.

Manganous bromide (anhydrous) *[13446-03-2]* **M 214.8, m 695°; $4H_2O$** *[10031-20-6]* **M 286.8, m 64°dec.** Rose-red deliquescent crystals soluble in EtOH. The H_2O is removed by heating at 100° then in HBr gas at 725° or dry in an atmosphere of N_2 at 200°.

Manganous chloride ($4H_2O$) *[13446-34-9]* **M 197.9.** Crystd from water (0.3ml/g) by cooling.

Manganous ethylenebis(dithiocarbamate) *[12427-38-2]* **M 265.3.** Crystd from EtOH.

Manganous lactate ($3H_2O$) *[51877-53-3]* **M 287.1.** Crystd from water.

Manganous sulphate (H_2O) *[10034-96-5]* **M 169.0.** Crystd from water (0.9ml/g) at 54-55° by evaporating about two-thirds of the water.

Mercuric acetate *[1600-27-7]* **M 318.7.** Crystd from glacial acetic acid.

Mercuric bromide *[7789-47-1]* **M 360.4, m 238.1°.** Crystd from hot saturated ethanolic soln, dried and kept at 100° for several hours under vacuum, then sublimed.

Mercuric chloride *[7487-94-7]* **M 271.5.** Crystd twice from distilled water, dried at 70° and sublimed under high vacuum.

Mercuric cyanide *[592-04-1]* **M 252.6.** Crystd from water.

Mercuric iodide *[7774-29-0]* **M 454.4, m 259°.** Crystd from MeOH or EtOH, and washed repeatedly with distilled water. Has also been mixed thoroughly with excess 0.001M iodine solution, filtered, washed with cold distilled water, rinsed with EtOH and Et_2O, and dried in air.

Mercuric oxide *[21908-53-2]* **M 216.6.** Dissolved in $HClO_4$ and ppted with NaOH soln.

Mercuric thiocyanate *[592-85-8]* **M 316.8, m 165°(dec).** Recryst from H_2O, and can form various crystal forms depending on conditions. Solubility in H_2O is 0.069% at 25°, but is more soluble at higher temps. Decomposes to Hg above 165°. **(POISONOUS)** [*JPC* **35** 1128 *1931*; *B* **68** 919 *1935*].

Mercurous nitrate ($2H_2O$) *[7782-86-7]* **M 561.2, m 70°(dec), d 4.78.** Solubility in H_2O containing 1% HNO_3 is 7.7%. Recrystd from a warm saturated soln of dilute HNO_3 and cool to room temp

slowly to give elongated prisms. Rapid cooling gives plates. Colourless crystals to be stored in the dark. **(POISONOUS)** [*JCS* 1312 *1956*].

Mercurous sulphate *[7783-36-0]* **M 497.3, d 7.56.** Recrystallise from dilute H_2SO_4., and dry in a vacuum under N_2 and store in the dark. **(POISONOUS).** Solubility in H_2O is 0.6% at 25°.

Mercury *[7439-97-6]* **M 200.6, m -38.9°, b 126°/1mm, 184°/10mm, 261°/100mm, 356.9°/atm, d_0 13.595.** After air had been bubbled through mercury for several hours to oxidise metallic impurities, it was filtered to remove coarser particles of oxide and dirt, then sprayed through a 4-ft column containing 10% HNO_3. It was washed with distilled water, dried with filter paper and distilled under vacuum.

Mercury(II) bis(cyclopentadienyl) *[18263-08-6]* **M 330.8.** Purified by low-temp recrystn from Et_2O.

Mercury dibromofluorescein (mercurochrome, merobromin), [2',7'-dibromo-4'-(hydroxymercurio)-fluorescein di sodium salt] *[129-16-8]* **M 804.8, m>300°.** The Na salt is dissolved in the minimum vol of H_2O, or the free acid suspended in H_2O and dilute NaOH added to cause it to dissolve, filter and acidify with dilute HCl. Collect the ppte wash with H_2O by centrifugation and dry in vacuum. The di Na salt can be purified by dissolving in the minimum volume of H_2O and ppted by adding EtOH, filter, wash with EtOH or Me_2CO and dry in a vacuum. Solubility in 95% EtOH is 2% and in MeOH it is 16%. [*JACS* 42 2355 *1920*].

Mercury orange [1-(4-chloromercuriophenylazo)-2-naphthol] *[3076-91-3]* **M 483.3, m 291.5-293°(corr) with bleaching.** Wash several times with boiling 50% EtOH and recrystallise from 1-butanol (0.9g/L of boiling alcohol). Fine needles insoluble in H_2O but slightly soluble in cold alcohols, $CHCl_3$ and soluble in aqueous alkalis. [*JACS* **70** 3522 *1948*].

Mercury(II) trifluoroacetate *[13257-51-7]* **M 426.6.** Recrystd from trifluoroacetic anhydride/trifluoroacetic acid [Lan and Kochi *JACS* **108** 6720 *1986*]. Very **TOXIC** and *hygroscopic.*

Metanil Yellow *[587-98-4]* **M 375.4.** Salted out from water three times with sodium acetate, then repeatedly extracted with EtOH [McGrew and Schneider, *JACS* **72** 2547 *1950*].

Methoxymethyl trimethylsilane (trimethylsilylmethyl methyl ether) *[14704-14-4]* **118.3, b 83°/740mm, d_4^{25} 0.758, n_D^{25} 1.3878.** Forms an azeotrope with MeOH (b 60°). If it contains MeOH (check IR for bands above 3000cm^{-1}) then wash with H_2O and fractionate. A possible impurity could be chloromethyl trimethylsilane (b 97°/740mm). [*JACS* **70** 4142 *1948*].

1-Methoxy-2-methyl-1-trimethylsiloxypropene (dimethyl ketene methyl trimethylsilyl acetal) *[31469-15-5]* **M 174.3, b 121-122°/0.35mm, 125-126°/0.4mm, 148-150°/atm, d 0.86.** Add Et_2O, wash with cold H_2O, dry (Na_2SO_4), filter, evaporate Et_2O, and distil oily residue in a vacuum. [*J Organometal Chem* **46** 59 *1972*].

Methylarsonic acid *[124-58-3]* **M 137.9, m 161°.** Crystd from absolute EtOH.

Methyl dichlorosilane *[75-54-7]* **M 115.0, m -92.5°, b 41°/748mm, 40.9°/760mm, 40-45°/atm, d $^{27}_{27}$1.105.** Impurities are generally other chloromethyl silanes. Distilled through a conventional Stedman column of 20 theoretical plates or more. It should be protected from H_2O by storing over P_2O_5. [*B* **52 695** *1919*; *JACS* **68** 9621*946*].

Methylmercuric chloride *[115-09-3]* **M 251.1, m 167°.** Crystd from absolute EtOH (20ml/g).

Methyl Orange see **sodium *p*-(*p*-dimethylaminobenzeneazo)-benzenesulphonate.**

Methylphenyl dichlorosilane. (dichloro methyl phenylsilane) *[149-74-6]* **M 1191.1, b 114-115°/50mm, 202-205°/atm, d 1.17.** Purified by fractionation using an efficient column. It hydrolyses

ca ten times more slowly than methyltrichlorosilane and *ca* sixty times more slowly than phenyltrichlorosilane. [*JPC* **61** 1591 *1957*].

Methylphosphonic acid *[993-13-5]* **M 96.0, m 104-106°, 105-107°, 108°.** If it tests for Cl^-, add H_2O and evaporate to dryness; repeat several times till free from Cl^-. The residue solidifies to a wax-like solid. Alternatively, dissolve the acid in the minimum volume of H_2O, add charcoal, warm, filter and evaporate to dryness in a vacuum over P_2O_5. [*JACS* **75** 3379 *1953*]. The *di-Na salt* is prepared from 24g of acid in 50ml of dry EtOH and a solution of 23g Na dissolved in 400ml EtOH is added. A white ppte is formed but the mixture is refluxed for 30min to complete the reaction. Filter off and recrystallise from 50% EtOH. Dry crystals in a vacuum desiccator. [*JCS* 3292 *1952*].

Methylphosphonic bis-dimethylamide see ***N,N,N'N'*-tetramethylphosphonic diamide**.

Methylphosphonic dichloride [676-97-1] **M 132.9, m 33°, 33-37°; 53-54°/10mm, 64-67°/20.5mm, 86°/44mm, 162°/760mm, d_4^{40} 1.4382.** Fractionally redistd until the purity as checked by hydrolysis and acidimetry for Cl^- is correct and should solidify on cooling. [*JCS* 3437 *1952*; *JACS* **75** 3379 *1952;* for IR see *Canad J Chem* **34** 1611 *1956*].

Methyl Thymol Blue, sodium salt *[1945-77-3]* **M 844.8, ε 1.89 x 10^4 at 435nm, pH 5.5.** Starting material for synthesis is Thymol Blue. Purified as for Xylenol Orange.

Methyl trichlorosilane *[75-79-6]* **M 149.5, b 13,7°/101mm, 64.3°/710.8mm, 65.5°/745mm, 66.1°/atm, d 1.263, n, 1.4110.** If very pure distil before use. Purity checked by ^{29}Si nmr, δ in MeCN is 13.14 ppm with respect to Me_4Si. Possible contaminants are other silanes which can be removed by fractional distillation through a Stedman column of >72 theoretical plates with total reflux and 0.35% take-off. The apparatus is under N_2 at a rate of 12 bubbles/min fed into the line using an Hg manometer to control the pressure. Sensitive to H_2O. [*JACS* **73** 4252 *1951*; *JOC* **48** 3667 *1983*].

Methyl triethoxysilane *[2031-67-6]* **M 178.31, b142-144.5°/742mm, 141°/765, 141.5°/775mm, d 0.8911, n 1.3820.** Repeated fractionation in a stream of N_2 through a 3' Heligrid packed Todd column. Hydrolysed by H_2O and yields cyclic polysiloxanes on hydrolysis in the presence of acid in C_6H_6. [*JACS* **77** 1292, 3990 *1955*].

Methyl trimethoxysilane *[185-55-3]* **M 136.2, b 102°/760mm, d 1.3687, n 1.3711.** Likely impurities are 1,3-dimethyltetramethoxy disiloxane (b 31°/1mm) and cyclic polysiloxanes, see methyl triethoxysilane. [*JOC* ***16*** 1400 *1952*, **20** 250 *1955*].

Methyl trimethylsilylacetate *[2916-76-9]* **M 146.3, b 65-68°/50mm, d 0.89.** Dissolved in Et_2O, shaken with 1M HCl, washed with H_2O, aqueous saturated $NaHCO_3$, H_2O again, and dried (a ppte may be formed in the $NaHCO_3$ soln and should be drawn off and discarded). The solvent is distd off and the residue is fractionated through a good column. IR ($CHCl_3$) ν 1728cm^{-1}. [*JOC* *32* 3535 *1967*, **45** 237 *1980*].

Methyl 2-(trimethylsilyl)propionate *[55453-09-3]* **M 160.3, b 155-157°/atm, d 0.89.** Dissolve in Et_2O, wash with aqueous $NaHCO_3$, H_2O, 0.1M HCl, H_2O again, dry ($MgSO_4$), evaporated and distil. [*JCS Perk I* 541 *1985*; *TET* **39** 3695 *1983*].

Methyl triphenoxyphosphonium iodide *[17579-99-6]* **M 452.2, m 146°.** Gently heat the impure iodide with good grade Me_2CO The saturated solution obtained is decanted rapidly from undissolved salt and treated with an equal volume of dry Et_2O. The iodide separates as beautiful flat needles which are collected by centrifugation, washed several times with dry Et_2O, and dried in a vacuum over P_2O_5. For this recrystn it is essential to minimise the time of contact with Me_2CO and to work rapidly and with rigorous exclusion of moisture. If the crude material is to be used, it should be stored under dry Et_2O, and dried and weighed *in vacuo* immediately before use. [*JCS Perk I* 982 *1974*; *JCS* 224 *1953*].

Methyl triphenylphosphonium bromide *[1779-49-3]* **M 357.3, m 229-230°(corr), 227-229°, 230-233°.** Wash with C_6H_6 and dry in a vacuum over P_2O_5. [*B* **87** 1318 *1954*; *JACS* **79** 6295 *1957*; *JOC* **24** 1494 *1959*]. The *iodide* crysts from H_2O has **m** 187.5-188.5° [*JCS* 1130 *1953*; *B* **580** 44 *1953*].

***N*-Methyl-*N*-trimethylsilyl acetamide** *[74479-74-3]* **M 145.3, b 48-49°/11mm, 84°/13mm, 105-107°/35mm (solid at room temp), d 0.90, n 1.4379.** Likely impurity is $Et_3N.HCl$ which can be detected by its odour. If it is completely soluble in C_6H_6, then redistil, otherwise dissolve in this solvent, filter and evaporate first in a vacuum at 12mm then fractionate, all operations should be carried out in a dry N_2 atmosphere. [*JACS* **88** 3390 *1966*; *B* **96** 1473 *1963*].

***N*-Methyl-*N*-trimethylsilyl trifluoroacetamide** *[24589-78-4]* **M 199.3, b 78-79°/130mm.** Fractionate through a 40mm Vigreux column. Usually it contains *ca* 1% of methyl trifluoroacetamide and 1% of other impurities which can be removed by gas chromatography or fractionating using a spinning band column. [*JC* **42** 103 *1969*, **103** 91 *1975*].

Methyl vinyl dichlorosilane *[124-70-9]* **M 141.1, 43-45.5°/11-11.5mm, 91°/742mm, 92.5°/743.2mm, 92.5-93°/atm, d 1.0917, n 1.444.** Likely impurities are dichloromethylsilane, butadienyl-dichloromethylsilane. Fractionate through a column packed with metal filing (20 theoretical plates) at atmospheric pressure. [*Isvest Akad SSSR Otd Chem* 1474 *1957* and 767 *1958*].

Molybdenum hexacarbonyl *[13939-06-5]* **M 264.0, m 150°(dec), b 156°.** Sublimed in a vacuum before use [Connor et al. *JCSDT* 511 *1986*].

Molybdenum hexafluoride *[7783-77-9]* **M 209.9, b 35°/760mm.** Purified by low-temperature trap-to-trap distillation over predried NaF. [Anderson and Winfield *JCSDT* 337 *1986*].

Molybdenum trichloride *[13478-18-7]* **M 202.3.** Boiled with 12M HCl, washed with absolute EtOH and dried in a vacuum desiccator.

Molybdenum trioxide *[1313-27-5]* **M 143.9.** Crystd from water (50ml/g) between 70° and 0°.

Monocalcium phosphate (H_2O) *[7758-23-8]* **M 154.1.** Crystd from a near-saturated soln in 50% aqueous reagent grade phosphoric acid at 100° by filtering through fritted glass and cooling to room temperature. The crystals were filtered off and this process was repeated three times using fresh acid. For the final crystn the solution was cooled slowly with constant stirring to give thin plate crystals that were filtered off on fritted glass, washed free of acid with anhydrous acetone and dried in a vacuum desiccator [Egan, Wakefield and Elmore, *JACS* **78** 1811 *1956*].

1-Naphthyl phosphate disodium salt *[2183-17-7]* **M 268.1.** The free acid has **m** 157-158° (from Me_2CO/C_6H_6). The free acid is crystd several times by adding 20 parts of boiling C_6H_6 to a hot solution of 1 part of free acid and 1.2 parts of Me_2CO. [*JACS* **77** 4002 *1955*]. The *monosodium salt* was ppted from a soln of the acid phosphate in MeOH by addition of an equivalent of MeONa in MeOH. [*JACS* *72* 624 *1950*].

2-Naphthyl phosphate monosodium salt *[14463-68-4]* **M 246.1.** Recrystd from H_2O (10ml) containing NaCl (0.4g). The salt is collected by centrifugation and dried in a vacuum desiccator, **m** 203-205° (partially resolidifies and melts at 244°). Crystd from MeOH (**m** 222-223°). The free acid is recrystd several times by addition of 2.5 parts of hot $CHCl_3$ to a hot solution of the free acid (1 part) in Me_2CO (1.3 parts), **m** 177-178°. [*JACS* **73** 5292 *1951*, **77** 4002 *1955*].

Neodynium chloride $6H_2O$ *[13477-89-9]* **M 358.7, m 124°.** Forms large purple prisms from conc solns of dilute HCl. Soluble in H_2O (2.46 parts in 1 part of H_2O) and EtOH.

Neodynium nitrate ($6H_2O$) *[16454-60-7]* **M 438.4, m 70-72°.** Crystallises with 5 and 6 molecules of H_2O from conc solutions in dilute HNO_3 by slow evaporation; 1 part is soluble in 10 parts of H_2O.

Neodymiun oxide *[1313-97-9]* **M 336.5.** Dissolved in $HClO_4$, ppted as the oxalate with doubly recrystd oxalic acid, washed free of soluble impurities, dried at room temperature and ignited in a platinum crucible at higher than 850° in a stream of oxygen [Tobias and Garrett *JACS* **80** 3532 *1958*].

Neon *[7440-01-9]* **M 20.2.** Passed through a copper coil packed with 60/80 mesh 13X molecular sieves which is cooled in liquid N_2, or through a column of Ascarite (NaOH-coated silica adsorbent).

Neopentoxy lithium *[3710-27-8]* **M 94.1.** Recrystd from hexane [Kress and Osborn *JACS* **109** 3953 *1987*].

Nickel (II) acetate ($4H_2O$) *[6018-89-9]* **M 248.9, d 1.744.** Recryst from aqueous AcOH as the green tetrahydrate. Soluble in 6 parts of H_2O. It forms lower hydrates and should be kept in a well closed container. [*Z Anorg Allegem Chem* **343** 92 *1966*].

Nickel (II) acetylacetonate *[3264-82-2]* **M 256.9, m 229-230°, b 220-235°/11mm, d^{17} 1.455.** Wash the green solid with H_2O, dry in a vacuum desiccator and recrystallise from MeOH. [*JPC* **62** 440 *1958*]. The complex can be conveniently dehydrated by azeotropic distn with toluene and the crystals may be isolated by concentrating the toluene solution. [*JACS* **76** 1970 *1954*].

Nickel bromide *[13462-86-9]* **M 218.5.** Crystd from dilute HBr (0.5ml /g) by partial evaporation in a desiccator.

Nickel chloride ($6H_2O$) *[7791-20-0]* **M 237.7.** Crystd from dilute HCl.

Nickel nitrate ($6H_2O$) *[13478-00-7]* **M 290.8, m 57°.** Crystd from water (0.3ml/g) by partial evaporation in a desiccator.

Nickelocene [bis-(cyclopentadienyl)nickel II] *[1271-28-9]* **M 188.9, m 173-174°(under N_2).** Dissolve in Et_2O, filter and evaporate in a vacuum. Purify rapidly by recrystn from pet ether using a solid CO_2-Me_2CO bath, **m** 171-173°(in an evacuated tube). Also purified by vacuum sublimation. [*JACS* **76** 1970 *1954*; *JINC* **2 95**, 110 *1956*].

Nickel (II) phthallocyanine *[14055-02-8]* **M 571.3, m >300°.** Wash well with H_2O and boiling EtOH and sublime at high vacuum in a slight stream of CO_2. A special apparatus is used (see reference) with the phthallocyanine being heated to red heat. The sublimate is made of needles with an extremely bright red lustre. The powder is dull greenish blue in colour. [*JCS* 1719 *1936*].

Nickel potassium sulphate see **potassium nickel sulphate.**

Nickel sulphate ($7H_2O$) *[1010-98-1]* **M 280.9.** Crystd from warm water (0.25ml/g) by cooling.

Nickel 5,10,15,20-tetraphenylporphyrin *[14172-92-0]* **M 671.4, λ_{max} 414(525)nm.** Purified by chromatography on neutral (Grade I) alumina, followed by recrystn from CH_2Cl_2/MeOH [Yamashita *JPC* **91** 3055 *1987*].

Niobium (V) chloride *[10026-12-7]* **M 270.2, m 204.7-209.5°, b ~250°(begins to sublime at 125°), d 2.75.** Yellow very deliquescent crystals which decompose in moist air to give HCl. Should be kept in a dry box flushed with N_2 in the presence of P_2O_5. Wash with CCl_4 and dry over P_2O_5. The yellow crystals usually contain a few small dirty white pellets among the yellow needles. These should be easily picked out. Upon grinding in a dry box, however, they turn yellow. $NbCl_5$ has been sublimed and fractionated in an electric furnace. [*Inorg Synth* **7** 163 *1963*; *JCS* S233 *1949*].

Nitric acid *[7697-37-2]* **M 63.0, m -42°, b 83°, d_{25} 1.5027; [Constant boiling acid has composition 68% HNO_3 + 32% H_2O, b 120.5°, d 1.41].** Obtained colourless (approx. 92%) by direct distn of fuming HNO_3 under reduced pressure at 40-50° with an air leak at the head of the fractionating column. Stored in a desiccator kept in a refrigerator. Nitrite-free HNO_3 can be obtained by vac distn from urea.

Nitric oxide *[10102-43-9]* **M 30.0, b -151.8°.** Bubbling through 10M NaOH removes NO_2. It can also be freed from NO_2 by passage through a column of Ascarite followed by a column of silica gel held at -197°K. The gas is dried with solid NaOH pellets or by passing through silica gel cooled at -78°, followed by fractional distillation from a liquid N_2 trap. This purification does not eliminate nitrous oxide. Other gas scrubbers sometimes used include one containing conc H_2SO_4 and another containing mercury. It is freed from traces of N_2 by a freeze and thaw method. **TOXIC.**

***p*-Nitrobenzenediazonium fluoroborate** *[456-27-9]* **M 236.9.** Crystd from water. **Can be EXPLOSIVE when dry.**

Nitrogen *[7727-37-9]* **M 28.0, b -195.8°.** Cylinder N_2 can be freed from oxygen by passage through Fieser's soln [which comprises 2g sodium anthraquinone-2-sulphonate and 15g sodium hydrosulphite dissolved in 100ml of 20% KOH (Fieser, *JACS* **46** 2639 *1924*)] followed by scrubbing with saturated lead acetate soln (to remove any H_2S generated by the Fieser soln), conc H_2SO_4 (to remove moisture), then soda-lime (to remove any H_2SO_4 and CO_2). Alternatively, after passage through Fieser's solution, N_2 can be dried by washing with a soln of the metal ketyl from benzophenone and Na wire in absolute ethyl ether. [If ether vapour in N_2 is undesirable, the ketyl from liquid Na-K alloy under xylene can be used].
Another method for removing O_2 is to pass the nitrogen through a long tightly packed column of Cu turnings, the surface of which is constantly renewed by scrubbing it with ammonia (s.g. 0.880) soln. The gas is then passed through a column packed with glass beads moistened with conc H_2SO_4 (to remove ammonia), through a column of packed KOH pellets (to remove H_2SO_4 and to dry the N_2), and finally through a glass trap packed with chemically clean glass wool immersed in liquid N_2. Nitrogen has also been purified by passage over Cu wool at 723°K and Cu(II) oxide [prepared by heating $Cu(NO_3)_2.6H_2O$ at 903°K for 24h] and then into a cold trap at 77°K.
A typical dry purification method consists of a mercury bubbler (as trap), followed by a small column of silver and gold turnings to remove any mercury vapour, towers containing anhydrous $CaSO_4$, dry molecular sieves or $Mg(ClO_4)_2$, a tube filled with fine Cu turnings and heated to 400° by an electric furnace, a tower containing soda-lime, and finally a plug of glass wool as filter. Variations include tubes of silica gel, traps containing activated charcoal cooled in a Dry-ice bath, copper on Kieselguhr heated to 250°, and Cu and Fe filings at 400°.

Nitrophenolarsonic acid *[121-19-7]* **M 350.1.** Crystd from water.

Nitroso-R-salt see **1-nitroso-2-naphthol-3,6-disulphonic acid, disodium salt, hydrate.**

1-Nitroso-2-naphthol-3,6-disulphonic acid, disodium salt, hydrate *[525-05-3]* **M 377.3, m >300°.** Purified by dissolution in aqueous alkali and precipitation by addition of HCl.

Nitrosyl chloride *[2696-92-6]* **M 65.5, b -5.5°.** Fractionally distilled at atmospheric pressure in an all-glass, low temperature still, taking the fraction boiling at -4° and storing it in sealed tubes.

Nitrous oxide *[10024-97-2]* **M 44.0, b -88.5°.** Washed with conc alkaline pyrogallol solution, to remove O_2, CO_2, and NO_2, then dried by passage through columns of P_2O_5 or Drierite, and collected in a dry trap cooled in liquid N_2. Further purified by freeze-pump-thaw and distn cycles under vacuum [Ryan and Freeman *JPC* **81** 1455 *1977*].

Octadecyl isonicotinate see hydrogen ionophore IV, ETH 1778

Octadecyl trichlorosilane *[112-04-9]* **M 387.9, b 159-162°/13mm, 185-199°/2-3mm, d_4^{30} 0.98.** Purified by fractional distillation. [*JACS* **69** 2916 *1947*].

Octadecyl trimethylammonium bromide *[1120-02-1]* **M 392.5, m ~250°dec, 230-240°(dec).** Cryst from EtOH or H_2O (sol 1 in 1000parts). Very soluble in Me_2CO. [*JACS* **68** 714 *1946*].

Octamethyl cyclotetrasiloxane *[556-67-2]* **M 296.6, m 17-19°, 17.58°, 18.5°; b 74°/20mm, 176.4°/760mm, $d_4^{29.3}$ 0.9451, n_D^{30} 1.3968.** Solid has two forms, **m** 16.30° and 17.65°. Dry over CaH_2 and distil. Further fractionation can be effected by repeated partial freezing and discarding the liquid phase. [*JACS* **76** 399 *1954*, **75** 6313 *1954*].

Octamethyl trisiloxane *[107-51-7]* **M 236.5, m -80°, b 151.7°/747mm, 153°/760mm.** Distil twice, the middle fraction from the first distillation is again distilled, and the middle fraction of the second distillation is used. [*JACS* **68** 358, 691 *1946*, *JCS* 1908 *1953*].

Octaphenyl cyclotetrasiloxane *[546-56-5]* **M 793.2, m 201-202°, 203-204°, b 330-340°/1mm.** Recryst from AcOH or C_6H_6 or EtOAc. It forms two stable polymorphs and both forms as well as the mixture melt at 200-201°. There is a metastable form which melts at 187-189°. [*JACS* **67** 2173 *1945*, **69** 488 *1947*].

Octyl trichlorosilane *[5283-66-9]* **M 247.7, b 96.5°/10mm, 112°/15mm. 119°/28mm, 229°/760mm, d 1.0744, n 1.4453.** Purified by repeated fractionation using a 15-20 theoretical plates glass column packed with glass helices. This can be done more efficiently using a spinning band column. The purity can be checked by analysing for Cl [*ca* 0.5-1g of sample is dissolved in 25ml of MeOH, diluted with H_2O and titrated with standard alkali. [*JACS* **68** 475 *1946*, **80** 1737 *1958*].

Orange I [tropaeolin 000 Nr1] (4-(4-hydroxy-1-naphthylazo)benzenesulphonic acid sodium salt) *[523-44-4]* **M 350.3, m >260°(dec).** Purified by dissolving in the minimum volume of H_2O, adding, with stirring, a large excess of EtOH. The salt separates as orange needles. It is collected by centrifugation or filtration, washed with absolute EtOH (3 x) and Et_2O (2x) in the same way and dried in a vacuum desiccator over KOH. The free acid can be recrystallised from EtOH. [*B* ***64*** 86 *1931*]. The purity can be checked by titration with titanium chloride [*JACS* **68** 2299 *1946*].

Orange II [tropaeolin 000 Nr2] (4-(2-hydroxy-1-naphthylazo)benzenesulphonic acid sodium salt) *[633-96-5]* **M 350.3.** Purification is as for Orange I. The solubility in H_2O is 40g/L at 25°. [*HCA* **35** 2579 *1952*]. Also purified be extracting with a small volume of water, then crystd by dissolving in boiling water, cooling to *ca* 80°, adding two volumes of EtOH and cooling. When cold, the ppte is filtered off, washed with a little EtOH and dried in air. It can be salted out from aqueous solution with sodium acetate, then repeatedly extracted with EtOH. Meggy and Sims [*JCS* 2940 *1956*], after crystallising the sodium salt twice from water, dissolved it in cold water (11ml/g) and conc HCl added to ppte the dye acid which was separated by centrifugation, redissolved and again ppted with acid. After washing the ppte three times with 0.5M acid it was dried over NaOH, recrystd twice from absolute EtOH, washed with a little Et_2O, dried over NaOH and stored over conc H_2SO_4 in the dark.

Orange G (1-phenylazo-2-naphthol-6,8-disulphonic acid disodium salt) *[1936-15-8]* **M 452.4.** Recryst from 75% EtOH, dry for 3h at 110° and keep in a vacuum desiccator over H_2SO_4. The free acid crystallises from EtOH or conc HCl in deep red needles with a green reflex. [*JACS* **48** 2483 *1923*, *JCS* 292 *1938*].

Orange RO *[5850-86-2]* **M 364.4.** Salted out three times with sodium acetate, then repeatedly extracted with EtOH.

Osmium tetroxide (osmic acid) *[20816-12-0]* **M 524..2, m 40.6°, b 59.4°/60mm, 71.5°/100mm, 109.3°/400mm, 130°/760mm, d 5.10.** It is **VERY TOXIC** and should be manipulated in a good fume cupboard. It attacks the eyes severely and is a good oxidising agent. It is volatile

and has a high vapour pressure (11mm) at room temp. It sublimes and dists well below its boiling point. It is sol in C_6H_6, H_2O (7.24% at 25°), CCl_4 (375% at 25°), EtOH and Et_2O. It is estimated by dissolving a sample in a glass stoppered flask containing 25ml of a solution of KI (previously saturated with CO_2) and acidified with 0.35M HCl. After gentle shaking in the dark for 30min, the solution is diluted to 200ml with distilled H_2O satd with CO_2 and titrated with standard thiosulphate using Starch indicator. This method is not as good as the gravimetric method. Hydrazine hydrochloride (0.1 to 0.3g) is dissolved in 3M HCl (10ml) in a glass stoppered bottle. After warming to 55-65°, a weighed sample of OsO_4 solution is introduced, and the mixture is digested on a water bath for 1h. The mixture is transferred to a weighed glazed crucible and evaporated to dryness on a hot plate. A stream if H_2 is started through the crucible and the crucible is heated over a burner for 20-30 min. The stream of H_2 is continued until the crucible in cooled to room temperature, and then the H_2 is displaced by CO_2 in order to avoid rapid combustion of H_2. Finally the crucible is weighed. [*Handbook of Preparative Inorganic Chemistry (ed Brauer)* Vol II 1603 *1965*; *JACS* **60** 1822 *1938*].

Oxygen *[7782-44-7]* **M 32.00, m -218.4°, b -182.96°, d^{-183} 1.149, $d^{-252.5}$ 1.426.** Purified by passage over finely divided platinum at 673°K and Cu(II) oxide (see under nitrogen) at 973°, then condensed in liquid N_2-cooled trap. **HIGHLY EXPLOSIVE in contact with organic matter.**

Palladium (11) acetate *[3375-31-3]* M 244.5, m 205°dec.

Recrystd from $CHCl_3$ as purple crystals. It can be washed with AcOH and H_2O and dried in air. Large crystals can be obtained by dissolving in C_6H_6 and allowing to evaporate slowly at room temp. It forms green adducts with nitrogen donors, dissolved in KI soln but is insoluble in aqueous saturated NaCl, and NaOAc. Soluble in HCl to form $PdCl_4^{2-}$. [*Chemistry & Ind ustry (London)* 544 *1964*; *JCS* 658 *1970*].

Palladium (II) acetyl acetone *[14024-61-4]* **M 304.6.** Recrystd from C_6H_6-pet ether and sublimed *in vacuo*. It is soluble in heptane, C_6H_6 (1.2% at 20°, 2.2 at 40°), toluene (0.56% at 20°, 1.4% at 40°) and acetylacetone (1.2% at 20°, 0.05% at 40°). [*JINC* **5** 295 *1957/8*; *Inorg Synth* **5** 105 *1957*].

Palladium (II) chloride *[7647-10-1]* **M 177.3, m 678-680°.** The anhydrous salt is insoluble in H_2O and dissolves in HCl with difficulty. The dihydrate forms red *hygroscopic* crystals that are readily reduced to Pd. Dissolve in conc HCl through which dry Cl_2 was bubbled. Filter this solution which contains H_2PdCl_4 and H_2PdCl_6 and on evaporation yields a residue of pure $PdCl_2$. [*Handbook of Preparative Inorganic Chemistry (ed Brauer)* Vol 2 1582 *1965*; *Org Synth* Col Vol III 685 1955].

Palladium (II) cyanide *[2035-66-7]* **M158.1.** A yellow solid, wash well with H_2O and dry in air. [*Inorg Chem* **2** 245 *1946*].

Palladium tetrakis(triphenylphosphine) see **tetrakis(triphenylphosphine) palladium.**

Palladium (II) trifluoroacetate *[42196-31-6]* **M 332.4., m 210°(dec).** Suspend in trifluoroacetic acid and evaporate on a steam bath a couple of times. The residue is then dried in vacuum (40-80°) to a brown powder. [*JCS* 3632 *1965*; *JACS* **102** 3572 *1980*].

Pentafluorophenyl dimethylchlorosilane (Flophemesyl chloride) *[20082-71-7]* **M 260.7, b 89-90°/10mm, d_4^{30} 1.403, n_D^{30} 1.447.** If goes turbid on cooling due to separation of some LiCl, then dissolve in Et_2O, filter and fractionate. [*JC* **89** 225 *1974*, **132** 548 *1977*,].

Perchloric acid *[7601-90-3]* **M 100.5, d 1.665.** The 72% acid has been purified by double distn from silver oxide under vacuum: this frees the acid from metal contamination. Anhydrous acid can be obtained by adding gradually 400-500ml of oleum (20% fuming H_2SO_4) to 100-120ml of 72% $HClO_4$ in a reaction flask cooled in an ice-bath. The pressure is reduced to 1mm (or less), with the reaction mixture at 20-25°. The temperature is gradually raised during 2h to 85°, the distillate being collected in a receiver cooled in Dry-ice.

For further details of the distillation apparatus [see Smith *JACS* **75** 184 *1953*]. **HIGHLY EXPLOSIVE, a strong protective screen should be used at all times.**

Phenylarsonic acid *[98-05-5]* **M 202.2, m 155-158°(dec).** Crystd from H_2O (3ml/g) between 90° and 0°.

Phenyl boric acid (benzeneboronic acid) *[98-80-6]* **M 121.9, m ca 43°, 215-216° (anhydride), 217-220°.** It recrystallises from H_2O, but can convert spontaneously to benzeneboronic anhydride or phenylboroxide on standing in dry air. Possible impurity is dibenzeneborinic acid which can be removed by washing with pet ether. Heating in an oven at 110°/760mm 1h converts it to the *anhydride* **m** 214-216°. Its solubility in H_2O is 1.1% at 0° and 2.5% at 25° and in EtOH it is 10% (w/v). It has a pKa^{25} of 8.64 in H_2O. [Gilman and Moore *JACS* **80** 3609 *1958*]. If the acid is required, not the anhydride, the acid (from recrystallisation in H_2O) is dried in a slow stream of air saturated with H_2O. The anhydride is converted to the acid by recrystallisation from H_2O. The acid gradually dehydrates to the anhydride if left in air at room temperature with 30-40% relative humidity. The melting point is usually that of the anhydride because the acid dehydrates before it melts [Washburn et al. *Org Synth* Coll Vol IV 68 *1963*].

Phenyl dimethyl chlorosilane (chlorodimethylphenylsilane) *[768-33-2]* **M 170.7, 79°/15mm, 189-191°/739mm, 196°/760mm, d_4^{30} 1.032, n_D^{35} 1.032.** Fractionate through a 1.5 x 18 inch column packed with stainless steel helices; better use a spinning band column. [*JACS* **74** 386 *1952*; **70** 1115 *1948*; *JCS* 494 *1953*].

1,2-Phenylenephosphorochloridate (2-chloro-1,3,2-benzodioxaphosphole-2-oxide) *[1499-17-8]* **M 190.5, m 52°. 58-59°, 59-61°, b 80-81°/1-2mm, 118°/10mm, 122°/12mm, 125°/16mm, 155°/33mm.** Distil in a vacuum, sets to a colourless solid. It is soluble in pet ether, benzene and slightly soluble in Et_2O. [*JCSC* 2092 *1970*; *A* **454** 109 *1927*].

Phenylmercuric hydroxide *[100-57-2]* **M 294.7, m 195-203°.** Crystd from dilute aqueous NaOH.

Phenylmercuric nitrate *[8003-05-2]* **M 634.4, m 178-188°.** Crystd from water.

Phenylphosphinic acid *[1779-48-2]* **M 142.1, m 70°, 71°, 83-85°, 86°.** Crystallises from H_2O (sol, 7.7% at 25°). Purified by placing the solid in a flask covered with dry Et_2O, and allowed to stand for 1 day with intermittent shaking. Et_2O was decanted off and the process repeated. After filtration, excess Et_2O was removed in vacuum. pKa1 = 1.92. [*A* **181** 265 *1876*; *AC* **29** 109 *1957*; NMR: *JACS* **78** 5715 *1956*].

Phenylphosphonic acid *[1571-33-1]* **M 158.1, m 164.5-166°.** Best recryst from H_2O by concentrating an aqueous soln to a small volume and allowing to crystallise. Wash the crystals with ice cold H_2O and dry in a vacuum desiccator over H_2SO_4. [*JACS* **78** 1045 *1954*]. pKa values in H_2O at 25° are 1.83 and 7.07, and in 50% EtOH 3.15 and 8.26. [*JACS* **75** 2209 *1953*]. [IR: *AC* **23** 853 *1951*].

Phenylphosphonic dichloride (P,P-dichlorophenyl phosphine oxide) *[824-72-6]* **M 195.0, b 83-84°/1mm, 135-136°/23mm, d_4^{30} 1.977, n_D^{30} 1.5578.** Fractionally distilled using a spinning band column. [*JACS* **76** 1045 *1954*; NMR: *JACS* **78** 3557, 5715 *1956*; IR: *AC* **23** 853 *1951*].

Phenylphosphonous acid *[121-70-0]* **M 141.1, m 71°.** Crystd from hot water.

Phenylphosphonous dichloride (P,P-dichloro phenyl phosphine) *[644-97-3]* **M 179.0, 68-70°/1mm, 224-226°/atm, d_4^{30} 1.9317, n_D^{35} 1.5962.** Vacuum distilled by fractionating through a 20cm column packed with glass helices (better use a spinning band column) [*JACS* **73** 755 *1951*; NMR: *JACS 78* 3557 *1956*; IR: *AC* **23** 853 *1951*]. It forms a yellow *Ni complex:* $Ni(C_6H_5Cl_2P)_4$ (**m** 91-92°, from H_2O)[*JACS* **79** 3681 *1957*] and a yellow complex with molybdenum carbonyl: $Mo(CO)_3.(C_6H_5Cl_2P)_3$ (**m** 106-110°dec)[*JCS* 2323 *1959*].

Phenyl phosphoro chloridate (diphenyl phosphoryl chloride) *[2524-64-3]* **M 268.6, b 141°/1mm, 194°/13mm, 275°/216mm, 314-316/272mm, d_4^{30} 1.2960, n_D^{35} 15490.** Fractionally distilled under a good vacuum, better use a spinning band column. [*JACS* **81** 3023 *1959*; IR: *JCS* 475, 481 *1952*].

Phenyl phosphoryl dichloride *[770-12-7]* **M 211.0, m -1°, b 103-104°/2mm, 110-111°/10mm, 130-134°/21mm, 241-243°/atm, d_4^{30} 1.4160, n_D^{30} 1.5216.** Fractionally distilled under as good a vacuum as possible using an efficient fractionating column or a spinning band column. It should be redistilled if the IR is not very good [IR: *JCS* 475, 481 *1952*; *JACS* **60** 750 *1938*, **80** 727 *1958*].

Phenylthio trimethylsilane (trimethyl phenylthio silane) *[4551-15-9]* **M 182.4, b 95-99°/12mm, d_4^{30} 0.97.** Purification is as for phenyl trimethyl silylmethyl sulphide.

Phenyl trimethoxylsilane (trimethoxysilyl benzene) *[2996-92-1]* **M 198.3, b 103°/20mm, 130.5-131°/45mm, d_4^{35} 1.022, n_D^{35} 1.4698.** Fractionate through an efficient column but note that it forms an azeotrope with MeOH which is a likely impurity. [*JACS* **75** 2712 *1953*; *J Gen Chem USSR (Engl Edn)* **25** 1079 *1955*].

Phenyl trimethylsilane (trimethylphenyl silane) *[768-32-1]* **M 150.3, b 67.3°/20mm, 98-99°/80mm, 170.6°/738mm, d_4^{25} 0.8646.** If the sample is suspect, then wash with H_2O and distil using a Podbielniak Heligrid column or better a spinning band column. [*JACS* **71** 2923 *1949*, **73** 4770 *1951*, **75** 2821 *1953*].

Phenyl trimethylsilylmethyl sulphide [(phenylthiomethyl)trimethylsilane] *[17873-08-4]* **M 196.4, b 48°/0.04mm, 113-115°/12mm, 158.5°/52mm, d_4^{30} 0.9671, n_D^{30} 1.5380.** If the sample is suspect then add H_2O, wash with 10% aqueous NaOH, H_2O again, dry (anhydrous $CaCl_2$) and fractionally distil through a 2ft column packed with glass helices. [*JACS* **76** 3713 *1954*].

Phosgene *[75-44-5]* **M 98.9, b 8.2°/756mm.** Dried with Linde 4A molecular sieves, degassed and distilled under vacuum. **HIGHLY TOXIC, should not be inhaled.**

Phosphonitrilic chloride (tetramer) *[1832-07-1]* **M $(115.9)_4$.** Purified by zone melting, then crystd from pet ether (b 40-60°) or *n*-hexane. [van der Huizen et al. *JCSDT* 1317 *1986*].

Phosphonitrilic chloride (trimer) (hexachlorocyclotriphosphazine) *[940-71-6]* **M $(115.9)_3$, m 112.8°, 113-114°.** Purified by zone melting, by crystallisation from pet.ether, *n*-hexane or benzene, and by sublimation. [van der Huizen et al. *JCSDT* 1311 *1986*; Meirovitch *JPC* **88** 1522 *1984*].

Phosphoric acid *[7664-38-2]* **M 98.0, m 42.3°.** Pyrophosphate can be removed from phosphoric acid by diluting with distilled H_2O and refluxing overnight. By cooling to 11° and seeding with crystals obtained by cooling a few millilitres in a Dry-ice/acetone bath, 85% orthophosphoric acid crystallises as $H_3PO_4.H_2O$. The crystals are separated using a sintered glass filter. It has pKa^{25} values of 2.15, 7.20 and 12.37 in H_2O.

Phosphorus (red) *[7723-14-0]* **M 31.0, m 590°/43atm, ignites at 200°, d 2.34.** Boiled for 15min with distilled H_2O, allowed to settle and washed several times with boiling H_2O. Transferred to a Büchner funnel, washed with hot H_2O until the washings are neutral, then dried at 100° and stored in a desiccator.

Phosphorus (white) *[7723-14-0]* **M 31.0, m 590, d 1.82.** Purified by melting under dilute H_2SO_4-dichromate mixture and allowed to stand for several days in the dark at room temperature. It remains liquid, and the initial milky appearance due to insoluble, oxidisable material gradually disappears. The phosporus can then be distilled under vacuum in the dark [Holmes *TFS* **58** 1916 *1962*]. Other methods include extraction with dry CS_2 followed by evaporation of the solvent, or washing with 6M HNO_3, then H_2O, and drying under vacuum. **POISONOUS.**

Phosphorus oxychloride *[10025-87-3]* **M 153.3, b 105.5°, n 1.461, d 1.675.** Distilled under reduced pressure to separate from the bulk of the HCl and the phosphoric acid, the middle fraction being distilled into ampoules containing a little purified mercury. These ampoules are sealed and stored in the dark for a 4-6 weeks with occasional shaking to facilitate reaction of any free chloride with the mercury. The $POCl_3$ is then again fractionally distilled and stored in sealed ampoules in the dark until used [Herber *JACS* **82** 792 *1960*]. Lewis and Sowerby [*JCS* 336 *1957*] refluxed their distilled $POCl_3$ with Na wire for 4h, then removed the Na and again distilled.

Phosphorus pentabromide *[7789-69-7]* **M 430.6, m <100°, b 106°(dec).** Dissolved in pure nitrobenzene at 60°, filtering off any insoluble residue on to sintered glass, then crystallised by cooling. Washed with dry Et_2O and removed the ether in a current of dry N_2. (All manipulations should be performed in a dry-box.) [Harris and Payne *JCS* 3732 *1958*]. Fumes in moist air because of hydrolysis. **TOXIC**.

Phosphorus pentachloride *[10026-13-8]* **M 208.2, m 179-180°(sublimes).** Sublimed at 160-170° in an atmosphere of chlorine. The excess chlorine was then displaced by dry N_2 gas. All subsequent manipulations were performed in a dry-box [Downs and Johnson *JACS* **77** 2098 *1955*]. Fumes in moist air.

Phosphorus pentasulphide *[1314-80-3]* **M 444.5, m 277-283°.** Purified by extraction and crystallisation with CS_2, using a Soxhlet extractor. Liberates H_2S in moist air.

Phosphorus pentoxide *[1314-56-3]* **M 141.9.** Sublimed at 250° under vacuum into glass ampoules. Fumes in moist air and reacts violently with water.

Phosphorus sesquisulphide P_4S_3 *[1314-85-8]* **M 220.1, m 172°.** Extracted with CS_2, filtered and evapd to dryness. Placed in H_2O, and steam was passed through for an hour. The H_2O was then removed, the solid was dried, followed by crystallisation from CS_2 [Rogers and Gross *JACS* **74** 5294 *1952*].

Phosphorus sulphochloride (phosphorus thiochloride) *[3982-91-0]* **M 169.4, m -35°, b 122-124°, 125°(corr), d_4^{30} 1.64, n_D^{30} 1.556.** Possible impurities are PCl_5, H_3PO_4, HCl and $AlCl_3$. Gently mix with H_2O to avoid a heavy emulsion, the product decolorises immediately and settles to the bottom layer.

Phosphorus tribromide *[7789-60-8]* **M 270.7, m -41.5°, b 168-170°/725mm, 171-173°/atm, 172.9°/760mm(corr), d_4^{30} 2.852.** It is decomposed by moisture, should be kept dry and is *corrosive*. Purified by distillation through an efficient fractionating column (see Whitmore and Lux *JACS* **54** 3451] in a slow stream of dry N_2, i.e. under strictly dry conditions. [*Inorg Synth* **2** 147 *1946*; *Org Synth* Col Vol II 358 *1943*]. Dissolve in CCl_4, dry over $CaCl_2$, filter and distil. [*Handbook of Preparative Inorganic Chemistry (ed Brauer)* vol I 532 *1963*]. Store in sealed ampoules under N_2 and kept away from light.

Phosphorus trichloride *[7719-12-2]* **M 137.3, b 76°, n 1.515, d 1.575.** Heated under reflux to expel dissolved HCl, then distilled. It has been further purified by vacuum fractionation several times through a -45° trap into a receiver at -78°.

Phosphorus triiodide *[13455-01-11]* **M 411.7, m 61°.** Decomposes in moist air and must be kept in a desiccator over $CaCl_2$. It is crystallised from sulphur-free CS_2 otherwise the m decreases to *ca* 55°. It is best prepared freshly. [*JACS* **49** 307 *1927*; *Handbook of Preparative Inorganic Chemistry (ed Brauer)* vol I 541 *1963*].

12-Phosphotungstic acid *[12501-23-4]* **M 2880.2.** A few drops of conc HNO_3 were added to 100g of phosphotungstic acid dissolved in 75ml of water, in a separating funnel, and the soln was extracted with ethyl ether. The lowest of the three layers, which contained a phosphotungstic acid-ether complex, was separated, washed several times with 2M HCl, then with water and again extracted with ether. Evaporation of the ether, under vacuum with mild heating on a water bath gave crystals which were dried under vacuum and ground [Matijevic and Kerker, *JACS* **81** 1307 *1959*].

Phthalocyanine *[574-93-6]* **M 514.6.** Purified by sublimation (two to three times) in an argon flow at 300-400Pa. Similarly for the Cu(II), Ni(II), Pb(II), VO(II) and Zn(II) phthalocyanine complexes.

Platinum (II) acetylacetonate *[15170-57-7]* **M 393.3, m 249-252°.** Recrystd from C_6H_6 as yellow crystals and dried in air or in a vacuum desiccator. [*B* **34** 2584 *1901*].

Platinum (II) chloride *[10025-65-7]* **M 266.0, d 5.87.** It is purified by heating at 450° in a stream of Cl_2 for 2h. Some sublimation occurs because the $PtCl_2$ sublimes completely at 560° as red (almost black) needles. This sublimate can be combined to the bulk chloride and while still at *ca* 450° it should be transferred to a container and cooled in a desiccator. A probable impurity is $PtCl_4$. To test for this add a few drops of H_2O (in which $PtCl_4$ is soluble) to the salt, filter and add an equal volume of saturated aqueous NH_4Cl to the filtrate. If no ppte is formed within 1 min then the product is pure. If a ppte appears then the whole material should be washed with small volumes of H_2O until the soluble $PtCl_4$ is removed. The purified $PtCl_2$ is partly dried by suction and then dried in a vacuum desiccator over P_2O_5. It is insoluble in H_2O but soluble in HCl to form chloroplatinic acid (H_2PtCl_4) by disproportionation. [*Inorg Synth* **6** 209 *1960*].

Platinum tetrakis(triphenylphosphine) see **tetrakis(triphenylphosphine) platinum.**

Poly(sodium 4-styrenesulphonate) [-$CH_2CH(C_6H_4SO_3Na)$-] *[25704-18-1]*. Recrystd from EtOH.

Potassium (metal) *[7440-09-07]* **M 39.1, m 62.3°.** Oil was removed from the surface of the metal by immersion in *n*-hexane and pure Et_2O for long periods. The surface oxide was next removed by scraping under ether, and the potassium was melted under vacuum. It was then allowed to flow through metal constricitons into tubes that could be sealed, followed by distillation under vacuum in the absence of mercury vapour (see Sodium). **EXPLOSIVE IN WATER.**

Potassium acetate *[127-08-2]* **M 98.2.** Crystd three times from water-ethanol (1:1) dried to constant weight in a vacuum oven, or crystd from anhydrous acetic acid and pumped dry under vacuum for 30h at 100°.

Potassium 4-aminobenzoate *[138-84-1]* **M 175.2.** Crystd from EtOH.

Potassium antimonyltartrate (H_2O) *[28300-74-5]* **M 333.9, [a]$_D$ +141° (c 2,H_2O).** Crystd from water (3ml/g) between 100° and 0°. Dried at 100°.

Potassium benzoate *[582-25-2]* **M 160.2.** Crystd from water (1ml/g) between 100° and 0°.

Potassium bicarbonate *[298-14-6]* **M 100.1.** Crystd from water at 65-70° (1.25ml/g) by filtering, then cooling to 15°. During all operations, CO_2 is passed through the stirred mixture. The crystals, sucked dry at the pump, are washed with distilled water, dried in air and then over H_2SO_4 in an atmosphere of CO_2.

Potassium biiodate *[13455-24-8]* **M 389.9.** Crystd three times from hot water (3ml/g), stirred continuously during each cooling. After drying at 100° for several hours, the crystals are suitable for use in volumetric analysis.

Potassium bisulphate *[7646-93-7]* **M 136.2, m 214°.** Crystd from H_2O(1ml/g) between 100° and 0°.

Potassium borohydride *[13762-51-1]* **M 53.9.** Crystd from liquid ammonia.

Potassium bromate *[7758-01-2]* **M 167.0.** Crystd from distilled H_2O(2ml/g) between 100° and 0°. To remove bromide contamination, a 5% soln in distilled H_2O, cooled to 10°, has been bubbled with gaseous chlorine for 2h, then filtered and extracted with reagent grade CCl_4 until colourless and odourless. After evaporating the aqueous phase to about half its volume, it was cooled again slowly to about 10°. The crystalline $KBrO_3$ was separated, washed with 95% EtOH and vacuum dried [Boyd, Cobble and Wexler *JACS* **74** 237 *1952*]. Another way to remove Br^- ions was by stirring several times in MeOH and then dried at 150° [Field and Boyd *JPC* **89** 3767 *1985*].

Potassium bromide *[7758-02-3]* **M 119.0.** Crystd from distilled water (1ml/g) between 100° and 0°. Washed with 95% EtOH, followed by Et_2O. Dried in air, then heated at 115° for 1h, pulverised and heated in a vacuum oven at 130° for 4h. Has also been crystd from aqueous 30% EtOH, or EtOH, and dried over P_2O_5 under vacuum before heating in an oven.

Potassium *tert*-butoxide *[865-47-4]* **M 112.2.** It sublimes at 220°/1 Torr. Last traces of *tert*-BuOH are removed by heating at 150-160°/2mm for 1h. It is best prepared fresh; likely impurities are *tert*-BuOH, KOH and K_2CO_3 depending on exposure to air. Its solubility at 25°-26° in hexane, toluene, Et_2O, and THF is 0.27%, 2.27%, 4.34% and 25.0% repectively. [*JACS* **78** 5938, 4364 *1956*].

Potassium carbonate *[584-08-7]* **M 138.2.** Crystd from water between 100° and 0°.

Potassium chlorate *[3811-04-9]* **M 122.6.** Crystd from water (1.8ml/g) between 100° and 0°, and the crystals are filtered onto sintered glass.

Potassium chloride *[7447-40-7]* **M 74.6.** Dissolved in conductivity water, filtered, and saturated with chlorine (generated from A.R. HCl and $KMnO_4$). Excess chlorine was boiled off, and the KCl was ppted by HCl (generated by dropping conc A.R. HCl into conc H_2SO_4). The ppte was washed with water, dissolved in conductivity water at 90-95°, and crystd by cooling to about -5°. The crystals were drained at the centrifuge, dried in a vacuum desiccator at room temperature, then fused in a platinum dish under N_2, cooled and stored in desiccator. Potassium chloride has also been sublimed in a stream of prepurified N_2 gas and collected by electrostatic discharge [Craig and McIntosh *Canad J Chem* **30** 448 *1952*].

Potassium chromate *[7784-00-6]* **M 194.2.** Crystd from conductivity water (0.6g/ml at 20°), and dried between 135° and 170°.

Potassium cobalticyanide *[13963-58-1]* **M 332.4.** Crystd from water to remove traces of HCN.

Potassium cyanate *[590-28-3]* **M 81.1.** Common impurities include ammonia and bicarbonate ion (from hydrolysis). Purified by preparing a saturated aqueous solution at 50°, neutralising with acetic acid, filtering, adding two volumes of EtOH and keeping for 3-4h in an ice bath. (More EtOH can lead to co-precipitation of $KHCO_3$.) Filtered, washed with EtOH and dried rapidly in a vacuum desiccator (P_2O_5). The process is repeated [Vanderzee and Meyers *JCS* **65** 153 *1961*].

Potassium cyanide *[151-50-8]* **M 65.1.** A saturated solution in H_2O-ethanol (1:3) at 60° was filtered and cooled to room temperature. Absolute EtOH was added, with stirring, until crystallisation ceased. The solution was again allowed to cool to room temperature (during 2-3h) then the crystals were filtered off, washed with absolute EtOH, and dried, first at 70-80° for 2-3h, then at 105° for 2h [Brown, Adisesh and Taylor *JPC* **66** 2426 *1962*]. Also purified by vacuum melting and zone refining. **HIGHLY POISONOUS.**

Potassium dichromate *[7778-50-9]* **M 294.2.** Crystd from water (1ml/g) between 100° and 0° and dried under vacuum at 156°.

Potassium dihydrogen citrate *[866-83-1]* **M 230.2.** Crystd from water. Dried at 80°.

Potassium dihydrogen phosphate *[7778-77-0]* **M 136.1.** Dissolved in boiling distilled water (2ml/g), kept on a boiling water-bath for several hours, then filtered through paper pulp to remove any turbidity. Cooled rapidly with constant stirring, and the crystals were separated on to hardened filter paper, using suction, washed twice with ice-cold water, once with 50% EtOH, and dried at 105°. Alternative crystns are from water, then 50% EtOH, and again water, or from conc aqueous solution by addition of EtOH. Freed from traces of Cu by extracting its aqueous solution with diphenylthiocarbazone in CCl_4, followed by repeated extraction with CCl_4 to remove traces of diphenylthiocarbazone.

Potassium dithionate *[13455-20-4]* **M 238.3.** Crystd from water (1.5ml/g) between 100° and 0°.

Potassium ethylxanthate *[140-89-6]* **M 160.3, m > 215°(decomp).** Crystd from absolute EtOH, ligroin-ethanol or acetone by addition of Et_2O. Washed with ether, then dried in a desiccator.

Potassium ferricyanide *[13746-66-2]* **M 329.3.** Crystd repeatedly from hot water (1.3ml/g). Dried under vacuum in a desiccator.

Potassium ferrocyanide ($3H_2O$) *[14459-95-1]* **M 422.4.** Crystd repeatedly from distilled water, never heating above 60°. Prepared anhydrous by drying at 110° over P_2O_5 in a vacuum desiccator. To obtain the trihydrate, it is necessary to equilibrate in a desiccator over saturated aqueous soln of sucrose and NaCl. Can also be ppted from a saturated solution at 0° by adding an equal volume of cold 95% EtOH, standing for several hours, then centrifuging and washing with cold 95% EtOH. Finally sucked air dry with a water-pump. The anhydrous salt can be obtained by drying in a platinum boat at 90° in a slow stream of N_2 [Loftfield and Swift *JACS* **60** 3083 *1938*].

Potassium fluoroborate *[14075-53-7]* **M 152.9.** Crystd several times from conductivity water (15ml/g).

Potassium fluorosilicate *[16871-90-2]* **M 220.3.** Crystd several times from conductivity water (100ml/g) between 100° and 0°.

Potassium hexachloroiridate (IV) *[16920-56-2]* **M 483.1.** Crystd from hot aqueous solution containing a few drops of HNO_3.

Potassium hexachloroosmate (IV) *[16871-60-6]* **M 481.1.** Crystd from hot dilute aqueous HCl.

Potassium hexachloroplatinate (IV) *[16921-30-5]* **M 486.0.** Crystd from water (20ml/g) between 100° and 0°.

Potassium hexacyanochromate (III) ($3H_2O$) *[13601-11-1]* **M 418.5.** Crystd from water.

Potassium hexafluorophosphate *[17084-13-8]* **M 184.1.** Crystd from alkaline aqueous solution, using polyethylene vessels, or from 95% EtOH, and dried in a vacuum desiccator over KOH.

Potassium hydrogen fluoride *[7789-29-9]* **M 78.1.**
Potassium hydrogen D-glucarate *[18404-47-2]* **M 248.2, m 188°(dec).** Crystd from water.

Potassium hydrogen malate *[4675-64-3]* **M 172.2.** A saturated aqueous solution at 60° was decolorised with activated charcoal, and filtered. The filtrate was cooled in water-ice bath and the salt was ppted by addition of EtOH. After being crystallised five times from ethanol-water mixtures, it was dried overnight at 130° in air [Eden and Bates *J Res Nat Bur Stand* **62** 161 *1959*].

Potassium hydrogen oxalate (H_2O) *[127-95-7]* **M 137.1.** Crystd from water by dissolving 20g in 100ml water at 60° containing 4g of potassium oxalate, filtering and allowing to cool to 25°. The crystals, after washing three or four times with water, are allowed to dry in air.

Potassium hydrogen phthalate *[877-24-7]* **M 204.2.** Crystd first from a dilute aqueous solution of K_2CO_3, then H_2O(3ml/g) between 100° and 0. Before being used as a standard in volumetric analysis, analytical grade potassium hydrogen phthalate should be dried at 120° for 2h, then allowed to cool in a desiccator.

Potassium hydrogen saccharate see **potassium hydrogen D-glucarate.**

Potassium hydrogen *d*-tartrate *[868-14-4]* **M 188.2, $[\alpha]_{546}^{20}$ +37.5° (c 10, M NaOH).** Crystd from water (17ml/g) between 100° and 0°. Dried at 110°.

Potassium hydroxide (solution) *[1310-58-3]* **M 56.1.** Its carbonate content can be reduced by rinsing KOH sticks rapidly with water prior to dissolving them in boiled out distilled water. Alternatively, a slight excess of saturated $BaCl_2$ or $Ba(OH)_2$ can be added to the soln which, after shaking well, is left so that the $BaCO_3$ ppte will separate out. Davies and Nancollas [Nature **165** 237 *1950*] rendered KOH solutions carbonate free by ion exchange using a column of Amberlite IR-100 in the OH^- form.

Potassium iodate *[7758-05-6]* **M 214.0.** Crystd twice from distilled water (3ml/g) between 100° and 0°, dried for 2h at 140° and cooled in a desiccator. Analytical reagent grade material dried in this way is suitable for use as an analytical standard.

Potassium iodide *[7681-11-0]* **M 166.0.** Crystd from distilled water (0.5ml/g) by filtering the near-boiling soln and cooling. To minimise oxidation to iodine, the crystn can be carried out under N_2 and the salt is dried under vacuum over P_2O_5 at 70-100°. Before drying, the crystals can be washed with EtOH or with acetone followed by pet ether. Has also been recrystallised from water/ethanol.

Potassium ionophore I (valinomycin) *[2001-95-8]* **M 111.3, m 186-187°, 190°,** $[\alpha]_D^{20}$ **+31.0° (c 1.6, C_6H_6).** Crystallises from dibutyl ether as colourless plates, also from Et_2O. It crystallises in two modifications, form A from 1-octane and form B from $EtOH/H_2O$. Soluble in pet ether, $CHCl_3$, AcOH, BuOAc and Me_2CO. [IR,NMR: *B* **88** 57 *1955*; *JACS* **97** 7242 *1975*].

Potassium isoamyl xanthate *[61792-26-5]* **M 202.4.** Crystd twice from acetone-ethyl ether. Dried in a desiccator for two days and stored under refrigeration.

Potassium laurate *[10124-65-9]* **M 338.4.** Recrystd three times from EtOH [Neto and Helene *JPC* **91** 1466 *1987*].

Potassium metaperiodate see **potassium periodate.**

Potassium nickel sulphate ($6H_2O$) *[13842-46-1]* **M 437.1.** Crystd from H_2O(1.7ml/g) between 75° and 0°.

Potassium nitrate *[7757-79-1]* **M 101.1, m 334°.** Crystd from hot water (0.5ml/g) by cooling (*cf* potassium nitrite below). Dried for 12h under vacuum at 70°.

Potassium nitrite *[7758-09-0]* **M 85.1, m 350°(dec).** A saturated solution at 0° can be warmed and partially evaporated under vacuum, the crystals so obtained being filtered from the warm solution. (This procedure is designed to reduce the level of nitrate impurity and is based on the effects of temperature on solubility. The solubility of KNO_3 in water is 13g/100ml at 0°, 247g/100ml at 100°; for KNO_2 the corresponding figures are 280g/100ml and 413g/100ml.)

Potassium nonafluorobutane sulphonate *[29420-49-3]* **M 338.2.** Wash with H_2O and dry in vacuum. The K salt when distilled with 100% H_2SO_4 gives the free acid which can be distilled (**b** 105°/22mm, 210-212°/760mm) and then converted to the K salt. [*JCS* 2640 *1957*].

Potassium oleate *[143-18-0]* **M 320.6.** Crystd from EtOH (1ml/g).

Potassium osmate (VI) dihydrate *[19718-36-6]* **M 368.4.** *Hygroscopic* **POISONOUS** crystals which are soluble in H_2O but insol in EtOH and Et_2O. It decomposes slowly in H_2O to form the tetroxide which attacks the eyes. The solid should be kept dry and in this form it is relatively safe. [*S* 610 *1972*].

Potassium oxalate *[6487-48-5]* **M 184.2.** Crystd from hot water.

Potassium perchlorate *[7778-74-7]* **M 138.6.** Crystd from boiling water (5ml/g) by cooling. Dried under vacuum at 105°.

Potassium periodate *[779-21-8]* **M 230.0.** Crystd from distilled water.

Potassium permanganate *[7722-64-7]* **M 158.0.** Crystd from hot water (4ml/g at 65°), then dried in a vacuum desiccator over $CaSO_4$. Phillips and Taylor [*JCS* 4242 *1962*] cooled an aqueous solution of $KMnO_4$, saturated at 60°, to room temperature in the dark, and filtered through a No.4 porosity sintered-glass filter funnel. The solution was allowed to evaporate in air in the dark for 12h, and the supernatant liquid was decanted from the crystals, which were dried as quickly as possible with filter paper.

Potassium peroxydisulphate *[7727-21-1]* **M 270.3.** Crystd twice from distilled water (10ml/g) and dried at 50° in a vacuum desiccator.

Potassium perrhenate *[10466-65-6]* **M 289.3.** Crystd from water (7ml/g), then fused in a platinum crucible in air at 750°.

Potassium persulphate see **potassium peroxydisulphate.**

Potassium *p*-phenolsulphonate *[30145-40-5]* **M 212.3.** Crystd several times from distilled water at 90°, after treatment with charcoal, by cooling to *ca* 10°. Dried at 90-100°.

Potassium phthalimide (phthalimide potassium salt) *[1074-82-4]* **M 185.2, m >300°.** The solid may contain phthalimide and K_2CO_3 from hydrolysis. If too much hydrolysis has occurred (this can be checked by extraction with cold Me_2CO in which the salt is insoluble, evaporation of the Me_2CO and weighing the residue) it would be better to prepare it afresh. If little hydrolysis had occurred then recryst from a large volume of EtOH, and wash solid with a little Me_eCO and dry in a continuous vacuum to constant weight. [Salzerg and Supriawski *Org Synth* Coll Vol I 119 *1941*; Raman and IR: Hase *J Molecular Structure* **48** 33 *1978*; Dykman *Chemistry and Industry (London)* 40 *1972*; IR, NMR: Assef et al. *Bull Soc Chim France* II 167 *1979*].

Potassium picrate *[573-83-1]* **M 267.2.** Crystd from water or 95% EtOH, and dried at room temperature in vacuum. It is soluble in 200 parts of cold water and 4 parts of boiling water. **THE DRY SOLID EXPLODES WHEN STRUCK OR HEATED.**

Potassium propionate *[327-62-8]* **M 112.2.** Crystd from water (30ml/g) or 95% EtOH.

Potassium reineckate *[34430-73-4]* **M 357.5.** Crystd from KNO_3 soln, then from warm water [Adamson *JACS* **80** 3183 *1958*].

Potassium (VI) ruthenate *[31111-21-4]* **M 243.3.** Dissolve in H_2O and evaporate until crystals are formed. The crystals are iridescent green prisms which appear red as thin films. Possible impurity is RuO_4; in this case wash with CCl_4 (which dissolves RuO_4). The concn of an aqueous solution of RuO_4^{2-} (orange colour) can be estimated from the absorbance at 385nm (ε 1030 M^{-1} cm^{-1}), or at 460nm (ε 1820 M^{-1} cm^{-1}). [*Canad J Chem* **50** 3741 *1972*; *JACS* **74** 5012 *1952*; *Handbook of Preparative Inorganic Chemistry (ed Brauer)* Vol II 1600 *1965*].

Potassium selenocyanate *[3425-46-5]* **M 144.1.** Dissolved in acetone, filtered and ppted by adding Et_2O.

Potassium sodium tartrate ($4H_2O$) *[304-59-6]* **M 282.3.** Crystd from distilled water (1.5ml/g) by cooling to 0°.

Potassium sulphate *[7778-80-5]* **M 174.3.** Crystd from distilled water (4ml/g at 20°; 8ml/g at 100°) between 100° and 0°.

Potassium *d*-tartrate (H_2O) *[921-53-9]* **M 235.3.** Crystd from distilled water (solubility: 0.4ml/g at 100°; 0.7ml/g at 14°).

Potassium tetrachloroplatinate(II) *[10025-99-7]* **M 415.1.** Crystd from aqueous 0.75M HCl (20ml/g) between 100° and 0°. Washed with ice-cold water and dried.

Potassium tetracyanopalladate (II) $3H_2O$ *[14516-46-2]* **M 377.4.** *All operations should be carried out in an efficient fume cupboard - **Cyanide is very** **POISONOUS*** Dissolve the complex (*ca* 5g) in a solution of KCN (4g) in H_2O (75ml) with warming and stirring and evaporate hot till crystals appear. Cool, filter off the crystals and wash with a few drops of cold H_2O. Further concentration of the mother liquors provides more crystals. The complex is recrystallised from H_2O as the colourless *trihydrate*. It effloresces in dry air and dehydrates at 100° to the *monohydrate*. The *anhydrous salt* is obtained by heating at 200°, but at higher temperatures it decomposes to $(CN)_2$, Pd and KCN. [*Inorg Synth* **2** 245 *1946*].

Potassium tetrafluoroborate (potassium borofluoride) *[14075-53-7]* **M 125.9, m 530°, d_4^{30} 2.505.** Cryst from H_2O (sol % (temp): 0.3 (3°), 0.45 (20°), 1.4 (40°), 6.27 (100°), and dry under vacuum. Non-hygroscopic salt. A 10% solution is transparent blue at 100°, green at 90° and yellow at 60°. [*B* **65** 535 *1932*; *Handbook of Preparative Inorganic Chemistry (ed Brauer)* vol 1 223 *1963*].

Potassium tetroxalate ($2H_2O$) *[127-96-8]* **M 358.3.** Crystd from water below 50°. Dried below 60° at atmospheric pressure.

Potassium tetraphenylborate *[3244-41-5]* **M 358.3.** Ppted from a soln of KCl acidified with dilute HCl, then crystallised twice from acetone, washed thoroughly with water and dried at 110° [Findeis and de Vries *AC* **28** 1899 *1956*].

Potassium thiocyanate *[333-20-0]* **M 97.2, m 172°.** Crystd from H_2O if much chloride ion is present in the salt, otherwise from EtOH or MeOH (optionally by addition of Et_2O). Filtered on a Büchner funnel without paper, and dried in a desiccator at room temperature before being heated for 1h at 150°, with a final 10-20min at 200° to remove the last traces of solvent [Kolthoff and Lingane *JACS* **57** 126 *1935*]. Stored in the dark.

Potassium thiosulphate *[10294-66-3]* **M 190.3.** Crystd from warm water (0.5ml/g) by cooling in an ice-salt mixture.

Potassium thiotosylate *[28519-50-8]* **M 226.4.** Recrystallise from absolute EtOH and dry at 130°. In wet EtOH the *monohydrate* can be obtained. [*J Gen Chem USSR (Engl Edn)* **28** 1345 *1958*].

Potassium trifluoroacetate *[2923-16-2]* **M 152.1, m 140-142°.** To purify dissolve the salt in trifluoroacetic acid with *ca* 2% of trifluoroacetic anhydride, filter and evaporate carefully to dryness (avoid over heating), and finally dry in a vacuum at 100°. It can be recrystallised from trifluoroacetic acid (solubility in the acid is *ca* 50.1%). [*JACS* **74** 4746 *1952*, **76** 4285 *1954*; *JINC* **9** 166 *1959*].

Potassium trimethylsilanolate (trimethylsilanol potassium salt) *[10519-96-7]* **M 128.3, m 131-135° (cubic form), d^{25} 1.11, 125°dec (orthorhombic form).** Recryst from H_2O and dried at 100°/1-2mm. [*JACS* **75** 5615 *1953*; IR: *JOC* **17** 1555 *1952*].

Potassium tungstate (*ortho* $2H_2O$) *[37349-36-3]* **M 362.1.** Crystd from hot water (0.7ml/g).

Praseodymium acetate *[6192-12-7]* **M 318.1.** Recrystd several times from water [Ganapathyl *JACS* **109** 3159 *1986*].

Praseodymium trichloride ($6H_2O$) *[10361-79-2]* **M 355.4.** Its 1M soln in 6M HCl was passed twice through a Dowex-1 anion-exchange column. The eluate was evaporated in a vacuum desiccator to about half its volume and allowed to crystallise [Katzin and Gulyas *JPC* **66** 494 *1962*].

Praseodymium oxide (Pr_6O_{11}) *[12036-32-7]* **M 1021.4.** Dissolved in acid, ppted as the oxalate and ignited at 650°.

Propargyl triphenyl phosphonium bromide *[2091-46-5]* **M 381.4, m 179°.** Recrystallises from 2-propanol as white plates. Also crystallises from EtOH, **m** 156-158°. IR has ν 1440, 1110cm^{-1} (P-C). [*A* **682** 62 *1965*; *JOC* **42** 200 *1977*].

Pyridinium chlorochromate *[26299-14-9]* **M 215.6.** Dry in a vacuum for 1h. It is not hygroscopic and can be stored for extended periods at room temp without change. If very suspect it can be readily prepared. [*TET LETT* 2647 *1975*; *S* 245 *1982*].

Pyridinium dichromate *[20039-37-6]* **M 376.2, m 144-146°, 145-148°.** Dissolve in the minimum volume of H_2O and add 5 volumes of cold Me_2CO and cool to -20°. After 3h the orange crystals are collected, washed with a little cold Me_2CO and dried in a vacuum. It is soluble in dimethylformamide (0.9g/ml at 25°), and in H_2O, and has a characteristic IR with ν 930, 875, 765 and 730cm^{-1}. [*TET LETT* 399 *1979*; *Chemistry & Industry (London)* 1594 *1969*].

3-(2-Pyridyl)-5,6-diphenyl-1,2,4-triazine-*p,p'*-disulphonic acid, monosodium salt (H_2O) *[63451-29-6]* **M 510.5.** Purified by recrystn from water or by dissolving in the minimum volume of water, followed by addition of EtOH to ppte the pure salt.

Pyrocatechol Violet *[115-41-3]* **M 386.4, ε 1.4 x 10^4 at 445nm in acetate buffer pH 5.2-5.4.** Recrystd from glacial acetic acid. Very *hygroscopic*. [Mustafin et al. *Zh Analit Khim* **22** 1808 *1967*].

Pyrogallol Red *[32638-38-3]* **M 418.4, m >300°(dec), e 4.3 x 10^4 at 542nm, pH 7.9-8.6.** Recrystd from aqueous alkaline solution (Na_2CO_3 or NaOH) by precipitation on acidification [Suk *Collect Czech Chem Commun* **31** 3127 *1966*].

Quinolinium chlorochromate *[108703-35-1]* M 265.6, m 127-130°.

A yellow-brown solid which is stable in air for long periods. If it has deteriorated or been kept for too long, it is best to prepare it freshly. Add freshly distilled quinoline (13ml) to a mixture of chromic acid (CrO_3) (10g) and ~ 5M HCl (11ml of conc HCl and 10ml of H_2O) at 0°. A yellow-brown solid separates, it is filtered off on a sintered glass funnel, dried for 1h in a vacuum, and can be stored for extended periods without serious loss in activity. It is a good oxidant for primary alcohol in CH_2Cl_2. [Singh et al. *Chemistry and Industry (London)* 751 *1986*; method of Corey and Suggs *TET LETT* 2647 *1975*].

Reinecke salt see **ammonium reineckate.**

Rhodium (II) acetate dimer ($2H_2O$) *[15956-28-2]* **M 478.0.** Dissolve 5g in boiling MeOH (*ca* 600ml) and filter. Concentrate to 400ml and chill overnight at *ca* 0° to give dark green crystals of the MeOH adduct. Concn of the mother liquors gives a further crop of $[Rh(OAc)_2]_2.2MeOH$. The adduct is then heated at 45° in vacuum for 2h (all MeOH is lost) to leave the emerald green crystals of the actetate. [*JCS (A)* 3322 *1970*]. Alternatively dissolve in glacial AcOH and reflux for a few hs to give an emerald green soln. Evaporate most of the AcOH on a steam bath then heat the residue at 120°/1h. Extract the residue with boiling Me_2CO. Filter, concentrate to half its volume and keep at 0°/18h. Collect the crystals, wash with ice cold Me_2CO and dry at 110°. It is soluble in most organic solvents with which it forms adducts including NMe_3 and Me_2S and give solutions with different colours varying from green to orange and red. [UV: *Inorg Synth* **2** 960 *1963*].

Rhodium (II) chloride *[10049-07-7]* **M 209.3.** Probable impurities are KCl and HCl. Wash solid well with small volumes of H_2O to remove excess KCl and KOH and dissolve in the minimum volume of conc HCl. Evaporate to dryness on a steam bath to give wine-red coloured $RhCl_3.3H_2O$. Leave on the steam bath until odour of HCl is lost - do not try to dry further as it begins to decompose above 100° to the oxide and

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HCL. It is not soluble in H_2O but soluble in alkalis or CN solns and forms double salts with alkali chlorides. [*Inorg Synth* **7** 214 *1063*].

Rubidium bromide *[7789-39-1]* **M 165.4, m 682°, b 1340°, d 3.35.** A white crystalline powder which crystallises from H_2O (solubility: 50% in cold and 67% in boiling H_2O to give a neutral soln). Also crystd from near-boiling water (0.5ml/g) by cooling to 0°.

Rubidium chlorate *[13446-71-4]* **M 168.9.** Crystd from water (1.6ml/g) by cooling from 100°.

Rubidium chloride *[7791-11-9]* **M 120.9.** Crystd from water (0.7ml/g) by cooling to 0° from 100°.

Rubidium nitrate *[13126-12-0]* **M 147.5.** Crystd from hot water (0.25ml/g) by cooling to room temperature.

Rubidium perchlorate *[13510-42-4]* **M 184.9.** Crystd from hot water (1.6ml/g) by cooling to 0°.

Rubidium sulphate *[7488-54-2]* **M 267.0.** Crystd from water (1.2ml/g) between 100° and 0°.

Ruthenium (III) acetylacetonate *[14284-93-6]* **M 398.4, 240°(dec).** Purified by recrystn from benzene. [*JACS* **74** 6146 *1952*].

Ruthenium (III) chloride ($2H_2O$) (β–form) *[148980-67-0]* **M 207.4 + H_2O.** Dissolve in H_2O, filter and concentrate to crystallise in the absence of air to avoid oxidation. Evaporate the solution in a stream of HCl gas while being heated just below it boiling point until a syrup is formed and finally to dryness at 80-100° and dried in a vacuum over H_2SO_4. When heated at 700° in the presence of Cl_2 the insoluble α-form is obtained [*Handbook of Preparative Inorganic Chemistry (ed Brauer)* Vol II 1598 *1965*; *JOC* **46** 3936 *1981*].

Ruthenium dioxide *[12157-25-6]* **M 133.1.** Freed from nitrates by boiling in distilled water and filtering. A more complete purification is based on fusion in a KOH-KNO_3 mix to form the soluble ruthenate and perruthenate salts. The melt is dissolved in water, and filtered, then acetone is added to reduce the ruthenates to the insoluble hydrate oxide which, after making a slurry with paper pulp, is filtered and ignited in air to form the anhydrous oxide [Campbell, Ortner and Anderson *AC* **33** 58 *1961*].

Ruthenocene [bis-(cyclopentadienyl)ruthenium] *[1287-13-4]* **M 231.2, m 195.5°, 199-210°.** Sublime in high vacuum at 120°. Yellow crystals which can be recrystallised from CCl_4 as transparent plates. [*JACS* **74** 6146 *1952*].

Selenious acid *[7783-00-8]* M 129.0. Crystd from water.

Selenium *[7782-49-2]* **M 79.0, m 217.4°.** Dissolved in small portions in hot conc HNO_3 (2ml/g) filtered and evaporated to dryness to give selenious acid which was then dissolved in conc HCl. Passage of SO_2 into the solution ppted selenium (but not tellurium) which was filtered off and washed with conc HCl. This purification process was repeated. The selenium was then converted twice to the selenocyanate by treating with a 10% excess of 3M aqueous KCN, heating for half an hour on a sand-bath and filtering. Addition of an equal weight of chopped ice to the cold solution, followed by an excess of cold, conc HCl, with stirring (in a well ventilated fume hood because HCN is evolved) ppted selenium powder, which, after washing with water until colourless, and then with MeOH, was heated in an oven at 105°, then by fusion for 2h under vacuum. It was cooled, crushed and stored in a desiccator [Tideswell and McCullough *JACS* **78** 3036 *1956*].

Selenium dioxide *[7446-08-4]* **M 111.0, m 340°.** Purified by sublimation, or by solution in HNO_3, pptn of selenium which, after standing for several hours or boiling, is filtered off, then re-oxidised by HNO_3 and cautiously evaporated to dryness below 200°. The dioxide is dissolved in water and again evaporated to dryness.

Silica *[7631-86-9].* Purification of silica for high technology applications uses isopiestic vapour distillation from conc volatile acids and is absorbed in high purity water. The impurities remain behind. Preliminary cleaning to remove surface contaminants uses dip etching in HF or a mixture of HCl, H_2O_2 and deionised water [Phelan and Powell *Analyst* **109** 1299 *1984*].

Silica gel *[63231-67-4].* Before use as a drying agent, silica gel is heated in an oven, then cooled in a desiccator. Conditions in the literature range from heating at 110° for 15h to 250° for 2-3h. Silica gel has been purified by washing with hot acid (in one case successively with aqua regia, conc HNO_3, then conc HCl; in another case digested overnight with hot conc H_2SO_4), followed by exhaustive washing with distilled water (one week in a Soxhlet apparatus has also been used), and prolonged oven drying. Alternatively, silica gel has been extracted with acetone until all soluble material was removed, then dried in a current of air, washed with distilled water and oven dried. Silica gel has also been washed successively with water, M HCl, water, and acetone, then activated at 110° for 15h.

Silicon monoxide *[10097-28-6]* **M 44.1, m > 1700°, d 2.18.** Purified by sublimation in a porcelain tube in a furnace at 1250° (4h) in a high vacuum (10^{-4}mm) in a stream of N_2. It is obtained as brownish black scales. [*Handbook of Preparative Inorganic Chemistry (ed Brauer)* vol I 696 *1963*].

Silicon tetraacetate *[562-90-3]* **M 264.3, m 110-111°, b 148°/5-6mm.** It can be crystallised from mixtures of CCl_4 and pet ether or Et_2O, or from acetic anhydride and then dried in a vacuum desiccator over KOH. Ac_2O adheres to the crystals and is removed first by drying at room temp then at 100° for several hours. It is soluble in Me_2CO, is very *hygroscopic* and effervesces with H_2O. It decomposes at 160-170°. [*Z Obsc Chim (Engl Edn)* **27** 985 *1957*; *Handbook of Preparative Inorganic Chemistry (Brauer)* vol I 701 *1963*].

Silicon tetrachloride *[10026-04-7]* **M 169.9, m -70°, b 57.6°, d 1.483.** Distd under vacuum and stored in sealed ampoules under N_2. Very sensitive to moisture.

12-Silicotungstic acid (tungstosilicic acid; $H_4SiW_{12}O_{40}$) *[12027-38-2]* **M 2914.5.** Extracted with ethyl ether from a solution acidified with HCl. The ethyl ether was evaporated under vacuum, and the free acid was crystallised twice [Matijevic and Kerker *JPC* **62** 1271 *1958*].

Silver (metal) *[7440-22-4]* **M 107.9, m 961.9°, b 2212°, d 10.5.** For purification by electrolysis, see Craig et al. [*J Res Nat Bur Stand* **64A** 381 *1960*].

Silver acetate *[563-63-3]* **M 166.9.** Shaken with acetic acid for three days, the process being repeated with fresh acid, the solid then being dried in a vacuum oven at 40° for 48h. Has also been recrystallised from water containing a trace of acetic acid, and dried in air.

Silver bromate *[7785-23-1]* **M 235.8.** Crystd from hot water (80ml/g).

Silver bromide *[7785-23-1]* **M 187.8, m 432°.** Purified from Fe, Mn, Ni and Zn by zone melting in a quartz vessel under vacuum.

Silver chlorate *[7783-92-8]* **M 191.3.** Recrystd three times from water (10ml/g at 15°; 2ml/g at 80°).

Silver chloride *[7783-90-6]* **M 143.3, m 455°.** Purified by recrystn from conc NH_3 solution.

Silver chromate *[7784-01-2]* **M 331.8, d^{25} 5.625**. Wash the red-brown powder with H_2O, dry in a vacuum, then powder well and dry again in a vacuum at 90°/5h. Solubility in H_2O is 0.0014% at 10°. [*JOC* **42** 4268 *1977*].

Silver cyanide *[506-64-9]* **M 133.9, m dec at 320°, d 3.95.** **POISONOUS** white or grayish white powder. Stir thoroughly with H_2O, filter, wash well with EtOH and dry in air in the dark. It is very insoluble in H_2O (0.000023g in 100ml H_2O) but is soluble in HCN or aqueous KCN to form the soluble $Ag(CN)_2^-$ complex. [*B* **72** 299 *1939*; *JACS* **52** 184 *1930*].

Silver diethyldithiocarbamate *[1470-61-7]* **M 512.3.** Purified by recrystn from pyridine. Stored in a desiccator in a cool and dark place.

Silver difluoride *[7783-95-1]* **M 145.9, m 690°, d 4.7.** Highly **TOXIC** because it liberates HF and F. Very *hygroscopic* and reacts violently with H_2O. It is a powerful oxidising agent and liberates O_3 from dilute acids, and I_2 from I^- soln. Store in quartz or iron ampoules. White when pure, otherwise it is brown-tinged. Thermally stable up to 700°. [*Handbook of Preparative Inorganic Chemistry (ed Brauer)* vol I 241 *1963*].

Silver fluoride *[7775-41-9]* **M 126.9, m 435°, b *ca* 1150°, d 5.852.** *Hygroscopic* solid with a solubility of 135g/100ml of H_2O at 15°, and forms an insoluble basic fluoride in moist air. Purified by washing with AcOH and dry C_6H_6, then kept in a vacuum desiccator at room temperature to remove benzene and stored in opaque glass bottles. Flaky *hygroscopic* crystals which darken on exposure to light. It *attacks* bone and teeth. [*JCS* 4538 *1952*; *Handbook of Preparative Inorganic Chemistry (ed Brauer)* vol I 240 *1963*].

Silver iodate *[7783-97-3]* **M 282.8.** Washed with warm dilute HNO_3, then water and dried at 100°, or recrystallised from ammoniacal solution by adding HNO_3, filtering, washing with water and drying at 100°.

Silver lactate *[128-00-7]* **M 196.9, m ~ 100°.** Recrystd from H_2O by adding EtOH. The solid was collected washed with EtOH then Et_2O and dried at 80° to give the dihydrate. White powder soluble in 15 parts of H_2O but only slightly soluble in EtOH. [*A* **63** 89 *1847*; *HCA* **2** 251 *1919*].

Silver nitrate *[7761-88-8]* **M 169.9, m 212°.** Purified by recrystn from hot water (solubility of $AgNO_3$ in water is 992g/100ml at 100° and 122g/100ml at 0°). It has also been purified by crystn from hot conductivity water by slow addition of freshly distilled EtOH.

CAUTION: avoid using EtOH for washing the ppte; and avoid concentrating the filtrate to obtain further crops of $AgNO_3$ owing to the risk of EXPLOSION (as has been reported to us) caused by the presence of silver fulminate. When using EtOH in the purification the apparatus should be enveloped in a strong protective shield. [Tully, *News Ed (Am Chem Soc)* **19** 3092 *1941*; Garin and Henderson *J Chem Educ* **47** 741 *1970*; Bretherick, *Handbook of Reactive Chemical Hazards* 4th edn, Butterworths, London, 1985, pp 13-14].

Before being used as a standard in volumetric analysis, analytical reagent grade $AgNO_3$ should be finely powdered, dried at 120° for 2h, then cooled in a desiccator.

Recovery of silver residues as $AgNO_3$ **[use protective shield during the whole of this procedure]** can be achieved by washing with hot water and adding 16M HNO_3 to dissolve the solid. Filter through glass wool and concentrate the filtrate on a steam bath until precipitation commences. Cool the solution in an ice-bath and filter the precipitated $AgNO_3$. Dry at 120° for 2h, then cool in a desiccator in a vacuum. Store over P_2O_5 in a vacuum in the dark. *AVOID contact with hands due to formation of black stains.*

Silver nitrite *[7783-99-5]* **M 153.9, m 141°(dec).** Crystd from hot conductivity water (70ml/g) in the dark. Dried in the dark under vacuum.

Silver(I) oxide *[20667-12-3]* **M 231.7.** Leached with hot water in a Soxhlet apparatus for several hours to remove any entrained electrolytes.

Silver (II) oxide *[1301-96-8]* **M 123.9, m >100°(dec), d^{25} 7.22.** Soluble in 40,000 parts of H_2O, and should be protected from light. Stir with an alkaline solution of potassium peroxysulphate ($K_2S_2O_8$) at 85-90°. The black AgO is collected, washed free from sulphate with H_2O made slightly alkaline and dried in air in the dark. [*Inorg Synth* **4** 12 *1953*].

Silver perchlorate (H_2O) *[7783-93-9]* **M 207.3.** Refluxed with benzene (6ml/g) in a flask fitted with a Dean and Stark trap until all the water was removed azeotropically (*ca* 4h). The soln was cooled and diluted with dry pentane (4ml/g of $AgClO_4$). The ppted $AgClO_4$ was filtered off and dried in a desiccator over P_2O_5 at 1mm for 24h [Radell, Connolly and Raymond *JACS* **83** 3958 *1961*]. It has also been recrystallised from perchloric acid. [**Caution** *due to* **EXPLOSIVE** *nature in the presence of organic matter*].

Silver permanganate *[7783-98-4]* **M 226.8, d 4.49.** Violet crystals which can be crystallised from hot H_2O (sol is 9g/L at 20°). Store in the dark. Oxidising agent, decomposed by light.

Silver sulphate *[10294-26-5]* **M 311.8.** Crystd by dissolving in hot conc H_2SO_4 containing a trace of HNO_3, cooling and diluting with water. The ppte was filtered off, washed and dried at 120°.

Silver thiocyanate *[1701-93-5]* **M 165.9, m 265°(dec), d 3.746.** Digest the solid salt with aqueous NH_4NCS, wash thoroughly with H_2O and dry at 110° in the dark. Soluble in dilute aqueous NH_3. Dissolve in strong aqueous NH_4NCS solution, filter and dilute with large volume of H_2O when the Ag salt separates. The solid is washed with H_2O by decantation until free from NCS^- ions, collected, washed with H_2O, EtOH and dried in an air oven at 120°. Alternatively dissolve in dilute aqueous NH_3 and single crystals are formed by free evaporation of the solution in air. [*JCS* 836, 2405 *1932*; IR and Raman: *Acta Chem Scand* **13** 1607 *1957*; *Acta Cryst* **10** 29 *1957*].

Silver tosylate *[16836-95-6]* **M 279.1.** The anhydrous salt is obtained by recrystn from H_2O. [*B* **12** 1851 *1879*].

Silver trifluoroacetate *[2966-50-9]* **M 220.9, m 251-255°.** Extract the salt (Soxhlet) with Et_2O. The extract is filtered and evaporated to dryness, then the powdered residue is completely dried in a vacuum desiccator over silica gel. Solubility in Et_2O is 33.5g in 750ml. It can be recrystd from C_6H_6 (sol: 1.9g in 30ml of C_6H_6; and 33.5g will dissolve in 750ml of anhydrous Et_2O). [*JOC* **23** 1545 *1958*; *JCS* 584 *1951*]. It is also soluble in trifluoroacetic acid (15.2% at 30°), toluene, *o*-xylene and dioxane [*JACS* **76** 4285 *1954*].

Silver trifluoromethanesulphonate *[2923-28-6]* **M 256.9.** Recrystd twice from hot CCl_4 [Alo et al. *JCSPT* 808 *1986*].

Sodium (metal) *[7440-23-5]* **M 23.0, m 97.5°, d 0.97.** The metal was placed on a coarse grade of sintered-glass filter, melted under vacuum and forced through the filter using argon. The Pyrex apparatus was then re-evacuated and sealed off below the filter, so that the sodium could be distilled at 460° through a side arm and condenser into a receiver bulb which was then sealed off [Gunn and Green *JACS* **80** 4782 *1958*]. **EXPLODES and IGNITES in water.**

Sodium acetate *[127-09-3]* **M 82.0, m 324°.** Crystd from acetic acid and pumped under vacuum for 10h at 120°. Alternatively, crystd from aqueous EtOH, as the trihydrate. This material can be converted to the anhydrous salt by heating slowly in a porcelain, nickel or iron dish, so that the salt liquefies. Steam is evolved and the mass again solidifies. Heating is now increased so that the salt melts again. (NB: if it is heated too strongly, the salt chars.) After several minutes, the salt is allowed to solidify and cooled to a convenient temperature before being powdered and bottled (water content should now less than 0.02%).

Sodium acetylide *[1066-26-8]* **M 48.0.** It disproportionates at *ca* 180° to sodium carbide. It sometimes contains diluents, e.g. xylene, butyl ether or dioxane which can be removed by filtration followed by a vacuum at 65-60°/5mm. Alternatively the acetylide is purged with HC≡CH at 100-125° to remove diluent. NaC_2H adsorbs 2.2x, 2.0x and 1.6x its wt of xylene, butyl ether and dioxane respectively. Powdered NaC_2H is yellow or yellow-gray in colour and is relatively stable. It can be heated to *ca* 300° in the absence of air. Although no explosion or evolution of gas occurs, it turns brown due to disproportionation. At 170-190° in air it ignites slowly and burns smoothly. At 215-235° in air it flash-ignites and burns quickly. It can be dropped into a *slight* excess of H_2O without flashing or burning but vigorous evolution of HC≡CH (**HIGHLY FLAMMABLE IN AIR**) occurs. The sample had been stored in the absence of air for one year without deterioration. Due to the high flammability of HC≡CH the salt should be stored dry, and treated with care.

After long storage, NaC≡CH can be redissolved in liquid NH_3 and used for the same purposes as the fresh material. However it may be slightly turbid due to the presence of moisture. [*JOC* **22** 649 *1957*; *JACS* **77** 5013 *1955*; *Inorg Synth* **2** 76, 81 *1946 Org Synth* **30** 15 1950].

Sodium alginate *[9005-38-3].* Freed from heavy metal impurities by treatment with ion-exchange resins (Na^+-form), or with a dilute solution of the sodium salt of EDTA. Also dissolved in 0.1M NaCl, centrifuged and fractionally ppted by gradual addition of EtOH or 4M NaCl. The resulting gels were centrifuged off, washed with aqueous EtOH or acetone, and dried under vacuum. [Büchner, Cooper and Wassermann *JCS* 3974 *1961*].

Sodium *n*-alkylsulphates. Recrystd from EtOH/acetone [Hashimoto and Thomas *JACS* **107** 4655 *1985*].

Sodium amide *[7782-92-5]* **M 39.0, m 210°.** It reacts *violently* with H_2O and is soluble in liquid NH_3 (1% at 20°). It should be stored in wax-sealed container is small batches. It is very *hygroscopic* and absorbs CO_2 and H_2O. If the solid is discoloured by being yellow or brown in colour then it should be destroyed as it can be highly **EXPLOSIVE.** It should be replaced if discoloured. It is best destroyed by covering with much toluene and slowly adding dilute EtOH with stirring until all the ammonia is liberated (FUME CUPBOARD). [*Inorg Synth* **1** 74 *1939*; *Handbook of Preparative Inorganic Chemistry (ed Brauer)* Vol I 465 *1963*; *Org Synth* Col Vol III, 778 *1955*].

Sodium 4-aminobenzoate *[555-06-6]* **M 159.1.** Crystd from water.

Sodium 4-aminosalicylate *[133-10-8]* **M 175.1.** Crystd from water at room temperature (2ml/g) by adding acetone and cooling.

Sodium ammonium hydrogen phosphate *[13011-54-6]* **M 209.1.** Crystd from hot water (1ml/g).

Sodium amylpenicillin *[575-47-3]* **M 350.4.** Crystd from moist acetone or moist ethyl acetate.

Sodium anthraquinone-1,5-disulphonate (H_2O) *[853-35-0]* **M 412.3.** Separated from insoluble impurities by continuous extraction with water. Crystd twice from hot water and dried under vacuum.

Sodium anthraquinone-1-sulphonate (H_2O) *[107439-61-2]* **M 328.3.** Crystd from hot water (4ml/g) after treatment with active charcoal, or from water by addition of EtOH. Dried under vacuum over $CaCl_2$, or in an oven at 70°. Stored in the dark.

Sodium anthraquinone-2-sulphonate (H_2O) *[131-08-8]* **M 328.3.** Recrystd from MeOH [Costa and Bookfield *JCSFT 1* **82** 991 *1986*].

Sodium antimonyl tartrate *[34521-09-0]* **M 308.8.** Crystd from water.

Sodium arsenate ($7H_2O$) *[10048-95-0]* **M 312.0.** Crystd from water (2ml/g).

Sodium azide *[26628-22-8]* **M 65,0.** Crystd from hot water or from water by the addition of absolute EtOH or acetone. Also purified by repeated crystn from an aqueous solution saturated at 90° by cooling it to 10°, and adding an equal volume of EtOH. The crystals were washed with acetone and the azide dried at room temperature under vacuum for several hours in an Abderhalden pistol. [Das et al. *JCSFT 1* **78** 3485 *1982*]. **HIGHLY POISONOUS.**

Sodium barbitone *[144-02-5]* **M 150.1.** Crystd from water (3ml/g) by adding an equal volume of EtOH and cooling to 5°. Dried under vacuum over P_2O_5.

Sodium benzenesulphinate *[873-55-2]* **M 164.2, m >300°.** Recrystd from EtOH and dried at 120°for 4h under reduced pressure [Kornblum and Wade *JOC* **52** 5301 *1987*].

Sodium benzenesulphonate *[144-42-4]* **M 150.1.** Crystd from EtOH or aqueous 70-100% MeOH, and dried under vacuum at 80-100°.

Sodium benzoate *[532-32-1]* **M 144.1.** Crystd from EtOH (12ml/g).

Sodium benzylpenicillin *[69-57-8]* **M 356.4.** Crystd from methanol-ethyl acetate.

Sodium bicarbonate *[144-55-8]* **M 84.0.** Crystd from hot water (6ml/g). The solid should not be heated above 40° due to the formation of carbonate.

Sodium bis(trimethylsilyl)amide (hexamethyl disilazane sodium salt) *[1070-89-9]* **M 183.4, m 165-167°(sintering at 140°).** It can be sublimed at 170°/2 Torr (bath temp 220-250°) onto a cold finger, and can be recrystd from C_6H_6 (sol: 10g in 100ml at 60°). It is slightly soluble in Et_2O and is decomposed by H_2O. [*B* **94** 1540 *1961*].

Sodium bisulphite *[7631-90-5]* **M 104.1.** Crystd from hot H_2O (1ml/g). Dried at 100° under vac for 4h.

Sodium borate (borax) *[1330-43-4]* **M 201.2.** Most of the water of hydration was removed from the decahydrate by evacuation at 25° for three days, followed by heating to 100° and evacuation with a high-speed diffusion pump. The dried sample was then heated gradually to fusion (above 966°), allowed to cool gradually to 200°, then tranferred to a desiccator containing P_2O_5 [Grenier and Westrum *JACS* **78** 6226 *1956*].

Sodium borate (decahydrate, hydrated borax) *[1303-96-4]* **M 381.2.** Crystd from water (3.3ml/g) keeping below 55° to avoid formation of the pentahydrate. Filtered at the pump, washed with water and equilibrated for several days in a desiccator containing an aqueous solution saturated with respect to sucrose and NaCl. Borax can be prepared more quickly (but its water content is somewhat variable) by washing the recrystd material at the pump with water, followed by 95% EtOH, then Et_2O, and air dried at room temperature for 12-18h on a clock glass.

Sodium borohydride *[16940-66-2]* **M 37.8.** After adding $NaBH_4$ (10g) to freshly distilled diglyme (120ml) in a dry three-necked flask fitted with a stirrer, nitrogen inlet and outlet, the mixture was stirred for 30min at 50° until almost all of the solid had dissolved. Stirring was stopped, and, after the solid had settled, the supernatant liquid was forced under N_2 pressure through a sintered-glass filter into a dry flask. [The residue was centrifuged to obtain more of the solution which was added to the bulk]. The solution was cooled slowly to 0° and then decanted from the white needles that separated. The crystals were dried by pumping for 4h to give anhydrous $NaBH_4$. Alternatively, after the filtration at 50° the solution was heated at 80° for 2h to give a white ppte of substantially anhydrous $NaBH_4$ which was collected on a sintered-glass filter under N_2, then pumped at 60° for 2h [Brown, Mead and Subba Rao *JACS* **77** 6209 *1955*].
$NaBH_4$ has also been crystd from isopropylamine by dissolving it in the solvent at reflux, cooling, filtering and allowing the solution to stand in a filter flask connected to a Dry-ice/acetone trap. After most of the solvent was passed over into the cold trap, crystals were removed with forceps, washed with dry ethyl ether and dried under vacuum. [Kim and Itoh *JPC* **91** 126 *1987*]. Somewhat less pure crystals were obtained more rapidly by using Soxhlet extraction with only a small amount of solvent and extracting for about 8h. The crystals that formed in the flask were filtered off, then washed and dried as before. [Stockmayer, Rice and Stephenson *JACS* **77** 1980 *1955*]. Other solvents used for crystallisation include water and liquid ammonia.

Sodium bromate *[7789-38-0]* **M 150.9.** Crystd from hot water (1.1ml/g) to decrease contamination by NaBr, bromine and hypobromite. [Noszticzius et al. *JACS* **107** 2314 *1985*].

Sodium bromide *[7647-15-6]* **M 102.9.** Crystd from water (0.86ml/g) between 50° and 0°, and dried at 140° under vacuum (this purification may not eliminate chloride ion).

Sodium 4-bromobenzenesulphonate *[5015-75-8]* **M 258.7.** Crystd from MeOH, EtOH or distd water.

Sodium *ter*-butoxide *[865-48-5]* **M 96.1.** It sublimes at 180°/1 Torr. Its solubility in *ter*-BuOH is 0.208M at 30.2° and 0.382M at 60°, and is quite soluble in tetrahydrofuran (32g/100g). It should not be used if it has a brown colour. [*JACS* **78** 4364, 3614 *1956*, *Inorg Synth* **1** 87 1939; IR: *JOC* **21** 156 *1956*].

Sodium butyrate *[156-54-7]* **M 110.1.** Prepared by neutralisation of the acid and recrystn from EtOH.

Sodium cacodylate ($3H_2O$) *[124-65-2]* **M 214.0.** Crystd from aqueous EtOH.

Sodium carbonate *[497-19-8]* **M 106.0.** Crystd from water as the decahydrate which was redissolved in water to give a near-saturated soln. By bubbling CO_2, $NaHCO_3$ was ppted. It was filtered, washed and ignited for 2h at 280° [MacLaren and Swinehart *JACS* **73** 1822 *1951*]. Before being used as a volumetric standard, analytical grade material should be dried by heating at 260-270° for 0.5h and allowed to cool in a desiccator. For preparation of primary standard sodium carbonate, see *PAC* **25** 459 *1969*.

Sodium carboxymethylcellulose *[9004-32-4]*. Dialysed for 48h against distilled water.

Sodium cetyl sulphate *[1120-01-0]* **M 344.5.** Crystd from MeOH.

Sodium chlorate *[7775-09-9]* **M 106.4.** Crystd from hot water (0.5ml/g).

Sodium chloride *[7647-14-5]* **M 58.4.** Crystd from saturated aqueous solution (2.7ml/g) by passing in HCl gas, or by adding EtOH or acetone. Can be freed from bromide and iodide impurities by adding chlorine water to an aqueous solution and boiling for some time to expel free bromine and iodine. Traces of iron can be removed by prolonged boiling of solid NaCl in 6M HCl, the crystals then being washed with EtOH and dried at *ca* 100°. Sodium chloride has been purified by sublimation in a stream of pre-purified N_2 and collected by electrostatic discharge [Ross and Winkler *JACS* **76** 2637 *1954*]. For use as a primary analytical standard, analytical reagent grade NaCl should be finely ground, dried in an electric furnace at 500-600° in a platinum crucible, and allowed to cool in a desiccator. For most purposes, however, drying at 110-120° is satisfactory.

Sodium chlorite *[7758-19-2]* **M 90.4.** Crystd from hot water and stored in a cool place. Has also been crystd from MeOH by counter-current extraction with liquid ammonia [Curti and Locchi *AC* **29** 534 *1957*]. Major impurity is chloride ion; can be recrystallised from 0.001M NaOH.

Sodium 4-chlorobenzenesulphonate *[5138-90-9]* **M 214.6,**
Sodium 4-chloro-*m*-toluenesulphonate *[5138-92-1]* **M 228.7.** Crystd twice from MeOH and dried under vacuum.

Sodium chromate ($4H_2O$) *[10034-82-9]* **M 234.0.** Crystd from hot water (0.8ml/g).

***dl*-Sodium creatinephosphate ($4H_2O$)** *[922-32-7]* **M 327.1.** Crystd from water-ethanol.

Sodium cyanate *[917-61-3]* **M 65.0, m 550°, d_4^{20} 1.893.** Colourless needles from EtOH. Solubility in EtOH is 0.22g/100g at 0°C. Soluble in H_2O but can be recrystallised from small volumes of it.

Sodium cyanoborohydride *[25895-60-7]* **M 62.8, m 240-242°(dec), d^{28} 1.20.** Very *hygroscopic* solid, soluble in H_2O (212% at 29°, 121% at 88°), tetrahydrofuran (37% at 28°, 42.2% at 62°), very soluble in EtOH but insoluble in Et_2O, C_6H_6 and hexane. It is stable to acid up to pH 3 but is hydrolysed in 12N HCl. The rate of hydrolysis at pH 3 is 10^{-8} that of $NaBH_4$. The fresh commercially available material is usually sufficiently pure. If very pure material is required one of the following procedures must be used [*S* 135 *1975*]:
The $NaBH_3CN$ is dissolved in tetrahydrofuran (20% w/v), filtered and the filtrate is treated with a fourfold volume of CH_2Cl_2. The solid is collected and dried in a vacuum [*Inorg Chem.* **9** 2146 *1970*].
Dissolve the $NaBH_3CN$ in dry $MeNO_2$, filter, and pour the filtrate into a 10-fold volume of CCl_4 with vigorous stirring. The white ppte is collected, washed several times with CCl_4 and dried in a vacuum [*Inorg Chem* **9** 624 *1970*].

When the above procedures fail to give a clean product then dissolve the $NaBH_3CN$ (10g) in tetrahydrofuran (80ml) and add N MeOH/HCl until the pH is 9. Pour the solution with stirring into dioxane (250ml). The solution is filtered, and heated to reflux. A further volume of dioxane (150ml) is added slowly with swirling. The solution is cooled slowly to room temp then chilled in ice and the crystalline dioxane complex is collected, dried in a vacuum for 4h at 25°, the 4h at 80° to yield the amorphous dioxane-free powder is 6.7g with purity >98% [*JACS* **93** 2897 *1971*]. The purity can be checked by iodometric titration [*AC* **91** 4329 *1969*].

Sodium *p*-cymenesulphonate *[77060-21-0]* **M 236.3.** Dissolved in water, filtered and evaporated to dryness. Crystd twice from absolute EtOH and dried at 110°.

Sodium decanoate (sodium caproate) *[1002-62-6]* **M 194.2.** Neutralised by adding a slight excess of the free acid, recovering the excess acid by Et_2O extraction. The salt is crystd from solution by adding pure acetone, repeating the steps several times, then dried in an oven at *ca* 110° [Chaudhury and Awuwallia *TFS* **77** 3119 *1981*].

Sodium 1-decanesulphonate *[13419-61-9]* **M 244.33.** Recrystd from absolute EtOH and dried over silica gel.

Sodium *n*-decylsulphate *[142-87-0]* **M 239.3.** Rigorously purified by continuous Et_2O extraction of a 1% aqueous solution for two weeks.

Sodium deoxycholate (H_2O) *[302-95-4]* **M 432.6, $[\alpha]_D^{20}$ +48° (c 1, EtOH).** Crystd from EtOH and dried in an oven at 100°. The solution is freed from soluble components by repeated extraction with acid-washed charcoal.

Sodium dibenzyldithiocarbamate *[55310-46-8]* **M295.4, m 230°(dec).** The free acid when recrystd twice from dry Et_2O has **m** 80-82°. The Na salt is reppted from aqueous EtOH or EtOH by addition of Et_2O or Me_2CO [*AC* **50** 896 *1978*]. The *NH_4 salt* has **m** 130-133°; *Cu salt* (yellow crystals) has **m** 284-286° and the *Ti salt* has **m** 64-70°.

Sodium 2,5-dichlorobenzenesulphonate *[5138-93-2]* **M 249.0.** Crystd from MeOH, and dried under vacuum.

Sodium dichromate *[7789-12-0]* **M 298.0, m 84.6° ($2H_2O$), 356° (anhydr); b 400°(dec), d_4^{25} 2.348.** Crystd from small volumes of H_2O by evaporation to crystallisation. Solubility in H_2O is 238% at 0° and 508% at boiling. Red dihydrate is slowly dehydrated by heating at 100° for long periods. It is deliquescent, a powerful oxidising agent-*do not place in contact with skin- wash immediately as it is* ***caustic.***

Sodium 5,5-diethylbarbiturate see **sodium barbitone.**

Sodium diethyldithiocarbamate ($3H_2O$) *[20624-25-3]* **M 225.3, m 94-96°(anhydr).** Recrystd from water.

Sodium di(ethylhexyl)sulphosuccinate (Aerosol-OT) *[577-11-7]* **M 444.6.** Dissolved in MeOH and inorganic salts which ppted were filtered off. Water was added and the solution was extracted several times with hexane. The residue was evaporated to one fifth its original volume, benzene was added and azeotropic distillation was continued until no water remained. Solvent was then evaporated. The white solid was crushed and dried in vacuum over P_2O_5 for 48h [El Seoud and Fendler *JCSFT I* **71** 452 *1975*].

Sodium diethyloxalacetate *[88330-76-1]* **M 210.2.** Extracted several times with boiling Et_2O (until the solvent remained colourless) and then the residue was dried in air.

Sodium diformylamide *[18197-26-7]* **M 95.0.** Grind under dry tetrahydrofuran (fumehood), filter and wash with this solvent then dry in vacuum. [IR and prepn: *S* 122 *1990*; *B* **100** 355 *1967*, ***102*** 4089 *1969*].

Sodium dihydrogen orthophosphate ($2H_2O$) *[7558-80-7]* **M 156.0.** Crystd from warm water (0.5ml/g) by chilling.

Sodium 2,2'-dihydroxy-1-naphthaleneazobenzene-5'-sulphonate *[2092-55-9]* **M 354.3.** Purified by precipitation of the free acid from aqueous solution using conc HCl, washing and extracting with EtOH in a Soxhlet extractor. The acid ppted on evaporation of the EtOH and was reconverted to the sodium salt.

Sodium 2,4-dihydroxyphenylazobenzene-4'-sulphonate *[30117-38-5]* **M 304.2.** Crystd from absolute EtOH.

Sodium *p*-(*p*-dimethylaminobenzeneazo)-benzenesulphonate *[23398-40-5]* **M 327.3.** Crystd from water.

Sodium *p*-dimethylaminoazobenzene-*o*'-carboxylate *[845-10-3]* **M 219.2,**
Sodium *p*-dimethylaminoazobenzene-*p*'-carboxylate *[845-46-5]* **M 219.2.** Ppted from aqueous soln as the free acid which was recrystallised from 95% EtOH, then reconverted to the sodium salt.

Sodium 2,4-dimethylbenzenesulphonate *[827-21-4]* **M 208.2,**
Sodium 2,5-dimethylbenzenesulphonate *[827-19-0]* **M 208.2.** Crystd from MeOH and dried under vacuum.

Sodium dimethyldithiocarbamate hydrate *[128-04-1]* **M 143.2, m 106-108°, 120-122°.** Crystallise from a small volume of H_2O, or dissolve in minimum volume of H_2O and add cold Me_2CO and dry in air. The solution in Me_2CO is ~50g/400ml. The dihydrate loses H_2O on heating at 115° to give the hemi hydrate which decomposes on further heating [IR: *Canad J Chem.* **34** 1096 *1956*].

Sodium *N*,*N*-dimethylsulphanilate *[2244-40-8]* **M 223.2, m >300°.** Crystd from water.

Sodium dithionite ($2H_2O$) *[7631-94-9]* **M 242.1.** Crystd from hot water (1.1ml/g) by cooling.

Sodium dodecanoate *[629-25-4]* **M 200.3.** Neutralised by adding a slight excess of dodecanoic acid, removing it by ether extraction. The salt is recrystd from the aqueous solution by adding pure acetone, repeating the process several times (see sodium decanoate).

Sodium 1-dodecanesulphonate *[2386-53-0]* **M 272.4.** Twice recrystd from EtOH.

Sodium dodecylbenzenesulphonate *[25155-30-0]* **M 348.5.** Recrystd from propan-2-ol.

Sodium dodecylsulphate (SDS, sodium laurylsulphate) *[151-21-3]* **M 288.4, m 204-207°.** Purified by Soxhlet extraction with pet ether for 24h, followed by dissolution in acetone:MeOH:H_2O 90:5:5(v/v) and recrystn [Politi et al. *JPC* **89** 2345 *1985*]. Also purified by two recrystns from absolute EtOH, aqueous 95% EtOH, MeOH, isopropanol or a 1:1 mixture of EtOH:isopropanol to remove dodecanol, and dried under vacuum [Ramesh and Labes *JACS* **109** 3228 *1987*]. Also purified by foaming [see Cockbain and McMullen *TFS* **47** 322 *1951*] or by liquid-liquid extraction [see Harrold *J Colloid Sci* **15** 280 *1960*]. Dried over silica gel. For DNA work it should be dissolved in excess MeOH passed through an activated charcoal column and evaporated until it crystallises out.
Also purified by dissolving in hot 95% EtOH (14ml/g), filtering and cooling, then drying in a vacuum desiccator. Alternatively, it was crystd from H_2O, vacuum dried, washed with anhydrous Et_2O, vacuum dried. These operations were repeated five times [Maritato *JPC* **89** 1341 *1985*; Lennox and McClelland *JACS* **108** 3771 *1986*; Dressik *JACS* **108** 7567 *1986*].

Sodium ethoxide *[141-52-6]* **M 68.1.** *Hygroscopic* powder which should be stored under N_2 in a cool place. Likely impurity is EtOH which can be removed by warming at 60-80° under high vacuum. Other

impurities, if kept in air for long periods are NaOH and Na_2CO_3. In this case the powder cannot be used if these impurities affect the reactivity and a fresh sample should be acquired [IR: *JOC* **21** 156 *1956*].

Sodium ethylmercurithiosalicylate *[14737-80-5]* **M 404.8.** Crystd from ethanol-ethyl ether

Sodium ethylsulphate *[546-74-7]* **M 166.1.** Recrystd three times from MeOH-Et_2O and vacuum dried.

Sodium ferricyanide (H_2O) *[14217-21-1]* **M 298.9.** Crystd from hot water (1.5ml/g) or by precipitation from 95% EtOH.

Sodium ferrocyanide ($10H_2O$) *[13601-19-9]* **M 484.1.** Crystd from hot water (0.7ml/g), until free of ferricyanide as shown by absence of Prussian Blue formation with ferrous sulphate soln.

Sodium fluoride *[7681-49-4]* **M 42.0.** Crystd from water by partial evaporation in a vacuum desiccator,. or dissolved in water, and *ca* half of it ppted by addition of EtOH. Ppte was dried in an air oven at 130° for one day, and then stored in a desiccator over KOH.

Sodium fluoroacetate (mono) *[62-74-8]* **M 100.0, m 200-205°(dec).** A free flowing white **TOXIC** powder which is purified by dissolving in *ca* 4 parts of H_2O and the pH is checked. If it is alkaline, add a few drops of FCH_2CO_2H to make the solution just acidic. Evaporate (fumehood) on a steam bath until crystals start to separate, cool and filter the solid off. More solid can be obtained by adding EtOH to the filtrate. Dry at 100° in vacuum. [*JCS* 1778 *1948*].

Sodium fluoroborate *[13755-29-8]* **M 109.8.** Crystd from hot water (50ml/g) by cooling to 0°. Alternatively, purified from insoluble material by dissolving in a minimum amount of water, then fluoride ion was removed by adding conc lanthanum nitrate in excess. After removing lanthanum fluoride by centrifugation, the supernatant was passed through a cation-exchange column (Dowex 50, Na^+-form) to remove any remaining lanthanum [Anbar and Guttman *JPC* **64** 1896 *1960*].

Sodium fluorosilicate *[16893-85-9]* **M 188.1.** Crystd from hot water (40ml/g) by cooling.

Sodium formaldehyde sulphoxylate dihydrate (sodium hydroxymethylsulphinate, Rongalite) *[149-44-0]* **M 134.1, m 63-64° (dihydrate).** Crystallises from H_2O as the dihydrate, decomposes at higher temperatures. Store in a closed container in a cool place. It is insoluble in EtOH and Et_2O and is a good reducing agent. [X-ray structure: *JCS* 3064 *1955*]. Note that this compound {$HOCH_2SO_2Na$} should not be confused with formaldehyde sodium bisulphite adduct {$HOCH_2SO_3Na$} from which it is prepared by reduction with Zn.

Sodium formate (anhydrous) *[141-53-7]* **M 68.0.** A saturated aqueous solution at 90° (0.8ml water/g) was filtered and allowed to cool slowly. (The final temperature was above 30° to prevent formation of the hydrate.) After two such crystns the crystals were dried in an oven at 130°, then under high vacuum. [Westrum, Chang and Levitin *JPC* **64** 1553 *1960*; Roecker and Meyer *JACS* **108** 4066 *1986*]. The salt has also been recrystd twice from 1mM DTPA, then twice from water [Bielski and Thomas *JACS* **109** 7761 *1987*].

Sodium D-gluconate *[527-07-1]* **M 218.1, m 200-205°dec, $[\alpha]_{546}^{20}$ +14°, $[\alpha]_D^{20}$ +12 (c 20, H_2O).** Crystallise from a small volume of H_2O (sol 59g/100ml at 25°), or dissolve in H_2O and add EtOH since it is sparingly soluble in EtOH. Insoluble in Et_2OIt forms a Cu comples in alkaline soln and a complex with Fe in neutral solution. [*JACS* **81** 5302 *1959*].

Sodium glycochenodeoxycholate *[16564-43-5]* **M 472.6,**
Sodium glycocholate *[863-57-0]* **M 488.6.** Dissolved in EtOH, filtered and concentrated to crystallisation, and recrystallised from a little EtOH.

Sodium glycollate ($2H_2O$) *[2053-21-6]* **M 98.0.** Ppted from aqueous solution by EtOH, and air dried.

Sodium hexadecylsulphate *[1120-01-0]* **M 323.5.** Recrystd from absolute EtOH [Abu Hamdiyyah and Rahman *JPC* **91** 1531 *1987*].

Sodium hexafluorophosphate *[21324-39-0]* **M 167.9.** Recrystd from acetonitrile and vacuum dried for 2 days at room temperature. It is an **irritant** and is *hygroscopic*. [Delville et al. *JACS* **109** 7293 *1987*].

Sodium hexanitrocobaltate III ($Na_3[Co(NO)_6]$) *[13600-98-1]* **M 403.9.** Dissolve (*ca* 60g) in H_2O (300ml), filter to obtain a clear solution, add 96% EtOH (250ml) with vigorous stirring. Allow the ppte to settle for 2h, filter, wash with EtOH (4 X 25ml), twice with Et_2O and dry in air [*Handbook of Preparative Inorganic Chemistry (ed Brauer)* Vol II, 1541 *1965*]. Yellow to brown yellow crystals which are very soluble in H_2O, are decomposed by acid and form an insoluble K salt. Used for estimating K.

Sodium hydrogen diglycollate *[50795-24-9]* **M 156.1.** Crystd from hot water (7.5ml/g) by cooling to 0° with constant stirring, the crystals being filtered off on to a sintered-glass funnel and dried at 110° overnight.

Sodium hydrogen oxalate ($2H_2O$) *[1186-49-8]* **M 130.0.** Crystd from hot water (5ml/g) by cooling.

Sodium hydrogen succinate *[2922-54-5]* **M 140.0.** Crystd from water and dried at 110°.

Sodium hydrogen *d*-tartrate *[526-94-3]* **M 190.1, $[\alpha]_{546}$ +26° (c 1, H_2O).** Crystd from warm water (10ml/g) by cooling to 0°.

Sodium hydroxide (anhydrous) *[1310-73-2]* **M 40.0.** Common impurities are water and sodium carbonate. Sodium hydroxide can be purified by dissolving 100g in 1L of pure EtOH, filtering the solution under vacuum through a fine sintered-glass disc to remove insoluble carbonates and halides. (This and subsequent operations should be performed in a dry, CO_2-free box.) The soln is concentrated under vacuum, using mild heating, to give a thick slurry of the mono-alcoholate which is transferred to a coarse sintered-glass disc and pumped free of mother liquor. After washing the crystals several times with purified alcohol to remove traces of water, they are vacuum dried, with mild heating, for about 30h to decompose the alcoholate, leaving a fine white crystalline powder [Kelly and Snyder *JACS* **73** 4114 *1951*].

Sodium hydroxide solutions (*caustic*). Carbonate ion can be removed by passage through an anion-exchange column (such as Amberlite IRA-400; OH^--form). The column should be freshly prepared from the chloride form by slow prior passage of sodium hydroxide soln until the effluent gives no test for chloride ions. After use, the column can be regenerated by washing with dilute HCl, then water. Similarly, other metal ions are removed when a 1M (or more dilute) NaOH soln is passed through a column of Dowex ion-exchange A-1 resin in its Na^+-form.
Alternatively, carbonate contamination can be reduced by rinsing analytical reagent quality sticks of NaOH rapidly with H_2O, then dissolving them in distilled H_2O, or by preparing a concentrated aqueous soln of NaOH and drawing off the clear supernatant liquid. (Insoluble Na_2CO_3 is left behind.) Carbonate contamination can be reduced by adding a slight excess of conc $BaCl_2$ or $Ba(OH)_2$ to a NaOH soln, shaking well and allowing the $BaCO_3$ ppte to settle. If the presence of Ba in the soln is unacceptable, an electrolytic purification can be used. For example, sodium amalgam is prepared by the electrolysis of 3L of 30% NaOH with 500ml of pure mercury for cathode, and a platinum anode, passing 15 Faradays at 4A, in a thick-walled polyethylene bottle. The bottle is then fitted with inlet and outlet tubes, the spent soln being flushed out by CO_2-free N_2. The amalgam is then washed thoroughly with a large volume of deionised water (with the electrolysis current switched on to minimize loss of Na). Finally, a clean steel rod is placed in contact in the solution with the amalgam (to facilitate hydrogen evolution), reaction being allowed to proceed until a suitable concentration is reached, before being transferred to a storage vessel and diluted as required [Marsh and Stokes *Australian J Chem* **17** 740 *1964*].

Sodium 2-hydroxy-4-methoxybenzophenone-5-sulphonate *[6628-37-1]* **M 330.3.** Crystd from MeOH and dried under vacuum.

Sodium *p*-hydroxyphenylazobenzene-*p'*-sulphonate *[2623-31-1]* **M 288.2.** Crystd from 95% EtOH.

Sodium hypophosphite monohydrate *[10039-56-2]* **M 106.0.** Dissolve in boiling EtOH, cool and add dry Et_2O till all the salt separates. Collect and dry in vacuum. It is soluble in 1 part of H_2O. It liberates PH_3 on heating and can *ignite* spontaneously when heated. The anhydrous salt is soluble in ethylene glycol (33% w/w) and propylene glycol (9.7%) at 25°.

Sodium iodate *[7681-55-2]* **M 197.9.** Crystd from water (3ml/g) by cooling.

Sodium iodide *[7681-82-5]* **M 149.9.** Crystd from water/ethanol soln and dried for 12h under vacuum, at 70°. Alternatively, dissolved in acetone, filtered and cooled to -20°, the resulting yellow crystals being filtered off and heated in a vacuum oven at 70° for 6h to remove acetone. The NaI was then crystd from very dilute NaOH, dried under vacuum, and stored in a vacuum desiccator [Verdin *TFS* **57** 484 *1961*].

Sodium ionophore I (ETH 227) (N,N',N"-triheptyl-N,N',N"-trimethyl-4,4',4"-propylidynetris(3-oxabutyramide) *[61183-76-4]* **M 642.0.** It is purified (*ca* 200mg) by TLC on Kieselgel F_{254} with $CHCl_3/Me_2CO$ (1:1) as solvent, followed by HPLC (50mg) with an octadecyltrimethylsilane modified column (Mercksorb SI 100, 10μm) [IR, NMR, MS: *HCA* **59** 2417 *1976*].

Sodium ionophore V (ETH 4120) [4-octadecanoyloxymethyl-N,N,N',N'-tetracyclohexyl-1,2-phenylenedioxydiacetamide] *[129880-73-5]* **M 849.3.** Purified by recrystn from EtOAc. [Preparation and properties: *ACA* **233** 295 *1990*].

Sodium ionophore VI [bis(12-crown-4)methyl)dodecyl methyl malonate] *[80403-59-4]* **M 662.9.** Purified by gel permeation or column chromatography. [Preparation and NMR data: *J Electroanal Chem* **132** 99 *1982*].

Sodium isopropylxanthate *[140-93-2]* **M 158.2.** Crystd from ligroin/ethanol.

Sodium laurate *[629-25-4]* **M 222.0.** Crystd from MeOH.

Sodium mandelate *[114-21-6]* **M 174.1.** Crystd from 95% EtOH.

Sodium 2-mercaptoethanesulphonate (MESNA) *[19767-45-4]* **M 164.2.** It can be recrystd from H_2O and does not melt below 250°. It can be purified further by converting to the free acid by passing a 2M soln through an ion exchange (Amberlite IR-120) column in the acid form, evaporating the eluate in a vacuum to give the acid as a viscous oil (readily dec) which can be checked by acid and SH titration. It is then dissolved in H_2O, carefully neutralised with aqueous NaOH, evaporated and recrystd from H_2O [*JACS* **77** 6231 *1955*].

Sodium metanilate *[1126-34-7]* **M 195.2,**
Sodium metaperiodate ($NaIO_4$) *[7790-28-5]* **M 213.9.** Crystd from hot water.

Sodium metasilicate ($5H_2O$) *[6834-92-0]* **M 212.1.** Crystd from aqueous 5% NaOH solution.

Sodium methanethiolate [sodium methylmercaptide] *[5188-07-8]* **M 70.1.** Dissolve the salt (10g) in EtOH (10ml) and add Et_2O (100ml). Cool and collect the ppte, wash it with Et_2O and dry it in vacuum. It is a white powder which is very soluble in EtOH and H_2O. [*Bull Soc Chim Fr* **3** 2318 *1936*].

Sodium methoxide *[124-41-4]* **M 54.0.** It behaves the same as sodium ethoxide. It is *hygroscopic* and is hydrolysed by moist air to NaOH and EtOH. Material that has been kept under N_2 should be used. If erratic results are obtained, even with recently purchased NaOMe it should be freshly prepared thus: Clean Na (37g) cut in 1-3g pieces is added in small portions to stirred MeOH (800ml) in a 2L three necked flask equipped with a stirrer and a condenser with a drying tube. After all the Na has dissolved the MeOH is removed by distillation under vacuum and the residual NaOMe is dried by heating at 150° under vacuum and kept under dry N_2 [*Org Synth* **39** 51 *1959*].

Sodium 3-methyl-1-butanesulphonate *[5343-41-9]* **M 174.1.** Crystd from 90% MeOH.

Sodium molybdate ($2H_2O$) *[10102-40-6]* **M 241.9.** Crystd from hot water (1ml/g) by cooling to 0°.

Sodium monensin *[22373-78-0]* **M 693.8.** Recrystd from EtOH-H_2O [Cox et al. *JACS* **107** 4297 *1985*].

Sodium 1-naphthalenesulphonate *[85-47-2]* **M 230.2.** Recrystd from water or aqueous acetone [Okadata et al. *JACS* **108** 2863 *1986*].

Sodium 2-naphthalenesulphonate *[532-02-5]* **M 230.2.** Crystd from hot 10% aqueous NaOH or water, and dried in a steam oven.

Sodium 2-naphthylamine-5,7-disulphonate *[79004-97-0]* **M 235.4.** Crystd from water (charcoal) and dried in a steam oven.

Sodium nitrate *[7631-99-4]* **M 85.0.** Crystd from hot water (0.6ml/g) by cooling to 0°, or from concentrated aqueous solution by addition of MeOH. Dried under vacuum at 140°.

Sodium nitrite *[7632-00-0]* **M 69.0, m 271°.** Crystd from hot water (0.7ml/g) by cooling to 0°, or from its own melt. Dried over P_2O_5.

Sodium 1-octanesulphonate *[5324-84-5]* **M 216.2.** Recrystd from absolute EtOH.

Sodium oleate *[143-19-1]* **M 304.4, m 233-235°.** Crystd from EtOH and dried in an oven at 100°.

Sodium oxalate *[62-76-0]* **M 134.0.** Crystd from hot water (16ml/g) by cooling to 0°. Before use as a volumetric standard, analytical grade quality sodium oxalate should be dried for 2h at 120° and allowed to cool in a desiccator.

Sodium palmitate *[408-35-5]* **M 278.4, m 285-201°.** Crystd from EtOH and dried in an oven.

Sodium perchlorate (anhydrous) *[7601-89-0]* **M 122.4.** Because its solubility in water is high (2.1g/ml at 15°) and it has a rather low temperature coefficient of solubility, sodium perchlorate is usually crystd from acetone, MeOH, water-ethanol or dioxane-water (33g dissolved in 36ml of water and 200ml of dioxane). After filtering and crystallising, the solid is dried under vacuum at 140-150° to remove solvent of crystn. Basic impurities can be removed by crystn from hot acetic acid, followed by heating at 150°. If $NaClO_4$ is ppted from distilled water by adding $HClO_4$ to the chilled solution, the ppte contains some free acid.

Sodium *p*-phenolsulphonate ($2H_2O$) *[825-90-1]* **M 232.2.** Crystd from hot water (1ml/g) by cooling to 0°, or from MeOH, and dried in vacuum.

Sodium phenoxide *[139-02-6]* **M 116.1.** Washed with Et_2O, then heated under vacuum to 200° to remove any free phenol.

Sodium phenylacetate *[114-70-5]* **M 158.1.** Its aqueous solution was evaporated to crystallisation on a steam bath, the crystals being washed with absolute EtOH and dried under vacuum at 80°.

Sodium *o*-phenylphenolate ($4H_2O$) *[132-27-4]* **M 264.3.** Crystd from acetone and dried under vacuum at room temperature.

Sodium phosphoamidate *[3076-34-4]* **M 119.0.** Dissolved in water below 10°, and acetic acid added dropwise to pH 4.0 so that the monosodium salt was ppted. The ppte was washed with water and Et_2O, then air dried. Addition of one equivalent of NaOH to the solution gave the sodium salt, the solution being adjusted to pH 6.0 before use [Rose and Heald *BJ* **81** 339 *1961*].

Sodium phytate (H_2O) *[14306-25-3]* **M 857.9.** Crystd from water.

Sodium piperazine-*N,N'*-bis(2-ethanesulphonate) (H_2O) *[76836-02-7]* **M 364.3.** Crystd from water and EtOH.

Sodium polyacrylate (NaPAA) *[9003-04-7].* Commercial polyacrylamide was neutralised with an aqueous solution of NaOH and the polymer ppted with acetone. The ppte was redissolved in a small amount of water and freeze-dried. The polymer was repeatedly washed with EtOH and water to remove traces of low molecular weight material, and finally dried in vacuum at 60° [Vink *JCSFT 1* **75** 1207 *1979*]. Also dialysed overnight against distilled water, then freeze-dried.

Sodium poly(α-L-glutamate). It was washed with acetone, dried, dissolved in water and ppted with isopropanol at 5°. Impurities and low molecular weight fractions were removed by dialysis of the aqueous solution for 50h, followed by ultrafiltration through a filter impermeable to polymers of molecular weights greater the 10^4. The polymer was recovered by freeze-drying. [Mori et al. *JCSFT 1 2583 1978*].

Sodium propionate *[137-40-6]* **M 96.1, m 287-289°.** Recrystd from H_2O (solubility 10%), and dried by heating at 100° for 4h. Solubility of anhydrous salt in MeOH is 13% at 15° and 13.77% at 68°. It is insoluble in C_6H_6 and Me_2CO. [*JCS* 1341 *1934*].

Sodium pyrophosphate ($10H_2O$) *[13472-36-1]* **M 446.1.** Crystd from warm water and air dried at room temperature.

Sodium selenate *[13410-01-0]* **M 188.9,**
Sodium selenite *[10102-18-8]* **M 172.9.** Crystd from water.

Sodium silicate solution *[1344-09-8].* Purified by contact filtration with activated charcoal.

Sodium succinate *[150-90-3]* **M 162.1.** Crystd from hot water (1.2ml/g) by cooling to 0°. Dried at 125°.

Sodium sulphanilate *[515-74-2]* **M 195.2.** Crystd from water.

Sodium sulphate ($10H_2O$) *[7727-73-3]* **M 322.2.** Crystd from water at 30° (1.1ml/g) by cooling to 0°. Sodium sulphate becomes anhydrous at 32°.

Sodium sulphide ($9H_2O$) *[1313-84-4]* **M 240.2.** Some purification of the hydrated salt can be achieved by selecting large crystals and removing the surface layer (contaminated with oxidation products) by washing with distilled water. Other metal ions can be removed from Na_2S solutions by passage through a column of Dowex ion-exchange A-1 resin, Na^+-form. The hydrated salt can be rendered anhydrous by heating in a stream of H_2 or N_2 until water is no longer evolved. (The resulting cake should not be heated to fusion because it is readily oxidised.) Recrystd from distilled water [Anderson and Azowlay *JCSDT* 469 *1986*].

Sodium sulphite *[7757-83-7]* **M 126.0.** Crystd from warm water (0.5ml/g) by cooling to 0°. Purified by repeated crystns from deoxygenated water inside a glove-box, finally drying under vacuum. [Rhee and Dasgupta *JPC* **89** 1799 *1985*].

Sodium *R*-tartrate *[868-18-8]* **M 230.1.** Crystd from warm dilute aqueous NaOH by cooling.

Sodium taurocholate *[145-42-6]* **M 555.7.** Purified by recrystn and gel chromatography using Sephadex LH-20.

Sodium tetradecylsulphate *[1191-50-0]* **M 316.4.** Recrystd from absolute EtOH [Abu Hamdiyyah and Rahman *JPC* **91** 1531 *1987*].

Sodium tetrafluoroborate *[13755-29-8]* **M 109.8.** Recrystd from anhydrous MeOH and dried in a vacuum at 70° for 16h. It is affected by moisture. [Delville et al. *JACS* **109** 7293 *1987*].

Sodium tetrametaphosphate *[13396-41-3]* **M 429.9.** Crystd twice from water at room temperature by adding EtOH (300g of $Na_4P_4O_{12},H_2O$, 2L of water, and 1L of EtOH), washed first with 20% EtOH then with 50% EtOH and air dried [Quimby *JPC* **58** 603 *1954*].

Sodium tetraphenylborate [tetraphenyl boron Na] *[143-66-8]* **M 342.2.** Dissolve in dry MeOH and add dry Et_2O. Collect the solid and dry in a vacuum at 80°/2mm for 4h. Also can be extracted (Soxhlet) using $CHCl_3$ and crystallises from $CHCl_3$ as snow white needles. It is freely sol in H_2O, Me_2CO but insol in pet ether and Et_2O. An aqueous soln has pH ~ 5 and can be stored for days at 25° or lower, and for 5 days at 45° without deterioration. Its solubility in polar solvents increases with decrease in temp [*A* **574** 195 *1950*]. The salt can also be recrystd from acetone-hexane or $CHCl_3$, or from Et_2O-cyclohexane (3:2) by warming the soln to ppte the compound. Dried in a vacuum at 80°. Dissolved in acetone and added to an excess of toluene. After a slight milkiness developed on standing, the mixture was filtered. The clear filtrate was evaporated at room temperature to a small bulk and again filtered. The filtrate was then warmed to 50-60°, giving clear dissolution of crystals. After standing at this temperature for 10min the mixture was filtered rapidly through a pre-heated Büchner funnel, and the crystals were collected and dried in a vacuum desiccator at room temperature for 3 days [Abraham et al. *JCSFT 1* **80** 489 *1984*]. If the product gives a turbid aqueous solution, the turbidity can be removed by treating with freshly prepared alumina gel.

Sodium thioantimonate ($Na_3SbS_4.9H_2O$) *[10101-91-4]* **M 481.1.** Crystd from warm water (2ml/g) by cooling to 0°.

Sodium thiocyanate *[540-72-7]* **M 81.1, m 300°.** It is recrystd from EtOH or Me_2CO and the mother liquor is removed from the crystals by centrifugation. It is very deliquescent and should be kept in an oven at 130° before use. It can be dried in vacuum at 120°/P_2O_5 [*TFS* **30** 1104 *1934*]. Its solubility in H_2O is 113% at 10°, 178% at 46°, 225.6% at 101.4°; in MeOH 35% at 15.8°, 51% at 48°, 53.5% at 52.3°; in EtOH 18.4% at 18.8°, 24.4% at 70.9°; and in Me_2CO 6.85% at 18.8° and 21.4% at 56° [*JCS* 2282 *1929*].
Sodium thiocyanate has also been recrystd from water, acetonitrile or from MeOH using Et_2O for washing, then dried at 130°, or dried under vacuum at 60° for 2 days. [Strasser et al. *JACS* **107** 789 *1985*; Szezygiel et al. *JACS* **91** 1252 *1987*]. (The latter purification removes material reacting with iodine.) Sodium thiocyanate solns can be freed from traces of iron by repeated batch extractions with Et_2O.

Sodium thioglycollate *[367-51-1]* **M 114.1.** Crystd from 60% EtOH (charcoal).

Sodium thiosulphate ($5H_2O$) *[10102-17-7]* **M 248.2, (anhydrous)** *[7772-98-7]*. Crystd from EtOH-H_2O solns or from water (0.3ml/g) below 60° by cooling to 0°, and dried at 35° over P_2O_5 under vacuum.

Sodium *p*-toluenesulphinate *[824-79-3]* **M 178.2.** Crystd from water (to constant UV spectrum), and dried under vacuum or extracted with hot benzene, then dissolved in EtOH-H_2O and heated with decolorising charcoal. The solution was filtered and cooled to give crystals of the dihydrate.

Sodium *p*-toluenesulphonate *[657-84-1]* **M 194.2.** Dissolved in distilled water, filtered to remove insoluble impurities and evaporated to dryness. Then crystd from MeOH or EtOH, and dried at 110°. Its solubility in EtOH is not high (maximum 2.5%) so that Soxhlet extraction with EtOH may be preferable. Sodium *p*-toluenesulphonate has also been crystd from Et_2O and dried under vacuum at 50°.

Sodium trifluoroacetate *[2923-18-4]* **M 136.0, m 206-210°(dec).** A possible contaminant is NaCl. The solid is treated with CF_3CO_2H and evaporated twice. Its solubility in CF_3CO_2H is 13.1% at 29.8°. The residue is crystd from dil EtOH and the solid dried in vacuum at 100°. [*JACS* **76** 4285 *1954*]. It can be ppted from EtOH by adding dioxane, then crystd several times from hot absolute EtOH. Dried at 120-130°/1mm.

Sodium 2,2',4-trihydroxyazobenzene-5'-sulphonate *[3564-26-9]* **M 320.2.** Purified by precipitating the free acid from aqueous solution using concentrated HCl, then washing and extracting with EtOH in a Soxhlet extractor. Evaporation of the EtOH left the purified acid.

Sodium trimetaphosphate ($6H_2O$) *[7785-84-4]* **M 320.2.** Ppted from an aqueous soln at 40° by adding EtOH. Air dried.

Sodium 2,4,6-trimethylbenzenesulphonate *[6148-75-0]* **M 222.1.** Crystd twice from MeOH and dried under vacuum.

Sodium trimethylsilanoate (sodium trimethylsilanol) *[18027-10-6]* **M 112.2.** It is very soluble in Et_2O and C_6H_6 but moderately soluble in pet ether. It is purified by sublimation at 130-150° in a high vacuum. [IR: *JACS* **75** 5615 *1953*; *JOC* **17** 1555 *1952*].

Sodium triphosphate see **sodium tripolyphosphate.**

Sodium tripolyphosphate *[7758-29-4]* **M 367.9.** Purified by repeated pptn from aqueous solution by slow addition of MeOH and air dried. Also a solution of anhydrous sodium tripolyphosphate (840g) in water (3.8L) was filtered, MeOH (1.4L) was added with vigorous stirring to ppte $Na_5P_3O_{10}.6H_2O$. The ppte was collected on a filter, air dried by suction, then left to dry in air overnight. It was crystd twice more in this way, using a 13% aqueous solution (w/w), and leaching the crystals with 200ml portions of water [Watters, Loughran and Lambert *JACS* **78** 4855 *1956*]. Similarly, EtOH can be added to ppte the salt from a filtered 12-15% aqueous solution, the final solution containing *ca* 25% EtOH (v/v). Air drying should be at a relative humidity of 40-60%. Heat and vacuum drying should be avoided. [Quimby *JPC* **58** 603 *1954*].

Sodium tungstate ($2H_2O$) *[10213-10-2]* **M 329.9.** Crystd from hot water (0.8ml/g) by cooling to 0°.

Sodium *m*-xylenesulphonate *[30587-85-0]* **M 208.2,**
Sodium *p*-xylenesulphonate *[827-19-0]* **M 208.2.** Dissolved in distilled water, filtered, then evaporated to dryness. Crystd twice form absolute EtOH and dried at 110°.

Stannic chloride *[7646-78-8]* **M 260.5, d 2.215.** Refluxed with clean mercury or P_2O_5 for several hours, then distd under (reduced) N_2 pressure into a receiver containing P_2O_5. Finally redistd. Alternatively, distd from Sn metal under vacuum in an all-glass system and sealed off in large ampoules. Fumes in moist air.

Stannic iodide (SnI_4) *[7790-47-8]* **M 626.3, m 144°.** Crystd from anhydrous $CHCl_3$, dried under vacuum and stored in a vacuum desiccator.

Stannic oxide (SnO_2) *[18282-10-5]* **M 150.7.** Refluxed repeatedly with fresh HCl until the acid showed no tinge of yellow. The oxide was then dried at 110°.

Stannous biscyclopentadienyl *[26078-96-6]* **M 248.9.** Purified by vacuum sublimation. Handled and stored under dry N_2. The related thallium and indium compounds are similarly prepared.

Stannous chloride (anhydrous) *[7772-99-8]* **M 189.6.** Analytical reagent grade stannous chloride dihydrate is dehydrated by adding slowly to vigorously stirred, redistilled acetic anhydride (120g salt per 100g of anhydride). (In a fume cupboard.) After *ca* an hour, the anhydrous $SnCl_2$ is filtered on to a sintered-glass or Büchner funnel, washed free from acetic acid wth dry Et_2O (2 x 30ml), and dried under vacuum. It is stored in a sealed container. [Stephen *JCS* 2786 *1930*].

Strontium acetate *[543-94-2]* **M 205.7.** Crystd from AcOH, then dried under vacuum for 24h at 100°.

Strontium bromide *[10476-81-0]* **M 247.4.** Crystd from water (0.5ml/g).

Strontium chloride ($6H_2O$) *[1025-70-4]* **M 266.6, m 114°.** Crystd from warm water (0.5ml/g) by cooling to 0°.

Strontium chromate *[7789-06-2]* **M 203.6.** Crystd from water (40ml/g) by cooling.

Strontium hydroxide ($8H_2O$) *[18480-07-4]* **M 265.8.** Crystd from hot water (2.2ml/g) by cooling to 0°.

Strontium lactate ($3H_2O$) *[29870-99-5]* **M 319.8.** Crystd from aqueous EtOH.

Strontium nitrate *[10042-76-9]* **M 211.6.** Crystd from hot water (0.5ml/g) by cooling to 0°.

Strontium oxalate (H_2O) *[814-95-9]* **M 193.6.** Crystd from hot water (20ml/g) by cooling.

Strontium salicylate *[526-26-1]* **M 224.7.** Crystd from hot water (4ml/g) or EtOH.

Strontium tartrate *[868-19-9]* **M 237.7.** Crystd from hot water.

Strontium thiosalicylate ($5H_2O$) *[15123-90-7]* **M 289.8.** Crystd from hot water (2ml/g) by cooling to 0°.

Sulphamic acid *[5329-14-6]* **M 97.1, m 205°(dec).** Crystd from water at 70° (300ml per 25g), after filtering, by cooling a little and discarding the first batch of crystals (about 25g) before standing in an ice-salt mixture for 20min. The crystals were filtered by suction, washed with a small quantity of ice water, then twice with cold EtOH and finally with Et_2O. Air dried for 1h, then stored in a desiccator over $Mg(ClO_4)_2$ [Butler, Smith and Audrieth *IECAE* **10** 690 *1938*]. For preparation of primary standard material see *PAC* **25** 459 *1969*.

Sulphamide *[7803-58-9]* **M 96.1, m 91.5°.** Crystd from absolute EtOH.

Sulphur *[7704-34-9]* **M 32.1, m between 112.8° and 120°, depending on form.** Murphy, Clabaugh and Gilchrist [*J Res Nat Bur Stand* **64A** 355 *1960*] have obtained sulphur of about 99.999 moles per cent purity by the following procedure: Roll sulphur was melted and filtered through a coarse-porosity glass filter funnel into a 2L round-bottomed Pyrex flask with two necks. Conc H_2SO_4 (300ml) was added to the sulphur (2.5Kg), and the mixture was heated to 150°, stirring continuously for 2h. Over the next 6h, conc HNO_3 was added in about 2ml portions at 10-15min intervals to the heated mixture. It was then allowed to cool to room temperature and the acid was poured off. The sulphur was rinsed several times with distilled water, then remelted, cooled, and rinsed several times with distd water again, this process being repeated four or five times to remove most of the acid entrapped in the sulphur. An air-cooled reflux tube (*ca* 40cm long) was attached to one of the necks of the flask, and a gas delivery tube (the lower end about 1in above the bottom of the flask) was inserted into the other. While the sulphur was boiled under reflux, a stream of helium or N_2 was passed through to remove any water, HNO_3 or H_2SO_4, as vapour. After 4h, the sulphur was cooled so that the reflux tube could be replaced by a bent air-cooled condenser. The sulphur was then distilled, rejecting the first and the final 100ml portions, and transferred in 200ml portions to 400ml glass cylinder ampoules (which were placed on their sides during solidification). After adding about 80ml of water, displacing the air with N_2, and sealing the ampoule was cooled, and the water was titrated with 0.02M NaOH, the process being repeated until the acid content was negligible. Finally, entrapped water was removed by alternate evacuation to 10mm Hg and refilling with N_2 while the sulphur was kept molten.
Other purifications include crystn from CS_2 (which is less satisfactory becuase the sulphur retains appreciable amounts of organic material), benzene or benzene/acetone, followed by melting and degassing. Has also been boiled with 1% MgO, then decanted, and dried under vacuum at 40° for 2 days over P_2O_5. [For purification of S_6, "recryst. S_8" and "Bacon-Fanelli sulphur" see Bartlett, Cox and Davis *JACS* **83** 103, 109 *1961*].

Sulphur chloride see **sulphur monochloride.**

Sulphur dichloride *[10545-99-0]* **M 103.0, m -78°, b 59°/760mm(dec), d 1.621.** Twice distilled in the presence of a small amount of PCl_3 through a 12in Vigreux column, the fraction boiling between 55-61° being redistd (in the presence of PCl_3), and the fraction distilling between 58-61° retained. (The PCl_3 is added to inhibit the decomposition of SCl_2 into S_2Cl_2 and Cl_2). The SCl_2 must be used as quickly as possible after distn, within 1h at room temperature, The sample contains 4% S_2Cl_2. On long standing this reaches 16-18%.

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Sulphur dioxide *[7446-09-5]* **M 64.1, b -10°.** Dried by bubbling through concentrated H_2SO_4 and by passage over P_2O_5, then passed through a glass-wool plug. Frozen with liquid air and pumped to a high vacuum to remove dissolved gases.

Sulphuric acid *[7664-93-9]* **M 98.1, d 1.83.** Sulphuric acid, and also 30% fuming H_2SO_4, can be distilled in an all-Pyrex system, optionally from potassium persulphate. Also purified by fractional crystn of the monohydrate from the liquid. It ha pKa^{25} values of -3 and +1.96 in water.

Sulphur monochloride (sulphur monochloride) *[10025-67-9]* **M 135.0, m -77°; b 19.1°, 29-30°/12mm, 72°/100mm, 138°/760mm, d^{20} 1.677, n_D^{20} 1.67.** *Pungent, irritating golden yellow liquid.* When impure its colour is orange to red due to SCl_2 formed. It fumes in moist air and liberates HCl, SO_2 and H_2S in the presence of H_2O. Distil and collect the fraction boiling above 137° at atmospheric pressure. Fractionate this fraction over sulphur at *ca* 12mm using ground glass apparatus (b 29-30°). Alternatively purify by distn below 60° from a mixture containing sulphur (2%) and activated charcoal (1%), under reduced pressure (e.g. 50mm). It is soluble in EtOH, C_6H_6, Et_2O, CS_2 and CCl_4. Store in a closed container in the dark in a refrigerator. [*Handbook of Preparative Inorganic Chemistry (ed Brauer)* Vol I 371 *1963*].

Sulphur trioxide pyridine complex *[26412-87-3]* **M159.2, m 155-165°, 175°.** Wash the solid with a little CCl_4, then H_2O to remove traces of pyridine sulphate, and dry over P_2O_5 [*B* **59** 1166 *1926*; *S* 59 *1979*].

Sulphuryl chloride *[7791-25-2]* **M 135.0, m -54.1°, b 69.3°/760mm, d_4^{20} 1.67, n_D^{30} 1.44.** *Pungent, irritating colourless liquid.* It becomes yellow with time due to decomposition to SO_2 and HCl. Distil and collect fraction boiling below 75°/atm which is mainly SO_2Cl_2. To remove HSO_3Cl and H_2SO_4 impurities, the distillate is poured into a separating funnel filled with crushed ice and *briefly* shaken. The lower cloudy layer is removed, dried for some time in a desiccator over P_2O_5 and finally fractionated at atmospheric pressure. The middle fraction boils at 69-70° and is pure SO_2Cl_2. It decomposes gradually in H_2O to H_2SO_4 and HCl. Reacts **violently** with EtOH and MeOH and is soluble in C_6H_6, toluene Et_2O and acetic acid. [*Handbook of Preparative Inorganic Chemistry (ed Brauer)* Vol I 383 *1963*;; *Inorg Synth* **1** 114 *1939*].

Tantalium (V) chloride (tantalium pentachloride) *[7721-01-9]* M 358.2, m 216.2°, 216.5-220°; b 239°/atm., d 3.68.

Purified by sublimation in a current of Cl_2. Colourless needles when pure (yellow when contaminated with even less than 1% of $NbCl_5$). Sensitive to H_2O, even in conc HCl it decomposes to tantalic acid. Sol in EtOH. [*JACS* ***80*** 2952 *1958*; *Handbook of Preparative Inorganic Chemistry (ed Brauer)* Vol II 1302 *1965*].

Tantalium pentaethoxide *[6074-84-6]* **M 406.3, b 147°/0.2mm, 202°/10mm.** Purified by distillation. It associates in C_6H_6, EtOH, MeCN, pyridine and diisopropyl ether. [*JCS* 726 *1955*, 5 *1956*].

Telluric acid *[11120-48-2]* **M 229.6.** Crystd once from nitric acid, then repeatedly from hot water (0.4ml/g).

Tellurium *[13494-80-9]* **M 127.6, m 450°.** Purified by zone refining and repeated sublimation to an impurity of less than 1 part in 10^8 (except for surface contamination by TeO_2). [Machol and Westrum *JACS* **80** 2950 *1958*]. Tellurium is volatile at 500°/0.2mm. Also purified by electrode deposition [Mathers and Turner *Trans Amer Electrochem Soc* **54** 293 *1928*].

Tellurium dioxide *[7446-07-3]* **M 159.6.** Dissolved in 5M NaOH, filtered and ppted by adding 10M HNO_3 to the filtrate until the soln was acid to phenolphthalein. After decanting the supernatant, the ppte was washed five times with distilled water, then dried for 24h at 110° [Horner and Leonhard *JACS* **74** 3694 *1952*].

Terbium oxide *[12037-01-3]* **M 747.7.** Dissolved in acid, ppted as its oxalate and ignited at 650°.

Tetrabutylammonium borohydride *[33725-74-5]* **M 257.3, m 128-129°.** Purified by recrystn from EtOAc followed by careful drying under vacuum at 50-60°. Samples purified in this way showed no signs of loss of *active* H after storage at room temperature for more than 1 year. Nevertheless samples should be stored at *ca* 6° in tightly stoppered bottles if kept for long periods. It is soluble in CH_2Cl_2. [*JOC* **41** 690 *1976*; *TET LETT* 3173 *1972*].

Tetrabutylammonium chlorochromate *[54712-57-1]* **M 377.9, m 184-185°.** Recrystd from EtOAc-hexane. IR ν 920cm^{-1} in $CHCl_3$ [*S* 749 *1983*]. *Powerful oxidant.*

Tetrabutylammonium tetrafluoroborate *[429-42-5]* **M 329.3, m 161.8°.** Recryst from H_2O, aqueous EtOH or from EtOAc by cooling in Dry ice. *Acetate* **m** 118±2° (from BuCl); *bromide* **m** 118° (from EtOAc) and *nitrate* **m** 120° (from C_6H_6). [*JACS* **69** 2472 *1947*, **77** 2024 *1955*].

Tetrabutyl orthotitanate monomer (titanium tetrabutoxide) *[5593-70-4]* **M 340.4, b 142°/0.1mm, 134-136°/0.5mm, 160°/0.8mm, 174°/6mm, 189°/13mm, d_4^{35} 0.993, n_D^{25} 1.49.** Dissolve in C_6H_6, filter if solid is present, evaporate and vacuum fractionate through a Widmer 24inch column. The ester hydrolyses when exposed to air to give hydrated ortho-titanic acid. Titanium content can be determined thus: weigh a sample (*ca* 0.25g) into a weighed crucible and cover with 10ml of H_2O and a few drops of conc HNO_3. Heat (hot plate) carefully till most of the H_2O has evaporated. Cool and add more H_2O (10ml) and conc HNO_3 (2ml) and evaporate carefully (no spillage) to dryness and ignite residue at 600-650°/1h. Weigh the residual TiO_2. [*JCS* 2773 *1952*; *JOC* **14** 655 *1949*].

Tetrabutyl tin (tin tetrabutyl) *[1461-25-2]* **M 347.2, b 94.5-96°/0.28mm, 145°/11mm, 245-247°/atm, d_4^{20} 1.05, n_D^{24} 1.473.** Dissolve in Et_2O, dry over $MgSO_4$, filter, evaporate and distil under reduced pressure. Although it does not crystallise easily, once the melt has crystallised then it will recrystallise more easily. It is soluble in Et_2O, Me_2CO. EtOAc and EtOH but insoluble in MeOH and H_2O and shows no apparent reaction with H_2O. [*JOC* ***19*** 74 *1954*, *JCS* 1992 *1954*].

Tetraethoxysilane (tetraethyl orthosilicate) *[78-10-4]* **M 208.3, m -77°, b 165-166°/atm, d_4^{20} 0.933, n_D^{25} 1.382.** Fractionate through an 80cm Podbielniak type column with heated jacket and partial take-off head. Slowly decomposed by H_2O, soluble in EtOH. *It is **flammable** - irritates the eyes and mucous membranes.* [*JACS* **78** 5573 *1956*, *cf JCS* 5020 *1952*].

Tetraethylammonium hexafluorophosphate *[429-07-2]* **M 275.2, m >300°, 331°(dec).** Dissolve salt (0.8g) in hot H_2O (3.3ml) and cool to crystallise. Yield of prisms is 0.5g. Solubility in H_2O is 8.1g/L at 19° [*B* **63** 1067 *1930*].

Tetraethylammonium tetrafluoroborate *[429-06-1]* **M 217.1, m. 235°, 356-367°.** Dissolve in hot MeOH, filter and add Et_2O. It is soluble in ethylene chloride [*JACS* **69** 1016 *1947*, **77** 2025 *1955*].

Tetraethyl lead *[78-00-2]* **M 323.5.** Its more volatile contaminants can be removed by exposure to a low pressure (by continuous pumping) for 1h at 0°. Purified by stirring with an equal volume of H_2SO_4 (s.g. 1.40), keeping the temperature below 30°, repeating this process until the acid layer is colourless. It is then washed with dilute Na_2CO_3 and distilled water, dried with $CaCl_2$ and fractionally distilled at low pressure under H_2 or N_2 [Calingaert *Chem Rev* **2** 43 *1926*].

Tetraethylsilane *[631-36-7]* **M 144.3, b 153.8°/760mm, d_4^{30} 0.77, n_D^{30} 1.427.** Fractionate through a 3ft vacuum jacketted column packed with 1/4" stainless steel saddles. The material is finally percolated through a 2ft column packed with alumina and maintained in an inert atmosphere. [*JCS* 1992 *1954*; *JACS* **77** 272 *1955*].

1.1.3.3-Tetraisopropyldisiloxane *[18043-71-5]* **M 246.5, b 129-130°/6mm, d_4^{30} 0.89, n_D^{30} 1.47.** Fractionate under reduced pressure in a N_2 atm. [*JACS* **69** 1500 *1947*].

Tetraisopropyl orthotitanate (titanium tetraisopropyl) *[546-68-9]* **M 284.3, m 18.5°; b 80°/2mm, 78°/12mm, 228-229°/755mm.** Dissolve in dry C_6H_6, filter if a solid separates, evap and fractionate. It is hydrolysed by H_2O to give solid $Tl_2O(iso\text{-}OPr)_2$ **m** *ca* 48°. [*JCS* 2027, *1952*, 469 *1957*].

Tetrakis(diethylamino) titanium *[4419-47-0]* **M 336.4, b 85-90°/0.1mm, 112°/0.1mm, d_4^{30} 0.93, n_D^{30} 1.54.** Dissolve in C_6H_6, filter if a solid separates, evaporate under reduced pressure and distil. Orange liquid which reacts violenly with alcohols. [*JCS* 3857 *1960*].

Tetrakis(hydroxymethyl)phosphonium chloride *[124-64-1]* **M 190.6, m 151°.** Crystd from AcOH and dried at 100° in a vacuum. An 80% w/v aqueous solution has d_4^{20} 1.33 [*JACS* **77** 3923 *1955*].

Tetrakis(triphenylphosphine) palladium *[14221-01-3]* **M 1155.58, m 100-105°(dec).** Yellow crystals from EtOH. It is stable in air only for a short time, and prolonged exposure turns its colour to orange. Store in an inert atmosphere below room temp in the dark. [*JCS* 1186 *1957*].

Tetrakis(triphenylphosphine) platinum *[14221-02-4]* **M 1244.3, m 118°.** Recrystd by adding hexane to a cold saturated solution in C_6H_6. It is soluble in C_6H_6 and $CHCl_3$ but insoluble in EtOH and hexane. A less pure product is obtained if crystd by adding hexane to a $CHCl_3$ soln. Stable in air for several hours and completely stable under N_2. [*JACS* 2323 *1958*].

Tetramethoxysilane (tetramethyl orthosilicate) *[681-84-5]* **M 152.2, m 4.5°, b 122°/760mm.** Purification as for tetraethoxysilane. It has a vapour pressure of 2.5mm at 0°. [IR: *JACS* *81* 5109 *1959*].

Tetramethylammonium borohydride *[16883-45-7]* **M 89.0.** Recrystn from H_2O three times yields *ca* 94% pure compound. Dry in high vacuum at 100° for 3h. The solubility in H_2O is 48% (20°), 61% (40°); and in EtOH 0.5% (25°) and MeCN 0.4% (25°). It decompose slowly in a vacuum at 150°, but rapidly at 250°. The rate of hydrolysis of $Me_4N.BH_4$ (5.8M) in H_2O at 40° is constant over a period of 100h at 0.04% of original wt/h. The rate decreases to 0.02%/h in the presence of Me_4NOH (5% of the wt of $Me_4N.BH_4$). [*JACS* **74** 2346 *1952*].

Tetramethylammonium hexafluorophosphate *[558-32-7]* **M 219.1, m >300°, d_4^{25} 1.617.** The salt (0.63g) is recrystd from boiling H_2O (76ml), yielding pure (0.45) $Me_4N.PF_6$ after drying at 100°. It is a good supporting electrolyte. [*B* **63** 1067 *1930*].

Tetramethylammonium perchlorate *[2537-36-2]* **M 123.6, m>300°.** Crystallise twice from H_2O and dry at 100° in an oven. Insol in most organic solvents. [*JCS* 1210 *1933*].

Tetramethylammonium triphenylborofluoride *[437-11-6]* **M 392.2.** Crystd from acetone or acetone/ethanol.

2,4,6,8-Tetramethylcyclotetrasiloxane *[2370-88-9]* **M 240.5, m -69 ±3°, b 134°/750mm, 134.5-134.9°/755mm, d_4^{20} 0.99, n_D^{20} 1.3872.** It is purified by repeated redistillation, and fractions with the required ^1H NMR are collected. [*J Gen Chem USSR* (Engl Edn) **29** 262 *1959*; *JACS* **68** 962 *1946*].

1,1,3,3-Tetramethyldisiloxane *[3277-26-7]* **M 134.3, b 70.5-71°/731mm, 71-72°/atm, d_4^{30} 0.75, n_D^{25} 11.367.** Possible impurity is 1,1-5,5-tetramethyl-3-trimethylsiloxytrisiloxane **b** 154-155°/733mm. Fractionate, collect fractions boiling below 80° and refractionate. Purity can be analysed by alkaline hydrolysis and measuring the volume of H_2 liberated followed by gravimetric estimation of silica in the hydrolysate. It is unchanged when stored in glass containers in the absence of moisture for 2-3 weeks. Small amounts of H_2 are liberated on long storage. ***Care** should be taken when opening a container due to pressure developed.* [JACS **79** 974 *1958*; *JCS* 609 *1958*; IR: *Z anorg Chem* **299** 78 *1959*].

***N,N,N'N'*-Tetramethylphosphonic diamide (methylphosphonic bis-dimethylamide)** *[2511-17-3]* **M 150.2, b 60.5°/0.6mm, 138°/32mm, 230-230°/atm, d_4^{30} 1.0157, n_D^{30}1.4539.** Dissolve in heptane or ethylbenzene shake with 30% aqueous NaOH, stir for 1h, separate the organic layer and fractionate. [*JOC* **21** 413 *1956*]. IR has ν 1480, 1460, 1300, 1184, 1065 and 988-970cm^{-1} [*Canad J Chem* **33** 1552 *1955*].

Tetramethylsilane *[75-76-3]* **M 88.2, b 26.3°, n 1.359, d 0.639.** Distilled from conc H_2SO_4 (after shaking with it) or $LiAlH_4$, through a 5ft vacuum-jacketted column packed with glass helices into an ice-cooled condenser, then percolated through silica gel to remove traces of halide.

2,4,6,8-Tetramethyl tetravinyl cyclotetrasiloxane *[2554-06-5]* **M 344.7, m -43.5°, b 111-112°/10mm, 145-146°/13mm, 224-224.5°/758mm, d_4^{30} 0.98, n_D^{30}1.434.** A 7ml sample was distilled in a small Vigreux column at atmospheric pressure without polymerisation or decomposition. It is soluble in cyclohexane. [*JACS* **77** 1685 *1955*].

Tetraphenylarsonium chloride *[507-28-8]* **M 418.8, m 261-263°.** A neutralised aqueous soln was evaporated to dryness. The residue was extracted into absolute EtOH, evaporated to a small volume and ppted by addition of absolute Et_2O. It was again dissolved in a small volume of absolute EtOH or ethyl acetate and reppted with Et_2O. Alternatively purified by adding conc HCl to ppte the chloride dihydrate. Redissolved in water, neutralised with Na_2CO_3 and evaporated to dryness. The residue was extracted with $CHCl_3$ and finally crystallised from CH_2Cl_2 or EtOH by adding Et_2O. If the aqueous layer is somewhat turbid treat with Celite and filter through filter paper.

Tetraphenylarsonium iodide *[7422-32-4]* **M 510.2,**
Tetraphenylarsonium perchlorate *[3084-10-4]* **M 482.8.** Crystd from MeOH.

Tetraphenylboron potassium *[3244-41-5]* **M 358.2.** Recrystd from acetone or water.

Tetraphenylsilane *[1048-08-4]* **M 336.4, m 231-233°.** Crystd from benzene.

Tetraphenyltin *[595-90-4]* **M 427.1, m 226°.** Crystd from $CHCl_3$, xylene or benzene/cyclohexane, and dried at 75°/20mm.

Tetrapropylammonium perchlorate *[15780-02-6]* **M 285.8, 238-240°**. Purified by several recrystns from H_2O and dried in vacuum over P_2O_5 at 100°. [*ZPC* **165A** 245 *1933*, **144** 281 *1929*, **140** 97 *1929*].

Tetrasodium pyrene-1,3,6,8-tetrasulphonate *[59570-10-0]* **M 610.5.** Recrystd from aqueous acetone [Okahata et al. *JACS* **108** 2863 *1986*].

Thallium (I) acetate *[563-68-8]* **M 263.4, m 126-128°, 127°**. Likely impurity is H_2O because the white solid is deliquescent. Dry in a vacuum over P_2O_5 or for several days in a desiccator, and store in a well closed container. 7.5g dissolve in 100g of liquid SO_2 at 0°, and *ca* 2mol% in AcOH at 25°. **POISONOUS** [*TFS* **32** 1660 *1936*; *JACS* **52** 516].

Thallous bromide *[7789-40-4]* **M 284.3, m 460°.** Thallous bromide (20g) was refluxed for 2-3h with water (200ml) containing 3ml of 47% HBr. It was then washed until acid-free, heated to 300° for 2-3h and stored in brown bottles.

Thallous carbonate *[6533-73-9]* **M 468.7, m 268-270°.** Crystd from hot water (4ml/g) by cooling.

Thallous chlorate *[13453-30-0]* **M 287.8.** Crystd from hot water (2ml/g) by cooling.

Thallous chloride *[7791-12-0]* **M 239.8, m 429.9°.** Crystd from 1% HCl and washed until acid-free, or crystd from hot water (50ml/g), then dried at 140° and stored in brown bottles. Also purified by subliming

in vacuum, followed by treatment with dry HCl gas and filtering while molten. (Soluble in 260 parts of cold water and 70 parts of boiling water).

Thallous hydroxide *[12026-06-1]* **M 221.4.** Crystd from hot water (0.6ml/g) by cooling.

Thallous iodide *[7790-30-9]* **M 331.3.** Refluxed for 2-3h with water containing HI, then washed until acid-free, and dried at 120°. Stored in brown bottles.

Thallous nitrate *[10102-45-1]* **M 266.4.** Crystd from warm water (1ml/g) by cooling to 0°.

Thallous perchlorate *[13453-40-2]* **M 303.8.** Crystd from hot water (0.6ml/g) by cooling. Dried under vacuum for 12h at 100° (protect from possible **EXPLOSION**).

Thallous sulphate *[7446-18-6]* **M 504.8, m 633°.** Crystd from hot water (7ml/g) by cooling, then dried under vacuum over P_2O_5.

Thexyl dimethyl chlorosilane (dimethyl-[2,3-dimethyl-2-butyl] chlorosilane) *[67373-56-2]* **M 178.8, b 55-56°/10mm, 158-159°/720mm, d_4^{20} 0.970, n_D^{20} 1.428.** Purified by fractional distillation and stored in small aliquots in sealed ampoules. It is very sensitive to moisture and is estimated by dissolving an aliquot in excess of 0.1M NaOH and titrating with 0.1M HCl using methyl red as indicator. [*HCA* **67** 2128 *1984*].

***N*-(Thexyl dimethylsilyl)dimethylamine (*N*-[2,3-dimethyl-2-butyl]dimethylsilyl dimethylamine)** *[81484-86-8]* **M 187.4, b 156-160°/720mm.** Dissolve in hexane, filter, evaporate and distil. Colourless oil extremely sensitive to humidity. It is best to store small quatities in sealed ampoules after distillation. For estimation of purity crush an ampoule in excess 0.1N HCl and titrate the excess acid with 0.1M NaOH using methyl red as indicator. [*HCA* **67** 2128 *1984*].

Thionyl chloride *[7719-09-7]* **M 119.0, b 77°, d 1.636.** Crude $SOCl_2$ can be freed from sulphuryl chloride, sulphur monochloride and sulphur dichloride by refluxing with sulphur and then fractionally distilling twice. [The $SOCl_2$ is converted to SO_2 and sulphur chlorides. The S_2Cl_2 (**b** 135.6°) is left in the residue, whereas SCl_2 (**b** 59°) passes over in the forerun]. The usual purification is to distil from quinoline (50g $SOCl_2$ to 10g quinoline) to remove acid impurities, followed by distillation from boiled linseed oil (50g $SOCl_2$ to 20g of oil). Precautions must be taken to exclude moisture.
Thionyl chloride for use in organic syntheses can be prepared by distillation of technical $SOCl_2$ in the presence of diterpene (12g/250m $SOCl_2$), avoiding overheating. Further purification is achieved by redistillation from linseed oil (1-2%) [Rigby *Chemistry & Industry (London)* 1508 *1969*]. Gas chromatographically pure material is obtained by distillation from 10% (w/w) triphenyl phosphite [Friedman and Wetter *JCS (A)* 36 *1967*; Larsen et al. *JACS* **108** 6950 *1986*].

Thorium chloride *[1002-08-1]* **M 373.8.** Freed from anionic impurities by passing a 2M soln of $ThCl_4$ in 3M HCl through a Dowex-1 anion-resin column. The eluate was partially evaporated to give crystals which were filtered off, washed with Et_2O and stored in a desiccator over H_2SO_4 to dry. Alternatively, a saturated solution of $ThCl_4$ in 6M HCl was filtered through quartz wool and extracted twice with ethyl, or isopropyl, ether (to remove iron), then evaporated to a small volume on a hot plate. (Excess silica ppted, and was filtered off. The filtrate was cooled to 0° and saturated with dry HCl gas.) It was shaken with an equal volume of Et_2O, agitating with HCl gas, until the mixture becomes homogeneous. On standing, $ThCl_4.8H_2O$ ppted and was filtered off, washed with Et_2O and dried [Kremer *JACS* **64** 1009 *1942*].

Thorium sulphate ($4H_2O$) *[10381-37-0]* **M 496.2.** Crystd from water.

Thyroxine sodium salt ($5H_2O$) *[1491-91-4]* **M 888.9, $[\alpha]_{546}^{20}$ +20° (c 2, 1M HCl + EtOH, 1:4).** Crystd from absolute EtOH and dried for 8h at 30°/1mm.

Tin (powder) *[7440-31-5]* **M 118.7.** The powder was added to about twice its weight of 10% aqueous NaOH and shaken vigorously for 10min. (This removed oxide film and stearic acid or similar material sometimes added for pulverisation.) It was then filtered, washed with water until the washings were no longer alkaline to litmus, rinsed with MeOH and air dried. [Sisido, Takeda and Kinugama *JACS* **83** 538 *1961*].

Tin tetramethyl *[594-27-4]* **M 178.8, m 16.5°, b 78.3°/740mm.** It is purified by fractionation using a Todd column of 35-40 plates at atmospheric pressure. The purity of the fractions can be followed by IR [*JACS* **77** 6486 *1955*]. It readily dissolves stopcock silicone greases which give bands in the 8-10μ region. [*JACS* **76** 1169 *1954*].

Tin tetraphenyl *[595-90-4]* **M 427.1, m 221-228°, 224-225°.** Recrystallises from pet ether (b 77-120°) in yellow crystals [*JACS* **74** 531 *1952*].

Titanium tetrabutoxide see **tetrabutyl orthotitanate monomer.**

Titanium tetrachloride *[7550-31-0]* **M 189.7, b 136.4°, d 1.730.** Refluxed with mercury or a small amount of pure copper turnings to remove the last traces of light colour [due to $FeCl_3$ and $V(IV)Cl_4$], then distilled under N_2 in an all-glass system, taking precautions to exclude moisture. Clabaugh, Leslie and Gilchrist [*J Res Nat Bur Stand* **55** 261 *1955*] removed organic material by adding aluminium chloride hexahydrate as a slurry with an equal amount of water (the slurry being *ca* one-fiftieth the weight of $TiCl_4$), refluxing for 2-6h while bubbling in chlorine, which was subsequently removed by passing a stream of clean dry air. The $TiCl_4$ was then distilled, refluxed with copper and again distilled, taking precautions to exclude moisture. Volatile impurities were then removed using a technique of freezing, pumping and melting.

Tiron see **1,2-dihydroxybenzene-3,5-disulphonic acid, disodium salt.**

Titanium tetra-isopropoxide see **tetraisopropyl orthotitanate.**

Titanium tetrakis(diethylamide) see **tetrakis(diethylamino) titanium.**

Titanium trichloride *[7705-07-9]* **M 154.3, m >500°.** Brown purple powder that is very reactive with H_2O and pyrophoric when dry. It should be manipulated in a dry box. It is soluble in CH_2Cl_2 and tetrahydrofuran and is used as a M solution in these solvents in the ratio of 2:1, and stored under N_2. It is a powerful reducing agent. [*Inorg Synth* **6** 52 *1960*; *S* 833 *1989*].

Titanocene dichloride *[1271.1-19-8]* **M 248.9, m 260-280°(dec), 289.2 ±2°, 298-291°, d 1.60.** Bright red crystals from toluene or xylene-$CHCl_3$ (1:1) and sublimes at 190°/2mm. It is moderately soluble in EtOH and insoluble in Et_2O, C_6H_6, CS_2, CCl_4, pet ether and H_2O. [IR: *JACS* **76** 4281 *1954*; NMR and X-ray: *Canad J Chem* **51** 2609 *1973*, **53** 1622 *1975*].

Titanyl sulphate ($TiOSO_4.2H_2O$) *[1325-74-6]* **M 160.0.** Dissolved in water, filtered and crystd three times from boiling 45% H_2SO_4, washing with EtOH to remove excess acid, then with Et_2O. Air dried for several hours, then oven dried at 105-110°. [Hixson and Fredrickson *IEC* **37** 678 *1945*].

Tribenzyl chlorosilane *[18740-59-5]* **M 336.9, m 139-142°, 141-142°, b 300-360°/100mm.** It is recrystd three times from light petroleum; slender colourless needles, **m** 141°, sparingly soluble in pet ether and soluble in Et_2O. Does not fume in air but is decomposed by H_2O to give *tribenzyl silanol* **m** 106°(from pet ether). [*JCS* **93** 439 *1908*; *JOC* **15** 556 *1950*].

Tribenzyl phosphine *[76650-89-7]* **M 304.4, m 96-101°, b 203-210°/0.5mm.** Dissolve in Et_2O, dry over Na_2SO_4, evap and distil in an inert atmosphere. Distillate solidifies on cooling and is sublimed at 140°/0.001mm. This has **m** 92-95°(evacuated capillary). When air is bubbled through an Et_2O solution, it is oxidised to *tribenzyl phosphine oxide* , **m** 209-212° (evacuated capillary) (from Me_2CO). [*JCS* 2835 *1959*].

Tri-*n*-butyl borate *[688-74-4]* **M 230.2, b 232.4°, n 1.4092, d 0.857.** The chief impurities are *n*-butyl alcohol and boric acid (from hydrolysis). It must be handled in a dry-box, and can readily be purified by fractional distillation, under reduced pressure.

Tri-*n*-butyl chlorosilane *[995-45-9]* **M 234.9, b 93-94°/4.5mm, 134-139°/16mm, 250-252°/atm, 142-144°/29mm, d_4^{20} 0.88, n_D^{20} 1.447 .** Fractionate and store in small aliquots in sealed ampoules. [*JACS* **74** 1361 *1952*; *JOC* **24** 219 *1959*].

Tri-*n*-butyl phosphate *[126-73-8]* **M 266.3, m -80°; b 47°/0.45mm, 98°/0.1mm, 121-124°/3mm, 136-137°/5.5mm, 166-167°/17mm, 177-178°/27mm, 289°/760atm (some dec), d_4^{20} 0.980, n_D^{20} 1.44249.** The main contaminants in commercial samples are organic pyrophosphates, mono- and di- butyl phosphates and butanol. It is purified by washing successively with 0.2M HNO_3 (three times), 0.2M NaOH (three times) and water (three times), then fractionally distilled under vacuum. [Yoshida *JINC* **24** 1257 *1962*]. It has also been purified *via* its uranyl nitrate addition compound, obtained by saturating the crude phosphate with uranyl nitrate. This compound was crystd three times with *n*-hexane by cooling to -40°, and then decomposed by washing with Na_2CO_3 and water. Hexane was removed by steam distn and the water was then evaporated under reduced pressure and the residue was distilled under reduced pressure. [Siddall and Dukes *JACS* **81** 790 *1959*].
Alternatively wash with water, then with 1% NaOH or 5% Na_2CO_3 for several hours, then finally with water. Dry under reduced pressure and fractionate carefully under vacuum. Stable colourless oil, sparingly soluble in H_2O (1ml dissolves in 165ml of H_2O), but freely miscible in organic solvents. [*JACS* **74** 4953 *1952*, **80** 5441 *1958*; ^{31}P NMR: *JACS* **78** 5715 *1956*; *JCS* 1488 *1957*].

Tri-*n*-butyl phosphine *[998-40-3]* **M 202.3, b 109-110°/10mm, 115-116°/12mm, 149.5°/50mm, 240.4-242.2°/atm, d_4^{20} 0.822, n_D^{20} 1.4463.** Fractionally distilled under reduced pressure in an inert atm (N_2) through an 8" gauze packed column (**b** 110-111°/10mm) and redistilled in a vacuum and sealed in thin glass ampoules. It is easily oxidised by air to *tri-n-butylphosphine oxide*, **b** 293-296°/745mm. It has a characteristic odour, it is soluble in EtOH, Et_2O, and C_6H_6 but insoluble in H_2O and is less easily oxidised by air than the lower molecular weight phosphines. It forms complexes, e.g. with CS_2 (1:1) **m** 65.5° (from EtOH). [*JCS* 33 *1929*, 1401 *1956*].

Tri-*n*-butyl phosphite *[102-85-2]* **M 250.3, b 114-115°/5mm, 122°/12mm, 130°/17mm, 137°/26mm, d_4^{20} 0.926, n_D^{20} 1.4924 .** Fractionate with an efficient column. Stable in air but is slowly hydrolysed by H_2O. [*JCS* 1464 *1940*, 1488 *1957*; *JACS* **80** 2358, 2999 *1958*].

Tri-*n*-butyl tin chloride *[1461-22-9]* **M 325.5, b 98-100°/0.4mm, 140-152°/10mm, 172°/25mm, d_4^{20} 1.21, n_D^{20} 1.492.** Fractionate in an inert atmosphere, and seal in small aliquots in glass ampoules. Sensitive to moisture. [*JCS* 1446 *1947*; *J Appl Chem* **6** 93 *1956*].

Tributyl tin hydride *[688-73-3]* **M 291.1, b 76°/0.7mm, 81°/0.9mm, d_4^{20} 1.098, n_D^{20} 1.473.** Dissolve in Et_2O, add quinol (500mg for 300ml), dry over Na_2SO_4, filter, evaporate and distil under dry N_2. It is a clear liquid if dry and decompose very slowly. In the presence of H_2O traces of tributyl tin hydroxide are formed in a few days. Store in sealed glass ampoules in small aliquots. It is estimated by reaction with aq NaOH when H_2 is liberated. **CARE**: stored samples may be under pressure due to liberated H_2. [*J Appl Chem* **7** 366 *1957*].

Trichloroborane see **boron trichloride.**

B-Trichloroborazine *[933-18-6]* **M 183.1, m 87°, b 88-92°/21mm.** Purified by distillation from mineral oil.

Trichloromethyl trimethylsilane (trimethylsilyl trichloromethane) *[5936-98-1]* **M 191.6, m 130-132°, b 146-156°/749mm.** It distils at atmospheric pressure without decomposition and readily sublimes at 70°/10mm. It has one peak in the ^1H NMR spectrum (CH_2Cl_2) δ: 0.38ppm. [*S* 626 *1980*].

Tricyclohexylphosphine *[2622-14-2]* **M 280.4, m 82-83°.** Recrystd from EtOH [Boert et al. *JACS* **109** 7781 *1987*].

Triethoxysilane *[998-20-1]* **M 164.3, m -170°; b 131.2-131.8°/atm, 131.5°/760mm, d_4^{20} 0.98753, n_D^{20} 1.4377.** Fractionated using a column packed with glass helices of *ca* 15 theoretical plates in an inert atmosphere. Store in aliquots in sealed ampoules because it is sensitive to moisture. [*JACS* **72** 1377, 2032 *1950*; *JOC* **13** 280 *1948*].

Triethyl aluminum see **aluminum triethyl.**

Triethylborane *[97-94-9]* **M 146.0, b 118.6°, n 1.378, d 0.678.** Distilled at 56-57°/220mm.

Triethyl borate *[150-46-9]* **M 146.0, b 118°, n 1.378, d 0.864.** Dried with sodium, then distilled.

Triethyl phosphate *[78-40-0]* **M 182.2, b 40-42°/0.25-0.3mm, 98-98.5°/8-10mm, 90°/10mm, 130°/55mm, 204°/680mm, 215-216°/760mm, d_4^{25} 1.608, n_D^{20} 1.4053.** Dried by refluxing with solid BaO and fractionally distilled under reduced pressure. It is kept with Na and distilled. Stored in the receiver protected from light and moisture. Alternatively it is dried over Na_2SO_4 and distilled under reduced pressure. The middle fraction is stirred for several weeks over anhydrous Na_2SO_4 and again fractionated under reduced pressure until the specific conductance reached a constant low value of κ^{25} 1.19 x 10^8, κ^{40} 1.68 x 10^8, and κ^{55} 2.89 x 10^8 ohm^{-1} cm^{-1}. It has also been fractionated carefully under reduced pressure through a glass helices packed column. It is soluble in EtOH, Et_2O and H_2O (dec). [*JACS* **77** 4767 *1955*, **78** 6413, 3557 (P NMR) *1956*; *JCS* 3582 *1959*, IR: *JCS* 475 *1952* and *Canad J Chem* **36** 820 *1958*; *Organophosphorus Compounds* Kosolapoff, Wiley p258 *1950*].

Triethyl phosphine *[554-70-1]* **M 118.2, b 100°/7mm, 127-128°/744mm, d_4^{15} 0.812, n_D^{18} 1.457.** Dissolve in Et_2O and shake with a solution of AgI and KI to form the insoluble complex. Filter off the complex, dry over P_2O_5 and the Et_3P is regenerated by heating the complex in a tube attached to a vacuum system. It also forms a CS_2 complex in 300% excess of CS_2 which separates on cooling in a Dry Ice-Me_2CO bath. The solid is collected, washed with pet ether, dried for a short period and recrystd from MeOH, **m** 118-120°, 121-122°. Et_3P should be distilled in the presence of N_2, as it is oxidised by air to the oxide. [*JCS* 530 *1953*, 1828 *1937*; *JOC* **27** 2573 *1962*; *Organophosphorus Compounds* Kosolapoff, Wiley p31 *1950*].

Triethyl phosphite *[122-52-1]* **M 166.2, b 48-49°/11mm, b 52°/12mm, 57.5°/19mm, 157.9°/757mm, d_4^{20} 0.9687, n_D^{20} 1.4135.** Treat with Na (to remove water and any dialkyl phosphonate), then decant and distil under reduced pressure, with protection against moisture or distil in vacuum through an efficient Vigreux column or a column packed with Penn State 0.16 x 0.16 in protruded nickel packing and a variable volume take-off head. [*Org Synth* Col Vol IV 955 *1963*; *JACS* **78** 5817 *1956*, **80** 2999 *1958*; *Organophosphorus Compounds* Kosolapoff, Wiley p203 *1950*].

Triethyl phosphonoacetate *[867-13-0]* **M 224.2, b 83-84°/0.5mm, 103°/1.2mm, 143-144°/11mm, 260-262°/atm, d_4^{30} 1.1128, n_D^{25} 1.4299.** Fractionated under reduced pressure using an efficient column. [*JOC* **23** 1883 *1958*; *JACS* **68** 1103 *1946*, **72** 4198 *1950*].

Triethyl phosphonoformate *[1474-78-8]* **M 210.2, b 70-72°/0.1mm122.5-123°/8mm, 130-131°/10mm, 138.2°/12.5mm, d_4^{20} 1.22, n_D^{20} 1.423.** Dissolve in Et_2O, shake with H_2O (to remove any trace of NaCl impurity), dry (Na_2SO_4), evaporate and distil using an efficient fractionating column. [*B* **57** 1035 *1924*].

Triethyl 2-phosphonopropionate *[3699-66-9]* **M 238.2, b 76-77°/0.2mm, 137-138.5°/17mm, d_0^{20} 1.096, n_D^{20} 1.432.** Purified by fractional distillation with high reflux ratio, preferably using a spinning band column. [*JACS* 4198 *1950*].

Triethylsilane *[617-86-7]* **M 116.3, b 105-107°, b 107-108°, d 0.734. n 1.414.** Refluxed over molecular sieves, then distilled. It was passed through neutral alumina before use [Randolph and Wrighton *JACS* **108** 3366 *1986*].

Triethylsilyl-1,4-pentadiene (1,4-pentadien-3-yloxy-trimethylsilane) *[62418-65-9]* **M 198.4, b 72-74°/12mm, d_4^{20} 0.842, n_D^{20} 1.439.** Dissolve in pentane, wash with H_2O, dry (Na_2SO_4), evaporate, and distil under vacuum. R_F values on Kieselgel 60 are 0.15 (pentane) and 0.60 (C_6H_6). [IR, NMR, MS: *HCA* **64** 2002 *1981*].

Triethyltin hydroxide *[994-32-1]* **M 222.9.** Treated with HCl, followed by KOH, and filtered to remove diethyltin oxide [Prince *JCS* 1783 *1959*].

Trifluoromethyl trimethylsilane see **trimethylsilyl trifluoromethane.**

Tri-*n*-hexylborane *[1188-92-7]* **M 265.3.** Treated with hex-1-ene and 10% anhydrous Et_2O for 6h at gentle reflux under N_2, then vacuum distilled through an 18in glass helices-packed column under N_2 taking the fraction **b** 130°/2.1mm to 137°/1.5mm. The distillate still contained some di-*n*-hexylborane [Mirviss *JACS* **83** 3051 *1961*].

Trihydroxy-*n*-butylstannane see ***n*-butylstannoic acid.**

Triiron dodecacarbonyl *[17685-52-8]* **M 503.7, m 140°(dec).** It usually contains 10% by weight of MeOH as stabiliser. This can be removed by keeping in a vacuum at 0.5mm for at least 5h. It can be sublimed slowly at high vacuum and is soluble in organic solvents. [*JOC* **37** 930 *1972*, *JCS* 4632 *1960*; *Inorg Synth* **7** 193 *1963*].

Triisoamyl phosphate *[919-62-0]* **M 308.4, b 143°/3mm,**
Triisobutyl phosphate *[126-71-6]* **M 266.3, b 119-129°/8-12mm, 192°/760mm, d 0.962, n 1.421.** Purified by repeated crystallisation, from hexane, of its addition compound with uranyl nitrate. (see *tributyl phosphate*.) [Siddall *JACS* **81** 4176 *1959*].

Triisooctyl thiophosphate *[30108-39-5]* **M 450.6.** Purified by passage of its solution in CCl_4 through a column of activated alumina.

Triisopropyl phosphite *[116-17-6]* **M 208.2, b 58-59°/7mm, n^{25} 1.4082.** Distilled from sodium, under vacuum, through a column with glass helices. (This removes any dialkyl phosphonate).

Trimesitylphosphine *[23897-15-6]* **M 388.5, m 205-206°.** Recrystd from EtOH [Boert et al. *JACS* **109** 7781 *1987*].

Trimethallyl phosphate *[14019-81-9]* **M 260.3, b 134.5-140°/5mm, n^{25} 1.4454.** Purified as for triisoamyl phosphate.

Trimethoxysilane *[2487-90-3]* **M 122.2, m -114.8°; 81.1°/760mm, 84°/atm, d_4^{20} 0.957, n_D^{20} 1.359.** Likely impurities are $Si(OMe)_4$ and $H_2Si(OMe)_2$. Efficient fractionation is essential for removing these impurities, [IR: *JACS* **81** 5109 *1959*].

Trimethyl aluminum see **aluminum trimethanide.**

Trimethyl borane *[121-43-7]* **M 103.9, b 67-68°/742mm, d_4^{20} 0.928, n_D^{20} 1.3610.** Carefully fractionated through a gauze-packed column. Redistil and collect in weighed glass vials and seal. Keep away from moisture. It undergoes alkyl exchange with alcohols and forms azeotropes, e.g. with MeOH the azeotrope consists of 70% $(MeO)_3B$ and 30% MeOH with **b** 52-54°/atm, d 0.87. [*JCS* 2288 *1952*; *Chemistry and Industry (London)* 53 *1952*; *JACS* **75** 213 *1953*].

Trimethyl borate *[121-43-7]* **M 103.9, b 65°, n 1.359, d 0.933.** Dried with Na, then distilled.

Trimethyl boroxine *[823-96-1]* **M 125.5, b 80°/742mm, 79.3°/755mm, d_4^{20} 0.902.** Possible impurity is methylboronic acid. If present then add a few drops of conc H_2SO_4 and distil immediately, then fractionate through an efficient column. [*JACS* **79** 5179 *1957*; IR: *Z anorg Chem* **272** 303 *1953*].

Trimethyl chlorosilane *[75-77-4]* **M 108.6, b 56-57°/atm, 58°/760mm, d 0.86, n 1.388.** Likely impurities are other chlorinated methylsilanes, and tetrachlorosilane (**b** 57.6°/atm), some of which can form azeotropes. To avoid the latter very efficient fractional distillation is required. It has been fractionated through a 12 plate glass helices packed column with only the heart-cut material used. It has also been fractionated through a 90cm, 19mm diameter Stedman column. Also purified by redistilling from CaH_2 before use. [*JACS* **70**, 4254, 4258 *1948*; *JOC* **23** 50 *1958*].

Trimethyl phosphate *[512-56-1]* **M 140.1, b 77°/12mm, 94°/22mm, 110°/60mm, 197.2°/atm, d_4^{20} 1.0213, n_D^{20} 1.3961.** Purified by fractionation through and efficient column at high reflux ratio. It is quite soluble in H_2O, solubility is 1:1 at 25°. [*JACS* **74** 2923 *1952*; IR: *JCS* 847 *1952*; *Canad J Chem* **36** 820 *1958*; *Organophosphorus Compounds* Kosolapoff, Wiley p 258 *1950*].

Trimethyl phosphite *[121-45-9]* **M 124.1, b 22°/23mm, 86-86.5°/351mm, 111-112°/760mm, 111°/atm, d_4^{20} 1.0495, n_D^{20} 1.408.** Treated with Na (to remove water and any dialkyl phosphonate), then decanted and distilled with protection against moisture. It has also been treated with sodium wire for 24h, then distilled in an inert atmosphere onto activated molecular sieves [Connor et al. *JCSDT* 511 *1986*]. It has also been fractionally distilled using a spinning band column at high reflux ratio. It is a colourless liquid which is slowly hydrolysed by H_2O. [*JACS* **80** 2999 *1958*; IR: *JCS* 255 *1950*, P NMR: *JACS* **79** 2719 *1957*; *Organophosphorus Compounds*, Kosolapoff, Wiley p203 *1950*].

Trimethyl phosphine *[594-09-2]* **M 76.1, m -85.3; b 40-42°/atm.** Purified by fractional distillation using high vacuum and inert atmosphere because the phosphine is flammable and oxidises to the oxide in air [*JACS* **71** 2752 *1949*]. Alternatively, freshly distilled Me_3P (6g) is shaken with a solution of AgI (13.2g, 1.1mol) in saturated aqueous KI solution (50ml) for 2h. A white solid, not wetted with H_2O, separates rapidly. It is collected, washed with the KI solution, H_2O, and dried [*JCS* 1829 *1937*]. The silver complex is stable if kept dry in the dark in which state it can be kept indefinitely. Me_3P can be generated from the complex when required. The silver complex is decomposed by heating gently in one arm of an inverted U tube. The other arm is kept in a freezing mixture. The complex dissociates and pure Me_3P collects in the cold arm and is used at once. It should not be allowed to come in contact with air [*JCS* 708 *1938*]. The *HCl* is unstable and volatilises at 75°/0.4mm (120°/14mm). [*JACS* **67** 503 *1945*; IR: *TFS* **40** 41 *1944*; *Organophosphorus Compounds,* Kosolapoff, Wiley p31 *1950*].

Trimethylsilyl acetamide *[13435-12-6]* **M 131.3, m 38-43°, 52-54°, b 84°/13mm, 185-186°/atm.** Repeated distillation in an inert atmosphere, all operations to be performed under anhydrous atmosphere. In the presence of moisture trimethylsilanol (b 31-34°/26mm) is formed and is a likely impurity (check by NMR). [*B* **96** 1473 *1963*].

Trimethylsilyl acetonitrile (TMSAN) *[18293-53-3]***M 113.2, b 49-51°/10mm, 65-70°/20mm, d_4^{20} 0.8729, n_D^{20} 1.4420.** Check if NMR and IR spectra are correct, if not dissolve in C_6H_6 (10vols), wash with buffer (AcOH-AcONa pH *ca* 7) several times, dry ($CaCl_2$), evaporate and distil. IR: ν (CCl_4) 2215 (CN) cm^{-1}; NMR δ (CCl_4): 0.23 (s, 9H, $SiMe_3$), and 1.53 (s, 2H, CH_2CN) ppm. [*JCS Perk 1* 26 *1979*].

Trimethylsilyl azide *[46648-54-8]* **M 115.2, b 92-95°/atm, 95-99°/atm, d_4^{20} 0.878, n_D^{20} 1.441.** Distil through a Vigreux column in a N_2 atmosphere maintaining the oil bath temperature thermostated at 135-140°. Check the purity by ^1H NMR [CCl_3, δ : single peak at 13cps from Me_4Si. Likely impurities are siloxane hydrolysis products. The azide is thermally stable even at 200° when it decomposes slowly without explosive violence. All the same it is advisable to carry out the distillation behind a thick

safety screen in a fumehood because unforseen **EXPLOSIVE** azides may be formed on long standing. [*Org Synth* Col Vol VI 11030 *1988*].

Trimethylsilyl bromide see **bromo trimethyl silane**

Trimethylsilyl chloroacetate *[18293-71-5]* **M 166.7; m -20°, b 57-58°/14mm, 70-71°/30mm, 159°/760mm, d_4^{20} 1.057, n_D^{20} 11.4231.** Purified by repeated fractionation and taking the fractions with clean NMR spectra. [*JACS* 2371 *1952*].

Trimethylsilyl cyanide *[7677-24-9]* **M 99.2, m 8-11°, 10.5-11.5°, 11-12°, 12-12.5°; b 54-55°/87mm, 67-71°/168mm, 114-117°/760mm, 118-119°/760mm, d_4^{20} 0.79 n_D^{20} 1.43916.** Material should have only one sharp signal in the ^1H NMR (in CCl_4 with $CHCl_3$ as internal standard, δ: 0.4 ppm) and IR with ν at 2210cm^{-1} [*JACS* **74** 5247 *1952, 77* 3224 *1955*]; otherwise purify by fractionating through an 18 x 1/4 in column. [*JACS* **81** 4493 *1959*]. It has also been carefully distilled using a 60cm vac jacketed column. If volume of sample is small the cyanide can be chased (in the distillation) with xylene that had be previously distilled over P_2O_5. [*JOC* **39** 914 *1974*].

2-Trimethylsilyl-1,3-dithiane *[13411-42-2]* **M 192.2, b 54.5°/0.17mm, 100°/8mm, d_4^{20} 1.04, n_D^{20} 1.533.** Fractionally distil through an efficient column and collect the fractions that have the correct NMR and IR spectra. ^1H NMR (CCl_4) τ 6.36 ($SiMe_3$), 9.87 (SCHS) and dithiane H at 7 and 8 ppm (ratio 1:9:4::2) ppm from Me_4Si; UV λ_{max} 244nm (ε 711); sh 227nm (ε 800). [*JACS* **89** 434 *1967*].

Trimethylsilyl ethanol *[2916-68-9]* **M 118.3, b 53-55°/11mm, 75°/41mm, 95°/100mm, d_4^{25} 0.8254, n_D^{25} 1.4220.** It the NMR spectrum is not clean then dissolve in Et_2O, wash with aqueous NH_4Cl solution, dry (Na_2SO_4), evaporate and distil. The *3,4-dinitrobenzoyl* deriv has **m** 66° (from EtOH). [NMR: *JACS* **79** 974 *1957*; *Z Naturforsch* **14b** 137 *1959*].

2-(Trimethylsilyl)ethoxymethyl-trimethylphosphonium chloride *[82495-75-8]* **M 429.0, m 140-142°.** Wash the solid with AcOH and recryst from CH_2Cl_2-EtOAc. Dry in a vacuum desiccator. *Hygroscopic*. ^1H NMR ($CDCl_3$) δ: -0.2 (s, Me_3Si), 0.8 (t, 8Hz, CH_2Si), 3.83 (t, 8Hz, OCH_2), 5.77 (d, J_{PH} 4Hz, P^+-CH_2O) and 7.70 (m, aromatic H). [*A* 1031 *1983*].

Trimethylsilylethyl phenylsulphone (phenyl-2-trimethylsilylethylsulphone) *[73476-18-3]* **M 242.4, m 52°.** Dissolve in Et_2O, wash with saturated HCO_3^-, saturated NaCl, H_2O and dried ($MgSO_4$). Evaporation leaves residual crystals **m** 52°. [*TET LETT* **23** 1963 *1982*, *JOC* **53** 2688 *1985*].

1-(Trimethylsilyloxy)cyclopentene *[19980-43-9]* **M 156.3, b 45°/11mm, 75-80°/20-21mm, d_4^{20} 0.878, n_D^{20} 1.441.** If too impure as seen by the NMR spectrum then dissolve in 10 vols of pentane, shake with cold $NaHCO_3$(3 x 500ml), then 1.5M HCl (200ml) and aqueous $NaHCO_3$ (200ml) again, dry (Na_2SO_4), filter, evaporate and distil through a short Vigreux column. ^1H NMR: ($CDCl_3$) δ: 0.21 (s, 9H), 1.55 (m, 2H), 1.69 (m, 2H), 2.05 (br d, 4H) and 4.88 (br s, 1H) ppm. GLPC in a 6ft x 1/8in with 3% SP2100 on 100-120 mesh Supelcoport column should give one peak. [*Org Synth* Col Vol VIII 460 *1993*].

2-(Trimethylsilyloxy)furan *[61550-02-5]* **M 156.3, b 34-35°/9-10mm, 42-50°/17mm, 40-42°/25mm, d_4^{20} 0.950, n_D^{20} 1.436.** Fractionally distilled using a short path column. ^1H NMR in CCl_4 has δ: 4.90 (dd, *J* 1.3Hz, 3H), 6.00 (t, *J* 3Hz, 4H) and 6.60 (diffuses, 5H) ppm. [*Heterocycles* **4** 1663 *1976*].

4-Trimethylsilyloxy-3-penten-2-one (*cis*) **(acetylacetone enol trimethylsilyl ether)** *[13257-81-3]* **M 172.3, b 66-68°/4mm, 61-63°/5mm, d_4^{20} 0.917, n_D^{20} 1.452.** Fractionally distilled and stored in glass ampoules which are sealed under N_2. It hydrolyses readily in contact with moisture giving, as likely impurities, hexamethyl disiloxane and 2,4-pentanedione. [*JACS* **80** 3246 *1958*].

Trimethylsilyl isocyanate *[1118-02-1]* **M 115.2, b 90-92°/atm, 91.3-91.6°/atm, d_4^{20} 0.850 n_D^{20} 1.43943.** Purified by repeated fractionation as for the isothiocyanate. [*JCS* 3077 *1950*].

Trimethylsilyl isothiocyanate *[2290-65-5]* **M 131.3, m -33°; 142.6-143.1°/759mm, 143.8°/760mm, n_D^{20} 1.4809.** The ^1H NMR should have only one peak, if not purify by repeated fractionation in an all glass system using a 50cm (4mm internal diameter) column without packing. [*JACS* **69** 3049 *1947*; *B* **90** 1934 *1957*; *S* 51 *1975*].

Trimethylsilyl methanol *[3219-63-4]* **M 104.2, b 120-122°/754mm, 122-123°/768mm, d_4^{20} 0.83 n_D^{20} 1.4176.** If the NMR indicates impurities (should have only two signals) then dissolve in Et_2O, shake with aqueous 5N NaOH, M H_2SO_4, saturated aqueous NaCl, dry ($MgSO_4$) and distil using an efficient column at atmospheric pressure. The *3,5-dinitrobenzoate* has **m** 72-72.5°. [*Acta Chem Sin* ***23*** 291 *1957*, *Chem Abs* **52** 19911 *1958*; *JACS* **81** 1844 *1959*].

Trimethylsilyl methylamine (aminomethyl trimethylsilane) *[18166-02-4]* **M 103.2, b 101.6°/735mm, d_4^{20} 0.77, n_D^{20} 1.416.** A possible contaminant is hexamethyldisiloxane. Should have two ^1H NMR signals, if not dissolve in C_6H_6, shake with 15% aq KOH, separate, dry (Na_2SO_4), filter, evaporate and distil using a still of *ca* 10 theoretical plates. The water azeotrope has **b** 83°/735mm, hence it is important to dry the extract well. The *hydrochloride* has **m** 198/199° (from MeOH or Me_2CO). [*JACS* **73** 3867 *1951*; NMR, IR: *J Organometal Chem* **44** 279 *1972*].

Trimethylsilylmethyl phenylsulphone (phenyltrimethylsilylmethylsulphone) *[17872-92-5]* **M 228.4, m 28-32°, b 121°/0.01mm, 160°/6mm, n_D^{20} 1.5250.** Fractionate at high vacuum and recrystallise from pentane at -80°. If too impure (*cf* IR) dissolve in CH_2Cl_2 (*ca* 800ml for 100g), wash with 2M aqueous NaOH (2 x 200ml), brine, dry, evaporate and distil. [*JCS Perk 1* 1949 *1985*; IR and NMR: *JACS* **76** 3713 *1954*].

1-(Trimethylsilyl)-2-phenylacetylene (1-phenyl-2-trimethylsilylacetylene) *[78905-09-6]* **M 174.3, b 45-46°/0.1mm, 67°/5mm, 87.5°/9mm, d 0.8961 n 1.5284.** Dissolve in Et_2O, wash with H_2O, dry and fractionate through a Todd column. [*JACS* **80** 5298 *1958*].

3-(Trimethylsilyl)propyne *[13361-64-3]* **M 112.3, b 99-100°/760mm, d 0.7581, n 1.4091.** Fractionally distilled and 0.5% of 2,6-di-*tert*-butyl-*p*-cresol added to stabilise it. [*Doklady Acad USSR* **93** 293 *1953*; *Chem Abs* **48** 13616 *1954*].

1-Trimethylsilyl 1,2,4-triazole *[18293-54-4]* **M 141.3, b 74°/12mm, d_4^{20} 0.99, n_D^{20} 1.4604.** Fractionally distilled at atmospheric pressure in an inert atmosphere because it is moisture sensitive. [*B* ***93*** 2804 *1960*].

Trimethylsilyl trifluoromethane *[81290-20-2]* **M 142.2, b 54-55°, 55-55.5°; d_4^{20} 0.962, n_D^{20} 1.332.** Purified by distilling from trap to trap in a vacuum of 20mm using a bath at 45° and Dry ice-Me_2CO bath for the trap. The liquid in the trap is then washed with ice cold H_2O (3x), the top layer is collected, dried (Na_2SO_4), the liquid was decanted and fractionated through a helices packed column at atmospheric pressure. ^1H, ^{13}C, ^{19}F, and ^{29}Si NMR can be used for assessing the purity of fractions. [*TET LETT* **25** 2195 *1984*; *JOC* **56** 984 1991].

Trimethyl vinyl silane *[754-05-2]* **M 100.2, 54.4°/744mm, 55.5°/767mm, d_4^{25} 0.6865, n_D^{25} 1.3880.** If the ^1H NMR spectrum shows impurities then dissolve in Et_2O, wash with aq NH_4Cl soln, dry over $CaCl_2$, filter, evaporate and distil at atmospheric pressure in an inert atmosphere. It is used as a copolymer and may polymerise in the presence of a free radical donor. It is soluble in CH_2Cl_2. [*JOC* **17** 1379 *1952*].

Trineopentyl phosphate *[14540-59-1]* **M 320.4.** Crystd from hexane.

Tri-(4-nitrophenyl)phosphate *[3871-20-3]* **M 461.3, m 155-156°, 156°, 156-158°, 157-159°.** It has been recrystd from AcOH, dioxane, AcOEt and Me_2CO and dried in vacuum over P_2O_5. [*JACS* **72** 5777 *1950*, **79** 3741 *1957*].

Tri-*n*-octylphosphine oxide *[78-50-2]* **M 386.7, m 59.5-60°.** Mason, McCarty and Peppard [*J Inorg Nuclear Chem* **24** 967 *1962*] stirred an 0.1M solution in benzene with an equal volume of 6M HCl at 40° in a sealed flask for 48h, then washed the benzene solution successively with water (twice), 5% aq Na_2CO_3 (three times) and water (six times). The benzene and water were then evaporated under reduced pressure at room temperature. Zingaro and White [*JNC* **12** 315 *1960*] treated a pet ether solution with aqueous $KMnO_4$ (to oxidise any phosphinous acids to phosphinic acids), then with sodium oxalate, H_2SO_4 and HCl (to remove any manganese compounds). The pet ether solution was slurried with activated alumina (to remove phosphinic acids) and recrystd from pet ether or cyclohexane at -20°. It can also be crystd from EtOH.

Triphenylantimony *[603-36-1]* **M 353.1, m 52-54°.** Recrystd from acetonitrile [Hayes et al. *JACS* **107** 1346 *1985*].

Triphenylarsine *[603-32-7]* **M 306.2, m 60-62°.** Recrystd from EtOH or aqueous EtOH [Dahlinger et al. *JCSDT* 2145 *1986*; Boert et al. *JACS* **109** 7781 *1987*].

Triphenyl bismuth see **bismuth triphenyl.**

Triphenyl borane (borane triphenyl) *[960-71-4]* **M 242.1, m 134-140°, 137°, 139-141°, 142-142.5°, 147.5-148°, 151°, b 203°/15mm.** Recryst three times from Et_2O of C_6H_6 under N_2 and dry at 130°. It can be distilled in a high vacuum at 300-350°, and has been distilled (**b** 195-215°) in vacuum using a bath temp of 240-330°. N_2 was introduced into the apparatus before dismantling. It forms complexes with amines. [*Chemistry and Industry (London)* 1069 *1957*; *A* **563** 110 *1949*; *JACS* **57** 1259 *1935*].

Triphenyl chlorosilane see **chloro triphenyl silane.**

Triphenylchlorostannane *[639-58-7]* **M 385.5, m 104°.** Crystd repeatedly from pet ether (b 30-60°) or EtOH, then sublimed in a vacuum.

Triphenyl phosphate *[115-86-6]* **M 326.3, m 49.5-50°, b 245°/0.1mm.** Crystd from EtOH.

Triphenyl phosphine *[603-35-0]* **M 262.3, m 77-78°, 79°, 79-81°, 80.5°, 80-81°, b >360°(in inert gas), d_4^{25} 1.194, d_4^{80} 1.075 (liq).** Crystd from hexane, MeOH, ethyl ether, CH_2Cl_2/hexane or 95% EtOH. Dried at 65°/<1mm over $CaSO_4$ or P_2O_5. Chromatographed through alumina using (4:1) benzene/$CHCl_3$ as eluent. [Blau and Espenson et al. *JACS* **108** 1962 *1986*; Buchanan et al. *JACS* **108** 1537 *1986*; Randolph and Wrighton *JACS* **108** 3366 *1986*; Asali et al. *JACS* **109** 5386 *1987*]. It has also been crystd twice from pet ether and 5 times from Et_2O-EtOH to give **m** 80.5°. Alternatively dissolve in conc HCl, upon dilution with H_2O it separates and is then crystallised from EtOH-Et_2O. It recrystallises unchanged from AcOH. [*JCS* Supplement p121 *1949*; *JACS* **78** 3557 *1956*]. *$3Ph_3P$ .4HCl* crystallises when HCl gas is bubbled through an Et_2O solution; it has **m** 70-73°, but recrystallises very slowly. The *$HClO_3$* (1:1) salt has **m** 165-167°, but decomposes slowly at 100°. [IR, UV: *JACS* **80** 2117 *1958*; *Organophosphorus Compounds* Kosolapoff, Wiley p 32 *1950*].

Triphenyl phosphine dibromide *[1034-39-5]* **M 422.1, m 235°, 245-255°(dec).** Recrystd from MeCN-Et_2O. Although it has been recrystd from EtOH, this is not recommended as it converts alcohol to alkyl bromides. It deteriorates on keeping and it is best to prepare it afresh. [*JACS* **86** *1964*; *A* **626** 26 *1959*].

Triphenylphosphine oxide *[791-28-6]* **M 278.3, m 152.0°.** Crystd from absolute EtOH. Dried *in vacuo*.

Triphenyl phosphite *[101-28-6]* **M 310.3, b 181-189°/1mm, d 1.183.** Its ethereal soln was washed succesively with aqueous 5% NaOH, distilled water and saturated aqueous NaCl, then dried with Na_2SO_4 and distilled under vacuum after evaporating the ethyl ether.

Triphenyl silane *[789-25-3]* **M 260.4, m 45°, b 148-151°/1mm.** Purified by recrystn from MeOH. [*JACS* **81** 5925 *1959*; *Acta Chem Scand* **9** 947 *1955*; IR: *JACS* **76** 5880 *1954*].

Triphenylsilanol (hydroxytriphenylsilane) *[791-31-1]* **M 276.4, m 150-153°, 151-153°, 154-155°, 156°.** It can be purified by dissolving in pet ether, passing through an Al_2O_3 column, eluting thoroughly with CCl_4 to remove impurities and then eluting the silanol with MeOH. Evaporation gives crystals **m** 153-155°. It can be recrystallised from pet ether, CCl_4 or from benzene or Et_2O-pet ether (1:1). It has also been recrystallised by partial freezing from the melt to constant melting point. [*JACS* **81** 3288 *1959*; IR: *JOC* **17** 1555 *1952* and *JCS* 124 *1949*].

Triphenyltin hydroxide *[76-87-9]* **M 367.0.** West, Baney and Powell [*JACS* **82** 6269 *1960*] purified a sample which was grossly contaminated with tetraphenyltin and diphenyltin oxide by dissolving it in EtOH, most of the impurities remaining behind as an insoluble residue. Evaporation of the EtOH gave the crude hydroxide which was converted to triphenyltin chloride by grinding in a mortar under 12M HCl, then evaporating the acid soln. The chloride, after crystallisation from EtOH, had **m** 104-105°. It was dissolved in Et_2O and converted to the hydroxide by stirring with excess aqueous ammonia. The ether layer was separated, dried, and evaporated to give triphenyltin hydroxide which, after crystn from EtOH and drying under vacuum, was in the form of white crystals (**m** 119-120°), which retained some cloudiness in the melt above 120°. The hydroxide retains water (0.1-0.5 moles of water per mole) tenaciously.

Triphenyl vinyl silane *[18666-68-7]* **M 286.5, m 58-59°, 57-59.5°; 67-68°, b 190-210°/3mm.** It has been recrystallised from EtOH, 95% EtOH, EtOH-C_6H_6, pet ether (b 30-60°) and Et_2O, and has been distilled under reduced pressure. [*JACS* **74** 4582 *1952*; *JOC* **17** 1379 *1952*].

Tri-*n*-propyl borate *[688-71-1]* **M 140.1.** Dried with sodium and then distilled.

Triquinol-8-yl phosphate *[52429-99-9]* **M 479.4, m 193-197°, 202-203°.** Purified by recrystn from dimethylformamide. Purity was checked by paper chromatography, R_F 0.90 [Pr^iOH, saturated $(NH_4)_2SO_4$, H_2O; 2:79:19 as eluent]; IR (KBr) ν 1620–1570 (C=C, C=N) and 1253 (Π=O). [*Bull Chem Soc Japan* **47** 779 *1974*].

Tri-ruthenium dodecacarbonyl *[15243-33-1]* **M 6391, m 154-155°.** Recryst from C_6H_6 or cyclohexane as orange-red crystals, and sublime at 80-100°/0.1mm. It has ν_{CO} 2062 and 2032. [*JCSCC* 684 *1966*; *JCS (A)* 1238 *1967*; IR,UV: *Angew Chem (Engl Edn)* **7** 427 *1968*].

Tris-(2-biphenylyl) phosphate *[132-28-5]* **M 554.6, m 115.5-117.5°.** Crystd from MeOH containing a little acetone.

Tris(2,2'-bipyridine)ruthenium(II) dichloride ($6H_2O$) *[14323-06-9]* **M 748.6.** Recrystd from water then from MeOH [Ikezawa et al. *JACS* **108** 1589 *1986*].

Tris-(1,2-dioxyphenyl)cyclotriphosphazine (trispiro[1,3,5,2,4,6-triazatriphosphorine-2,2':-2,4":2,6"'-tris{1,3,2}benzodioxaphosphole) *[311-03-5]* **M 459.0, m 244-245°, 245°, 245-246°.** Recrystd from C_6H_6 or chlorobenzene, then triple sublimed (175°/0.1mm, 200°/0.1mm, 230°/0.05mm). UV has λ_{max}nm (log ε): 276 (3.72), 271 (3.79) 266sh (3.68) and 209 (4.38) in MeCN. IR (ν): 1270 (O-Ph), 1220 (P=N), 835 (P-O-Ph) and 745 (Ph) cm^{-1}. [Alcock *JACS* **86** 2591 *1964*; Alcock et al. *JACS* **98** 5120 *1976*; Meirovitch *JPC* **88** *1522 1984*].

(±)-Tris-(2-ethylhexyl)phosphate (TEHP, tri-isooctylphosphate, "trioctyl" phosphate, *[25103-23-5]*) *[78-42-2]* **M 434.6, b 186°/1mm, 219°/5mm, d^{25} 0.92042, n 1.44464.** TEHP, in an equal volume of ethyl ether, was shaken with aqueous 5% HCl and the organic phase was filtered to remove traces of pyridine (used as a solvent during manufacture) as its hydrochloride. This layer was shaken with aqueous Na_2CO_3, then water, and the ether was distilled off at room temperature. The ester was filtered, dried for 12h at 100°/15mm, and again filtered, then shaken intermittently for 2 days with activated alumina (100g/L). It was decanted through a fine sintered-glass disc (with exclusion of moisture), and distd under

vacuum. [French and Muggleton *JCS* 5064 *1957*]. Benzene can be used as a solvent (to give 0.4M soln) instead of ether. IR: 1702, 1701, 481 and 478cm^{-1} [Bellamy and Becker *JCS* 475 *1952*]. The *uranyl nitrate* salt was purified by partial crystallisation from hexane [Siddall *JACS* **81** 4176 *1959*].

Trisodium citrate ($2H_2O$) *[68-04-2]* **M 294.1.** Crystd from warm water by cooling to 0°.

Trisodium 8-hydroxy-1,3,6-pyrenetrisulphonate *[6358-69-6]* **M 488.8.** Purified by chromatography with an alumina column, and eluted with propan-1-ol-water (3:1, v/v). Recrystd from aqueous acetone (5:95, v/v) using decolorising charcoal.

Trisodium 1,3,6-naphthalenetrisulphonate *[5182-30-9]* **M 434.2.** The free acid was obtained by passage through an ion-exchange column and converted to the lanthanum salt by treatment with La_2O_3. This salt was crystallised twice from hot water. [The much lower solubility of $La_2(SO_4)_3$ and its retrograde temperature dependence allows a good separation from sulphate impurity]. The lanthanum salt was then passed through an appropriate ion-exchange column to obtain the free acid, the sodium or potassium salt. (The sodium salt is *hygroscopic*). [Atkinson, Yokoi and Hallada *JACS* **83** 1570 *1961*]. Also recrystd from aqueous acetone [Okahata et al. *JACS* **108** 2863 *1986*].

Trisodium orthophosphate ($12H_2O$) *[10101-89-0]* **M 380.1.** Crystd from warm dilute aqueous NaOH (1ml/g) by cooling to 0°.

Tris(2,4-pentandionate)aluminium *[13963-57-0]* **M 323.3, m 194°.** Recrystd twice from benzene.

Tritium *[10028-17-8]* **M 6.0.** Purified from hydrocarbons and ^3He by diffusion through the wall of a hot nickel tube [Landecker and Gray *Rev Sci Inst* **25** 1151 *1954*]. **RADIOACTIVE.**

Tri-*p*-tolyl phosphate *[20756-92-7]* **M 368.4, b 232-234°, d^{25} 1.16484, n 1.56703.** Dried with $CaCl_2$, then distd under vacuum and percolated through a column of alumina. Passage through a packed column at 150°, with a counter-current stream of nitrogen, under reduced pressure, removed residual traces of volatile impurities.

Tri-*o*-tolylphosphine *[6163-58-2]* **M 304.4, m 129-130°.** Crystd from EtOH [Boert et al. *JACS* **109** 7781 *1987*].

Tungsten (rod) *[7440-33-7]* **M 183.6.** Cleaned with conc NaOH solution, rubbed with very fine emery paper until its surface was bright, washed with previously boiled and cooled conductivity water and dried with filter paper.

Tungsten hexacarbonyl *[14040-11-0]* **M 351.9, d 2.650.** Sublimed *in vacuo* before use [Connoe et al. *JCSDT* 511 *1986*].

Tungsten (VI) trichloride *[13283-01-7]* **M 396.6, m 265°dec, 275°; b 346°, d_4^{25} 3.520.** Sublimed in a stream of Cl_2 in a high temperature furnace and collected in a receiver cooled in a Dry Ice-acetone bath in a inert atmosphere because it is sensitive to moisture. It is soluble in CS_2, CCl_4, $CHCl_3$, $POCl_3$, C_6H_6, pet ether and Me_2CO. Solns decompose on standing. Good crystals can be obtained by heating WCl_6 in CCl_4 to 100° in a sealed tube, followed by slow cooling (tablets of four-sided prisms). Store in a desiccator over H_2SO_4 in the dark. [*Inorg Synth* **3** 163 *1950*, **9** 133*1967*; *Handbook of Preparative Inorganic Chemistry (ed Brauer)* Vol II p1417 *1965*].

Uranium hexafluoride *[7783-81-5]* M 352.0, b 0°/17.4mm, 56.2°/765mm, m 64.8°.

Purified by fractional distillation to remove HF. Also purified by low temperature trap-to-trap distillation over pre-dried NaF [Anderson and Winfield *JCSDT* 337 *1986*].

Uranium trioxide *[1344-58-7]* **M 286.0.** The oxide was dissolved in $HClO_4$ (to give a uranium content of 5%), and the solution was adjusted to pH2 by addition of dilute ammonia. Dropwise addition of 30% H_2O_2, with rapid stirring, ppted U(VI) peroxide, the pH being held constant during the pptn, by addition of small amounts of the ammonia soln. (The H_2O_2 was added until further quantities caused no change in pH.) After stirring for 1h, the slurry was filtered through coarse filter paper in a Büchner funnel, washed with 1% H_2O_2 acidified to pH 2 with $HClO_4$, then heated at 350° for three days in a large platinum dish [Baes *JPC* **60** 878 *1956*].

Uranyl nitrate ($6H_2O$) *[10102-06-4]* **M 502.1, m 60.2°, b 118°.** Crystd from water by cooling to -5°, taking only the middle fraction of the solid which separated. Dried as the hexahydrate over 35-40% H_2SO_4 in a vacuum desiccator.

Vanadium (metal) *[7440-62-2]* M 50.9.

Cleaned by rapid exposure consecutively to HNO_3, HCl, HF, de-ionised water and reagent grade acetone, then dried in a vacuum desiccator.

Vanadium (III) acetonylacetonate *[13476-99-8]* **M 348.3, m 181-184°, 185-190°.** Crystd from acetylacetone as brown plates. It can be distilled in small quantities without decomposition. It is soluble in $CHCl_3$ and C_6H_6 and evaporation of a $CHCl_3$ solution yields brown crystals which are washed with cold EtOH and dried in vacuum or at 100° in a CO_2 atmosphere. Under moist conditions it readily oxidises [$V(AcAc)_3$ to $V(AcAc)_2O$]. [*JCS* **103** 78 *1913*, *Inorg Synth* **5** 105 *1957*; *AC* **30** 526 *1958*; UV: *JACS* **80** 5686 *1958*].

Vanadyl acetylacetonate *[3153-26-2]* **M 265.2, m 256-259°.** Crystd from acetone.

Vanadyl trichloride ($VOCl_3$) *[7727-18-6]* **M 173.3, m-79.5°; b 124.5-125.5°/744mm, 127.16°/760mm, d^{o} 1.854, d^{32} 1.811.** Should be lemon yellow in colour. If red it may contain VCl_4 and Cl_2. Fractionally distil and then redistil over metallic Na but be careful to leave some residue because the residue can become **EXPLOSIVE** in the presence of the metal **USE A SAFETY SHIELD** *and avoid contact with moisture.* It readily hydrolyses to vanadic acid and HCl. Store in a tightly closed container or in sealed ampoules under N_2. [*Inorg Synth* **1** 106 *1939*, **4** 80 *1953*].

Vinyl chlorosilane *[75-94-5]* **M 161.5, b 17.7°/46.3mm, 82.9°/599.4mm, 92°/742mm, 91-91.5°/atm, d_4^{20} 0.1.2717, n_D^{20} 1.435.** Fractionally distil at atmospheric pressure. It is H_2O sensitive and is stored in the dark and is likely to polymerise. [*B* **91** 1805 *1958*, **92** 1012 *1959*; *AC* **24** 1827 *1952*]

Water *[7732-18-5]* M 18.0, b 100°.

Conductivity water (specific conductance *ca* 10^{-7} mho) can be obtained by distilling water in a steam-heated tin-lined still, then, after adding 0.25% of solid NaOH and 0.05% of $KMnO_4$, distilling once more from an electrically heated Barnstead-type still, taking the middle fraction into a Jena glass bottle. During these operations suitable traps must be used to protect against entry of CO_2 and NH_3. Water only a little less satisfactory for conductivity measurements (but containing traces of organic material) can be obtained by passing ordinary distilled water through a mixed bed ion-exchange column containing, for example, Amberlite resins IR 120 (cation exchange) and IRA 400 (anion exchange), or Amberlite MB-1. This treatment is also a convenient one for removing traces of heavy metals. (The metals Cu, Zn, Pb, Cd and Hg can be tested for by adding pure concentrated ammonia to 10ml of sample and shaking vigorously with 1.2ml 0.001% dithizone in CCl_4. Less than 0.1μg of metal ion will impart a faint colour to the CCl_4 layer.) For almost all laboratory purposes, simple distillation yields water of adequate purity, and most of the volatile contaminants such as ammonia and CO_2 are removed if the first fraction of distillate is discarded.

Xylenol Orange (sodium salt) *[1611-35-4].* See entry in Chapter 3.

Zinc (dust) *[7440-66-6]* **M 65.4.** Commercial zinc dust (1.2Kg) was stirred with 2% HCl (3L) for 1min, (then the acid was removed by filtration), and washed in a 4L beaker with a 3L portion of 2% HCl, three 1L portions of distilled water, two 2L portions of 95% EtOH, and finally with 2L of absolute Et_2O. (The wash solutions were removed each time by filtration.) The material was then dried thoroughly and if necessary, any lumps were broken up in a mortar.

Zinc (metal) *[7440-66-6]* **M 65.4, m 420°, d 7.141.** Fused under vacuum, cooled, then washed with acid to remove the oxide.

Zinc acetate ($2H_2O$) *[5970-45-6]* **M 219.5.** Crystd (in poor yield) from hot water or, better, from EtOH.

Zinc acetonylacetate *[14024-63-6]* **M 263.6.** Crystd from hot 95% EtOH.

Zinc bromide *[7699-45-8]* **M 225.2.** Heated to 300° under vacuum (2 x 10^{-2}mm) for 1h, then sublimed.

Zinc caprylate *[557-09-5]* **M 351.8.** Crystd from EtOH.

Zinc chloride *[7646-85-7]* **M 136.3, m 283°.** The anhydrous material can be sublimed under a stream of dry HCl, followed by heating to 400° in a stream of dry N_2. Also purified by refluxing (50g) in dioxane (400ml) with 5g zinc dust, filtering hot and cooling to ppte $ZnCl_2$. Crystd from dioxane and stored in a desiccator over P_2O_5. It has also been dried by refluxing in thionyl chloride. [Weberg et al. *JACS* **108** 6242 *1986*]. *Hygroscopic: minimal exposure to the atmosphere is necessary.*

Zinc cyanide *[557-21-1]* **M 117.4.** It is a **POISONOUS** white powder which becomes black on standing if $Mg(OH)_2$ and carbonate are not removed in the preparation. Thus wash well with H_2O, then well with EtOH, Et_2O and dry in air at 50°. Analyse by titrating the cyanide with standard $AgNO_3$. Other likely impurities are $ZnCl_2$, $MgCl_2$ and traces of basic zinc cyanide; the first two salts can be washed out. It is soluble in aqueous KCN solutions. However, if purified in this way $Zn(CN)_2$ is not reactive in the Gattermann synthesis. For this the salt should contain at least 0.33 mols of KCl or NaCl which will allow the reaction to proceed faster. [*JACS* **45** 2375 *1923*, **60** 1699 *1938*; *Org Synth* Col Vol III 549 *1955*].

Zinc diethyldithiocarbamate *[14324-55-1]* **M 561.7,**
Zinc dimethyldithiocarbamate *[137-30-4]* **M 305.8, m 248-250°,**
Zinc ethylenebis[dithiocarbamate] *[12122-67-7]* **M 249.7.** Crystd several times from hot toluene or from hot $CHCl_3$ by addition of EtOH.

Zinc fluoride *[7783-49-5]* **M 103.4, m 872°; b 1500°, d^{25} 5.00.** Possible impurity is H_2O which can be removed by heating at 100° or by heating to 800° in a dry atmosphere. Heating in the presence of NH_4F produces larger crystals. It is sparingly sol in H_2O (1.51g/100ml) but more sol in HCl, HNO_3 and NH_4OH. It can be stored in glass bottles. [*Handbook of Preparative Inorganic Chemistry (ed Brauer)* Vol I p242 *1963*].

Zinc formate ($2H_2O$) *[557-41-5]* **M 191.4.** Crystd from water (3ml/g).

Zinc iodide *[10139-47-6]* **M 319.2.** Heated to 300° under vacuum (2 x 10^{-2}mm) for 1h, then sublimed.

Zinc *RS*-lactate ($3H_2O$) *[554-05-2]* **M 297.5.** Crystd from water (6ml/g).

Zincon (*o*-[1-(2-hydroxy-5-sulpho)-3-phenyl-5-formazono]-benzoic acid) *[135-52-4]* **M 459.4.** Main impurities are inorganic salts which can be removed by treatment with dilute acetic acid. Organic contaminants are removed by refluxing with ether. It can be recrystd from dilute H_2SO_4. [Fichter and Schiess *B* **33** 751 *1900*].

Zincon disodium salt (*o*-[1-(2-hydroxy-5-sulpho)-3-phenyl-5-formazono]-benzoic acid disodium salt) *[56484-13-0]* **M 484.4, m ~250-260° (dec).** Zincon soln is prepared by dissolving 0.13g of the powder in aqueous N NaOH (2ml diluted to 100ml with H_2O). This gives a deep red colour which is stable for one week. It is a good reagent for zinc ions but also forms stable complexes with transition metal ions. [UV-VIS: Bush and Yoe *AC* **26** 1345 *1954*; Hunter and Roberts *JCS* 820 *1941*; Platte and Marcy *AC* **31** 1226 *1959*] The free acid has been recrystd from dilute H_2SO_4. [Fichter and Scheiss *B* **33** 751 *1900*].

Zinc perchlorate ($6H_2O$) *[13637-61-1]* **M 372.4, m 105-107°.** Crystd from water.

Zinc phenol-*o*-sulphonate ($8H_2O$) *[127-82-2]* **M 555.8.** Crystd from warm water by cooling to 0°.

Zinc phthalocyanine *[14320-04-8]* **M 580.9.** Purified by repeated sublimation in a flow of oxygen-free N_2.

Zinc sulphate ($7H_2O$) *[7446-20-0]* **M 287.5.** Crystd from aqueous EtOH.

Zinc 5,10,15,20-tetraphenylporphyrin *[14074-80-7]* **M 678.1, λ_{max} 418(556)nm.** Purified by chromatography on neutral (Grade I) alumina, followed by recrystallisation from CH_2Cl_2/MeOH [Yamashita et al. *JPC* **91** 3055 *1987*].

Zinc trifluoromethanesulphonate *[54010-75-2]* **M 363.5, m >300°.** It should be dried at 125° for 2h at 3mm. It is soluble in CH_2Cl_2 but insoluble in pet ether. [*TET LETT* **24** 169 *1983*].

Zirconium (IV) propoxide *[23519-77-9]* **M 327.6, b 198°/0.03mm, 208°/0.1mm, d_4^{20} 1.06, n_D^{20} 1.454.** Although it was stated that it could not be crystallised or sublimed even at 150°/10^{-4} [*JCS* 280 *1951*], the propoxide has, when properly prepared, been purifed by distn in a high vacuum [*JCS* 2025 *1953*].

Zirconium tetrachloride *[10026-11-6]* **M 233.0, m 300°(sublimes).** Crystd repeatedly from conc HCl.

Zirconocene chloride hydride (bis[cyclopentadienyl]zirconium hydride chloride) (Schwartz reagent) *[37342-97-5]* **M 257.9.** It is a moisture and light sensitive compound. Its purity can be determined by reaction with a slight excess of Me_2CO whereby the active H reacts to produce $Cp_2ZrClOPr^i$ and the integrals of the residual Me_2CO in the ^1H NMR will show how pure the sample is. The presence of Cp_2ZrH_2 can be determined because it forms $Cp_2Zr(OPr^i)_2$. For very active compound it is best to prepare freshly from the dichloride by reduction with Vitride [$LiAl(OCH_2CH_2OH)_2H_2$], the white ppte is filtered off, washed with tetrahydrofuran, C_6H_6, Et_2O, dried in vacuum and stored under anhydrous conditions and in the dark. [IR: *JCSCC* 1105 *1969*; *JACS* **96** 8115 *1974*, **101** 3521 *1979*; *S* 1 *1988*].

Zirconocene dichloride (bis[cyclopentadienyl]zirconium dichloride) *[1291-32-3]* **M 292.3, m 242-245°, 248°.** Purified by recrystn from $CHCl_3$ or xylene, and dried in vacuum. ^1H NMR ($CDCl_3$) δ: 6.52 ppm from Me_4Si. Store in the dark under N_2 as it is moisture sensitive. [IR, NMR, MS: *Australian J Chem* **18** 173 *1965*; method of *JACS* **81** 1364 *1959*; and references in the previous entry].

Zirconyl chloride ($6H_2O$) *[7699-43-6]* **M 286.2.** Crystd repeatedly from 8M HCl as $ZrOCl_2.8H_2O$. (The product was not free from hafnium.)

Zirconyl chloride ($8H_2O$) *[13520-92-8]* **M 322.3.** Recrystd several times from water [Ferragina et al. *JCSDT* 265 *1986*].

CHAPTER 5

PURIFICATION OF BIOCHEMICALS AND RELATED PRODUCTS

Biochemicals are chemical species produced by living organisms. They range widely in size, from simple molecules such as formic acid and glucose to macromolecules such as proteins and nucleic acids. Their *in vitro* synthesis is often impossibly difficult and in such cases they are available (if at all) only as commercial tissue extracts which have been subjected to purification procedures of widely varying stringency. The desired chemical may be, initially, only a minor constituent of the source tissue which may vary considerably in its composition and complexity. Recent explosive advances in molecular biology have made it possible to produce substantial amounts of biological materials, which are present in nature in extremely small amounts, by recombinant DNA technology and expression in bacteria, yeast, insect and mammalian cells. The genes for these substances can be engineered such that the gene products, e.g. polypeptides or proteins, can be readily obtained in very high states of purity. However, many such products which are still obtained from the original natural sources are available commercially and may require further purification.

As a preliminary step the tissue might be separated into phases [e.g. whole egg into white and yolk, blood into plasma (or serum) and red cells], and the desired phase may be homogenised. Subsequent treatment usually comprises filtration, solvent extraction, salt fractionation, ultracentrifugation, chromatographic purification, gel filtration and dialysis. Fractional precipitation with ammonium sulphate gives crude protein species. Purification is finally judged by the formation of a single band of macromolecule (e.g. protein) on electrophoresis and/or analytical ultracentrifugation. Although these generally provide good evidence of high purity, none-the-less it does not follow that one band under one set of experimental conditions is an absolute indication of homogeneity.

During the past 20 or 30 years a wide range of methods for purifying substances of biological origin have become available. For small molecules (including many sugars and amino acids) reference should be made to Chapters 1 and 2. The more important methods used for large molecules, polypeptides and proteins in particular, comprise:

1. *Centrifugation.* In addition to centrifugation for sedimenting proteins after ammonium sulphate precipitation in dilute aqueous buffer, this technique has been used for fractionation of large molecules in a denser medium or a medium of varying density. By layering sugar solutions of increasing densities in a centrifuge tube, proteins can be separated in a sugar-density gradient by centrifugation. Smaller DNA molecules (e.g. plasmid DNA) can be separated from RNA or nuclear DNA by centrifugation in aqueous cesium chloride (*ca* 0.975g/ml of buffer) for a long time (e.g. 40h at 40,000 x g). The plasmid DNA band appears at about the middle of the centrifuge tube, and is revealed by the fluorescent pink band formed by the binding of DNA to ethidium bromide which is added to the CsCl buffer. *Microfuges* are routinely used for centrifugation in Eppendorf tubes (1.2-2ml) and can run up to speeds with 12,000 x g. *Analytical centrifugation*, which is performed under specific conditions in an analytical ultracentrifuge is very useful for determining purity, aggregation of protein subunits and the molecular weight of macromolecules. [D.Rickwood, T.C.Ford and J.Steensgaard *Centrifugation: Essential Data Series*, J Wiley & Sons, NY, *1994*].

2. *Gel filtration* with polyacrylamide (mol wt exclusion limit from 3000 to 300,000) and agarose gel (mol wt exclusion limit 0.5 to 150 x 10^6) is useful for separating macromolecules. In this technique high-molecular weight substances are too large to fit into the gel microapertures and pass rapidly through the matrix (with the void volume), whereas low molecular weight species enter these apertures and are held there for longer periods of time, being retarded by the column material in the equilibria, relative to the larger molecules. This method is also used for desalting solutions of macromolecules. *Dry gels* and *crushed beads* are also useful in the gel filtration process. Selective retention of water and inorganic salts by the gels or beads

(e.g. Sephadex G-25) results in increased concentration and purity of the protein fraction which moves with the void volume. (See also Chapter 1, pp 23, 45).

3. *Ion exchange* matrices are microreticular polymers containing carboxylic acid (e.g. Bio-Rad 70) or phosphoric acid (Pharmacia Mono-P) exchange functional groups for weak acidic cation exhangers, sulphonic acid groups (Dowex 50W) for strong acidic cation exchangers, diethylaminoethyl (DEAE) groups for weakly basic anion exchangers and quaternary ammonium (QEAE) groups for strong anion exchangers. The old cellulose matrices for ion exhanges have been replaced by Sephadex, Sepharose or Fractogel which have more even particle sizes with faster and more reproducible flow rates. Some can be obtained in fine, medium or coarse grades depending on particle size. These have been used extensively for the fractionation of peptides, proteins and enzymes. The use of *p*H buffers controls the strength with which the large molecules are bound to the support in the chromatographic process. Careful standardisation of experimental conditions and similarly the very uniform size distribution of Mono beads has led to high resolution in the purification of protein solutions. MonoQ (Pharmacia) is a useful strong anion exchanger, and MonoS (Pharmacia) is a useful strong cation exchanger whereas MonoP is a weak cation exchanger. These have been successful with medium pressure column chromatography (FPLC, see below in 8). Chelex 100 binds strongly and removes metal ions from macromolecules. [See also Chapter 1, pp. 20, 46].

4. *Hydroxylapatite* is used for the later stages of purification of enzymes. It consists essentially of hydrated calcium phosphate which has been precipitated in a specific manner. It combines the characteristics of gel and ionic chromatography. Crystalline hydroxylapatite is a structurally organised, highly polar material which, in aqueous solution (in buffers) strongly adsorbs macromolecules such as proteins and nucleic acids, permitting their separation by virtue of the interaction with charged phosphate groups and calcium ions, as well as by physical adsorption. The procedure therefore is not entirely ion-exchange in nature. Chromatographic separations of singly and doubly stranded DNA are readily achievable whereas there is negligible adsorption of low molecular weight species.

5. *Affinity chromatography* is a chromatographic technique whereby the adsorbant has a particular and specific affinity for one of the ingredients of the mixture to be purified. For example the adsorbant can be prepared by chemically binding an inhibitor of a specific enzyme (which is present in a complex mixture) to a matrix (e.g. Sepharose). When the mixture of impure enzyme is passed through the column containing the adsorbant, only the specific enzyme binds to the column. After adequate washing, the pure enzyme can be released from the column by either increasing the salt concentration (e.g. NaCl) in the eluting buffer or adding the inhibitor to the eluting buffer. The salt or inhibitor can then be removed by dialysis, gel filtration (above) or ultrafiltration (see below). [See W.H.Scouten *Affinity Chromatography*, J Wiley & Sons, NY, *1981*; and Chapter 1, pp. 24, 44].

6. In the *Isoelectric focusing* of large charged molecules on polyacrylamide or agarose gels, slabs of these are prepared in buffer mixtures (e.g. ampholines) which have various pH ranges. When a voltage is applied for some time the buffers arrange themselves on the slabs in respective areas according to their pH ranges (prefocusing). Then the macromolecules are applied near the middle of the slab and allowed to migrate in the electric field until they reach the pH area similar to their isoelectric points and focus at that position. This technique can also be used in a chromatographic mode, *chromatofocusing*, whereby a gel in a column is run (also under HPLC conditions) in the presence of ampholines (narrow or wide pH ranges as required) and the macromolecules are then run through in a buffer. *Capillary electrophoresis* systems in which a current is applied to set the gradiernt are now available in which the columns are fine capillaries and are used for qualitative and quantitative purposes [See R.Kuhn and S.Hoffstetter-Kuhn, *Capillary Electrophoresis*: Principles and Practice, Springer-Verlag Inc, NY, *1993*; P.Camilleri ed. *Capillary Electrophoresis - Theory and Practice*, CRC Press, Boca Raton, Florida, *1993*; D.R.Baker, *Capillary Electrophoresis*, J Wiley & Sons, NY, *1995*]. The bands are eluted according to their isoelectric points. Isoelectric focusing standards are available which can be used in a preliminary run in order to calibrate the effluent from the column, or alternatively the pH of the effluent is recorded using a glass electrode designed for the purpose. Several efficient commercially available apparatus are available for separating proteins on a preparative and semi-preparative scale.

7. *High performance liquid chromatography* (HPLC) is liquid chromatography in which the eluting liquid is sent through the column containing the packing (materials as in 2-6 above, which can withstand higher than atmospheric pressures) under pressure. On a routine basis this has been found useful for purifying proteins (including enzymes) and polypeptides after enzymic digestion of proteins or chemical cleavage (e.g. with CNBr) prior to sequencing (using reverse-phase columns such as μ-Bondapak C18). Moderate pressures (50-300psi) have been found most satisfactory for large molecules (FPLC). [See Scopes *AB* **114** 8 *1981*; *High Performance Liquid Chromatography and Its Application to Protein Chemistry,* Hearn in *Advances in Chromatography,* **20** 7 *1982*; B. A. Bidlingmeyer *Practical HPLC Methodology and Applications*, J Wiley & Sons, NY *1991*; L.R.Snyder, J.L.GlajCh and J.J.Kirkland *Practical HPLC Method Development*, J Wiley & Sons, NY *1988*; see also Chapter 1, pp. 23, 45].

8. *Ultrafiltration* using a filter (e.g. Millipore) can remove water and low-molecular weight substances without the application of heat. Filters with a variety of molecular weight exclusion limits not only allow the concentration of a particular macromolecule to be determined, but also the removal (by washing during filtration) of smaller molecular weight contaminants (e.g. salts, inhibitors or cofactors). This procedure has been useful for changing the buffer in which the macromolecule is present (e.g. from Tris-Cl to ammonium carbonate), and for desalting. Ultrafiltration can be carried out in a stirrer cell (Amicon) in which the buffer containing the macromolecule (particularly protein) is pressed through the filter, with stirring, under argon or nitrogen pressure (e.g. 20-60psi). During this filtration process the buffer can be changed. This is rapid (e.g. 2L of solution can be concentrated to a few mls in 1 to 2h depending on pressure and filter). A similar application uses a filter in a specially designed tube (Centricon tubes, Amicon) and the filtration occurs under centrifugal force in a centrifuge (4-6000rpm at 0°/40min). The macromolecule (usually DNA) then rests on the filter and can be washed on the filter by centrifugation. The macromolecule is recovered by inverting the filter, placing a conical receiver tube on the same side where the macromolecule rests, filling the other side of the filter tube with eluting solution (usually a very small volume e.g. 100 µl), and during further centrifugation this solution passes through the filter and collects the macromolecule from the underside into the conical receiver tube.

9. *Partial precipitation* of a protein in solution can often be achieved by controlled addition of a strong salt solution, e.g ammonium sulphate. This is commonly the first step in the purification process. Its simplicity is offset by possible denaturation of the desired protein and the (sometimes gross) contamination with other proteins. It should therefore be carried out by careful addition of small aliquots of the powdered salt or concentrated solution (below 4°, with gentle stirring) and allowing the salt to be evenly distributed in the solution before adding another small aliquot. Under carefully controlled conditions and using almost pure protein it is sometimes possible to obtain the protein in crystalline form suitable for X-ray analysis. **This is the ultimate in protein purification.** (T.L.Blundell and L.N.Johnson *Protein Crystallisation*, Academic Press, NY, 1976; A.McPherson *Preparation and Analysis of Protein Crystals*, J.Wiley & Sons, NY, 1982].

10. *Dialysis.* This is a process by which small molecules, e.g. ammonium sulphate, sodium chloride, are removed from a solution containing the protein or DNA using a membrane which is porous to small molecules. The solution (e.g. 10ml) is placed in a dialysis bag or tube tied at both ends, and stirred in a large excess of dialysing solution (e.g. 1.5 to 2 L), usually a weak buffer at *ca* 4°. The dialysing buffer is replaced with fresh buffer several times, e.g. four times in 24h. This procedure is similar to ultrafiltration (above) and allows the replacement of buffer in which the protein, or DNA, is dissolved. It is also possible to concentrate the solutions by placing the dialysis tube or bag in Sephadex G25 which allows the passage of water and salts from the inside of the bag thus concentrating the protein (or DNA) solution. Dialysis tubing is available from various distibutors but "Spectra/por" tubing (from Spectrum Medical Industries, Inc, LA) is particularly effective because it retains macromolecules and allows small molecules to dialyse out very rapidly thus reducing dialysing time considerably. This procedure is used when the buffer has to be changed so as to be compatible with the next purification or storage step, e.g. when the protein (or DNA) needs to be stored frozen in a particular buffer for extended periods.

11. *Gel Electrophoresis.* This is becoming a more commonly used procedure for purifying proteins, nucleic acids, nucleoproteins, polysaccharides and carbohydrates. The gels can be electroblotted onto membranes and the modern procedures of identifying, sequencing (proteins and nucleic acids) and amplifying (nucleic acids) on sub-micro scales have made this technique of separation a very important one. (See D.Patel *Gel Electrophoresis*, J.Wiley-Lis, Inc., 1994).

Other details of the above will be found in Chapters 1 and 2 which also contain relevant references.

Several illustrations of the usefulness of the above methods are given in the *Methods in Enzymology* series (Academic Press) in which 1000-fold purifications or more, have been readily achieved. In applying these sensitive methods to macromolecules, reagent purity is essential. It is disconcerting, therefore, to find that some commercial samples of the widely used affinity chromatography ligand Cibacron Blue F3GA contained this dye only as a minor constituent. The major component appeared to be the dichlorotriazinyl precursor of this dye. Commercial samples of Procion Blue and Procion Blue MX-R were also highly heterogeneous [Hanggi and Cadd *AB* **149** 91 *1985*]. Variations in composition of sample dyes can well account for differences in results reported by different workers. The purity of substances of biological origin should therefore be checked by one or more of the methods given above. Water of high purity should be used in all operations. Double glass distilled water or water purified by a MilliQ filtration system (see Chapter 2) is most satisfactory.

Brief general procedures for the purification of polypeptides and proteins. Polypeptides of up to *ca* 1-2000 (10-20 aminoacid residues) are best purified by reverse phase HPLC. The desired fractions that are collected are either precipitated from solution with EtOH or lyophilised. The purity can be checked by HPLC and identified by microsequencing (1-30 picomoles) to ascertain that the correct polypeptide was in hand. Polypeptides larger than these are sometimes classified as proteins, and are purified by one or more of the procedures described above. The purification of enzymes and functional proteins which can be identified by specific interactions is generally easier to follow because enzyme activities or specific protein interactions can be checked after each purification step. The commonly used procedures for purifying soluble proteins involve the isolation of an aqueous extract from homogenised tissues or extracts from ruptured cells from microorganisms or specifically cultured cells, for example, by sonication, freeze shocking or passage through a small orifice under pressure. Contaminating nucleic acids are removed by precipitation with a basic protein, e.g. protamine sulphate. The soluble supernatant is then subjected to fractionation with increasing concentrations of ammonium sulphate. The required fractions are then further purified by the procedures described in sections 2-9 above. If an affinity adsorbant has been identified then affinity chromatography can provide an almost pure protein in one step sometimes even from the crude extract. The rule of thumb is that a solution with a protein concentration of 1mg/ml has an absorbance A_{1cm} at 280nm of 1.0 units. Membrane-bound proteins are usually insoluble in water or dilute aqueous buffer and are obtained from the insoluble fractions, e.g. the microsomal fractions from the >100,000 x g ultracentrifugation supernatant. These are solubilised in appropriate detergents, e.g. Mega-10 (nonionic), Triton X-100 (ionic) detergents, and purified by methods 2 to 8 (previous section) in the presence of detergent in the buffer used. They are assayed also in the presence of detergent or membrane lipids.

The purity of proteins is best checked by *polyacrylamide gel electrophoresis* (PAGE). The gels are either made or purchased as pre-cast gels and can be with uniform or gradient gel composition. Proteins are applied onto the gels *via* wells set into the gels or by means of a comb, and travel along the gel surface by means of the current applied to the gel. When the buffer used contains sodium dodecylsulphate (SDS) the proteins are denatured and the denatured proteins (e.g. as protein subunits) separate on the gels mainly according to their molecular sizes. These can be identified by running marker proteins, with a range of molecular weights, simultaneously on a track alongside the proteins under study. The protein bands are visualised by fixing the gel (20% acetic acid) and staining with Coomassie blue followed by silver staining if higher sensitivity is required. A Pharmacia Ltd (Sweden) 'Phast Gel Electrophoresis" apparatus is very useful for rapid analysis of proteins. It uses small pre-cast polyacrylamide gels (two gels can be run simultaneously) with various uniform or gradient polyacrylamide concentrations as well as gels for isoelectric focussing. The gels are usually run for 0.5-1h and can be stained and developed (1-1.5h) in the same apparatus. The equipment can be used to electro-blot the protein bands onto a membrane from which the proteins can be isolated and sequenced or subjected to antibody or other identification procedures. It should be noted that all purification procedures are almost always carried out at *ca* 4° in order to avoid denaturation or inactivation of the protein being investigated. Anyone contemplating the purification of a protein is referred to: Professor R.K.Scopes's monograph *Protein Purification*, 3rd edn, Springer-Verlag, New York, 1994; M.L.Ladisch ed. *Protein Purification - from Molecular Mechanisms to Large-scale Processes*, American Chemical Society, Washington DC, 1990; E.L.V.Harris and S.Angal, *Protein Purification Applications - A Practical Approach*, IRL Press, Oxford, 1990; J.C.Janson and L.Rydén, *Protein Purification - Principles, High Resolution Methods and Applications*, VCH Publ. Inc., 1989; R.Burgess, *Protein Purification - Micro to Macro*, A.R.Liss, Inc., NY, 1987; S.M.Wheelwright, *Protein Purification, Design and Scale Up of Downstream Processing*, J Wiley & Sons, NY, 1994, references in the bibliography in Chapter 1, pp 44-47, and selected volumes of *Methods in Enzymology*, e.g. M.P.Deutscher ed. Guide to Protein Purification, *Methods in Enzymology* **182** *1990.*

Brief general procedures for purifying DNA. Oligo-deoxyribonucleotides (up to *ca* 60-mers) are conveniently purified by HPLC (e.g. using a Bio-Rad MA7Q anion exchange column and a Rainin Instrument Co, Madison, Dynamax-300Â C_8 matrix column) and used for a variety of molecular biology experiments. Plasmid and chromosomal DNA can be isolated by centrifugation in caesium chloride buffer (see section 1. centrifugation above), and then re-precipitated with 70% ethanol at -70° (18h), collected by centrifugation (microfuge) and dried in air before dissolving in TE (10mM TrisHCl, 1mM EDTA pH 8.0). The DNA is identified on an Agarose gel slab (0.5 to 1.0% DNA grade in 45mM Tris-borate + 1mM EDTA or 40mM Tris-acetate + 1mM EDTA pH 8.0 buffers) containing ethedium bromide which binds to the DNA and under UV light causes it be visualised as pink fluorescent bands. Marker DNA (from λ phage DNA cut with the

restriction enzymes Hind III and/or EcoRI) are in a parallel track in order to estimate the size of the unknown DNA. The DNA can be isolated from their band on the gel by transfer onto a nitro-acetate paper (NA 45) electrophoretically, by binding to silica or an ion exchange resin, extracted from these adsorbents and precipitated with ethanol. The DNA pellet is then dissolved in TE buffer and its concentration determined. A solution of duplex DNA (or RNA) of 50μg/ml gives an absorbance of 1.0units at 260nm/1cm cuvette (single stranded DNA or RNA gives a value of 1.3 absorbance units). DNA obtained in this way is suitable for molecular cloning. For experimental details on the isolation, purification and manipulation of DNA and RNA the reader is referred to: J.Sambrook, E.F.Fritsch and T.Maniatis, *Molecular Cloning - A Laboratory Manual* , 3rd edn, (3 volumes), Cold Spring Harbor Laboratory Press, NY, 1989; R.W.Davis, D.Botstein and J.R.Roth, *Advanced Bacterial Genetics - A Manual for Genetic Engineering*, Cold Spring Harbour Laboratory Press, NY, 1980. See Chapter 1, Bibliography for references to crystallisation of nucleic acids.

This chapter lists some representative examples of biochemicals and their origins, a brief indication of key techniques used in their purification, and literature references where further details may be found. Simpler low molecular weight compounds, particularly those that may have been prepared by chemical syntheses, e.g. acetic acid, glycine, will be found in Chapter 3. Only a small number of enzymes and proteins are included because of space limitations. The purification of some of the ones that have been included has been described only briefly. The reader is referred to comprehensive texts such as the *Methods in Enzymology* (Academic Press) series which currently runs to more than 264 volumes and *The Enzymes* (3rd Edn, Academic Press) which runs to 22 volumes for methods of preparation and purification of proteins and enzymes. Leading references on proteins will be found in *Advances in Protein Chemistry* (47 volumes, Academic Press) and on enzymes will be found in *Advances in Enzymology* (71 volumes, J Wiley & Sons). The *Annual Review of Biochemistry* (Annual Review Inc. Patlo Alto California] also is an excellent source of key references to the up-to-date information on known and new natural compounds with a variety of molecular weights.

Journal title abbreviations are as in Chapter 3.

Abrin A and Abrin B. Toxic proteins from seeds of *Abras precatorius*. Purified by successive chromatography on DEAE-Sephadex A-50, carboxymethylcellulose, and DEAE-cellulose. [Wei et al. *JBC* **249** 3061 *1974*].

Acetoacetyl coenzyme A trisodium salt trihydrate *[102029-52-7]* **M 955.6.** The pH of solution (0.05g/ml H_2O) is adjusted to 5 with 2N NaOH. This solution can be stored frozen for several weeks. Further purification can be carried out on a DEAE-cellulose formate column, then through a Dowex 50 (H^+) column to remove Na ions, concentrated by lyophilisation and redissolved in H_2O. Available as a soln of 0.05g/ml of H_2O. The concn of acetoacetylcoenzyme A is determined by the method of Stern et al. *JBC* **221** 15 *1956*. It is stable at pH 7-7.5 for several hours at 0° (half life *ca* 1-2h). At room temperature it is hydrolysed in *ca* 1-2h at pH 7-7.5. At pH 1.0/20° it is more stable than at neutrality. It is stable at pH 2-3/-17° for at least 6 months. [*JBC* **159** 1961 *1964*; **242** 3468 *1967*; Clikenbeard et al. *JBC* **250** 3108 *1975*; *JACS* **75** 2520 *1953*, **81** 1265 *1959*; see Simon and Shemin *JACS* **75** 2520 *1953*; Salem et al. *BJ* **258** 563 *1989*].

Acetobromo-α-D-galactose *[3068-32-4]* **M 411.2, m 87°, $[\alpha]_{546}^{20}$ +255°, $[\alpha]_D^{20}$ +210° (c 3, $CHCl_3$).** Purified as for the glucose analogue (see next entry). If the compound melts lower than 87° or is highly coloured then dissolve in $CHCl_3$ (*ca* 3 vols) and extract with H_2O (2 vols), 5% aqueous $NaHCO_3$, and again with H_2O and dry over Na_2SO_4. Filter and evaporate in a vacuum. The partially crystalline solid or syrup is dissolved in dry Et_2O (must be very dry) and recrystd by adding pet ether (b 40-60°) to give a white product. [McKellan and Horecker *Biochemical Preparations* **11** 111 *1960*].

Acetobromo-α-D-glucose *[572-09-8]* **M 411.2, m 87-88°, 88-89°, $[\alpha]_{546}^{20}$ +230°, $[\alpha]_D^{20}$ +195° (c 3, $CHCl_3$).** If nicely crystalline recryst from Et_2O-pentane. Alternatively dissolve in diisopropyl ether (dried over $CaCl_2$ for 24hours, then over P_2O_5 for 24hours) by shaking and warming (for as short a period as possible), filter warm. Cool to *ca* 45° then slowly to room temperature and finally at 5° for more than 2hours. Collect the solid, wash with cold dry diisopropyl ether and dry in a vacuum over $Ca(OH)_2$ and NaOH. Store dry

in a desiccator in the dark. Solutions can be stabilised with 2% $CaCO_3$. [Redemann and Niemann *Org Synth* **65** 236 *1987*, Coll Vol III 11 *1955*].

Acetoin dehydrogenase [from beef liver; acetoin NAD oxidoreductase] *[9028-49-3]* **M_r 76 000, [EC 1.1.1.5].** Purified *via* the acetone cake then Ca-phosphate gel filtration (unabsorbed), lyophilised and then fractionated through a DEAE-22 cellulose column. The Km for diacetyl in 40μM and for NADH it is 100μM in phosphate buffer at pH 6.1. [Burgos and Martin *Biochim Biophys Acta* **268** 261 *1972*; **289** 13 *1972*].

(-)-3-β-Acetoxy-5-etienic acid [3-β-acetoxy-5-etiocholenic acid, androst-5-ene-17-β-carboxylic acid] *[51424-66-9]* **M 306.5, m 238-240°, 241-242°, 243-245°, 246-247°, $[\alpha]_D^{20}$ -19.9° (c 1, Me_2CO), -36° (c 1, Dioxane), -33.5° ($CHCl_3$).** It is purified by recrystn from Me_2CO, Et_2O-pentane, or AcOH, and dried in a vacuum oven (105°/20mm) and sublimed at high vacuum. [Staunton and Eisenbram *Org Synth* **42** 4 *1962*; Steiger and Reichstein *HCA* **20** 1404 *1937*].

Acetylcholine bromide *[66-23-9]* **M 226.1, m 143°.** *Hygroscopic* solid but less than the hydrochloride salt. It crystd from EtOH as prisms. Some hydrolysis occurs in boiling EtOH particularly if it contains some H_2O. It can also be recryst from EtOH or MeOH by adding dry Et_2O. [*Acta Chem Scand* **12** 1492, 1497, 1502 *1958*].

Acetylcholine chloride *[60-31-1]* **M 181.7, m 148-150°, 151°.** It is very sol in H_2O (> 10%), and is very *hygroscopic*. If pasty, dry in a vacuum desiccator over H_2SO_4 until a solid residue is obtained. Dissolve in abs EtOH, filter and add dry Et_2O and the hydrochloride separates. Collect by filtration and store under very dry conditions. [*JACS* **52** 310 *1930*]. The *chloroplatinate* crystallises from hot H_2O in yellow needles and can be recrystd from 50% EtOH, **m** 242-244° [*BJ* **23** 1069 *1929*], other **m** given is 256-257°. The *perchlorate* crystallises from EtOH as prisms **m** 116-117°. [*J Amer Pharm Assocn* **36** 272 *1947*].

Acetyl-coenzyme A Synthase see **Acyl-coenzyme A Synthase** (below).

β-D-N-Acetylglucosaminidase [from M sexta insects) *[9012-33-3]* **M_r ~61,000, [EC 3.2.1.52].** Purified by chromatography on DEAD-Biogel, hydroxylapatite chromatography and gel filtration through Sephacryl S200. Two isoforms: a hexosaminidase EI with Km 177μM (V_{max} 328 sec^{-1}) and EII a chitinase with Km 160μM (V_{max} 103 sec^{-1}) with 4-nitrophenyl-β-acetylglucosamine as substrate. [Dziadil-Turner *Arch Biochem Biophys* **212** 546 *1981*].

β-D-N-Acetylhexosaminidase A and B (from human placenta). Purified by Sephadex G-200 filtration and DEAE-cellulose column chromatography. Hexosaminidase A was further purified by DEAE-cellulose column chromatography, followed by an ECTEOLA-cellulose column, Sephadex-200 filtration, electrofocusing and Sephadex G-200 filtration. Hexosaminidase B was purified by a CM-cellulose column, electrofocusing and Sephadex G-200 filtration. [Srivastava et al. *JBC* **249** 2034 *1974*].

***N*-Acetyl-D-lactosamine (2-acetylamino-*O*-β-D-lactopyranosyl-2-deoxy-D-glucose]** *[32181-59-2]* **M 383.4, m 169-171°, 170-171°, $[\alpha]_D^{18}$ +51.5°→ +28.8° (in 3h, c 1, H_2O].** Purified by recrystn from MeOH (with 1 mol of MeOH) or from H_2O. It is available as a soln of 0.5g /ml of H_2O. [Zilliken *JBC* **271** 181 *1955*].

***O*-Acetyl-β-methylcholine chloride [Methacholine chloride, Amechol, Provocholine, 2-acetoxypropyl-ammonium chloride]** *[62-51-1]* **M 195.7, m 170-173°, 172-173°.** It forms white *hygroscopic* needles from Et_2O and is soluble in H_2O, EtOH and $CHCl_3$. It decomposes readily in alkalies and slowly in H_2O. It should be handled and stored in a dry atmosphere. The *bromide* is less hygroscopic and the *picrate* has **m** 129.5-131° (from EtOH). [racemate: Annis and Ely *BJ* **53** 34 *1953*; IR of iodide: Hansen *Acta Chem Scand* **13** 155 *1959*].

***N*-Acetyl muramic acid [NAMA, *R*-2-(acetylamino)-3-*O*-(1-carboxyethyl)-2-deoxy-D-glucose]** *[10597-89-4]* **M 292.3, m ~125°(dec), $[\alpha]_D^{20}$ +41.2° (c 1.5, H_2O, after 24h).** See muramic acid below.

***N*-Acetyl neuraminic acid (NANA, *O*-Sialic acid, 5-acetamido-3,5-dideoxy-D-*glycero*-D-*glacto*-2-nonulosonic acid, lactaminic acid)** *[131-48-6]* **M 309.3, m 159°(dec), 181-183°(dec), 185-187°(dec), $[\alpha]_D^{25}$ -33° (c 2, H_2O, l 2).** A Dowex-1 x 8 (200-400 mesh) in the formate form was used, and was prepd by washing with 0.1M NaOH, then 2N sodium formate, excess formate was removed by washing with H_2O. *N*-Acetyl neuraminic acid in H_2O is applied to this column, washed with H_2O, then eluted with 2N formic acid at a flow rate of 1ml/min. Fractions (20ml) were collected and tested (Bial's orcinol reagent, *cf Biochemical Preparations* **7** 1 *1959*). NANA eluted at formic acid molarity of 0.38 and the Bial positive fractions are collected and lyophilised. The residue is recrystd from aqueous AcOH: Suspend 1.35g of residue in AcOH, heat rapidly to boiling, add H_2O dropwise until the suspension dissolves (do not add excess H_2O, filter hot and then keep at +5° for several hours until crystn is complete. Collect and dry in a vacuum over P_2O_5. Alternatively dissolve 1.35g of NANA in 14ml of H_2O, filter, add 160ml of MeOH followed by 360ml of Et_2O. Then add pet ether (b 40-60°) until heavy turbidity. Cool at 20° overnight. Yield of NANA is *ca* 1.3g. Dry over P_2O_5. at 1mm vacuum and 100° to constant weight. It mutarotates in Me_2SO: $[\alpha]_D^{20}$ -115° (after 7min) to -32° (after 24h). It is available as a soln of 0.01g/ml of H_2O and has a pKa of *ca* 2.6. [IR and synthesis: Cornforth et al. *BJ* **68** 57 *1958*; Zillikin and O'Brien *Biochemical Preparations* **7** 1 *1960*; ^{13}C NMR and 1-^{13}C synthesis: Nguyen, Perry *JOC* **43** 551 *1978*; Danishevski, DeNinno *JOC* **51** 2615 *1986*; Gottschalk, *The Chemistry and Biology of Sialic Acids and Related Substances*, Cambridge University Press, London, *1960*].

***N*-Acetyl neuraminic acid aldolase [from *Clostridium perfringens*, *N*-acetylneuraminic acid pyruvate lyase]** *[9027-60-5]* **[EC 4.1.3.3].** Purified by extraction with H_2O, protamine pptn, $(NH_4)_2SO_4$ pptn, Me_2CO pptn, acid treatment at pH 5.7 and pptn at pH 4.5. The equilibrium constant for pyruvate + *n*-acetyl-D-mannosamine ↔ *N*-acetylneuraminidate at 37° is 0.64. The Km for *N*-acetylneuraminic acid is 3.9mM in phosphate at pH 7.2 and 37°. [Comb and Roseman *Methods in Enzymology* **5** 391 *1962*]. The enzyme from Hogg kidney (cortex) has been purified 1700 fold by extraction with H_2O, protamine sulphate pptn, $(NH_4)_2SO_4$ pptn, heat treatment between 60-80°, a second $(NH_4)_2SO_4$ pptn and starch gel electrophoresis. The Km for *N*-acetylneuraminic acid is 1.5mM. [Brunetti et al. *JBC* **237** 2447 *1962*].

***N*-Acetyl-penicillamine** *[D- 15537-71-0, DL-59-53-0]* **M 191.3, m 183°, 186-187° (DL-form), 189-190° (D-form), $[\alpha]_D^{25}$ +18° (c 1, 50% EtOH).** Both forms are recrystd from hot H_2O. A pure sample of the D-form was obtained after five recrystns. [Crooks in *The Chemistry of Penicillin* Clarke, Johnson and Robinson eds, Princeton University Press, 470 *1949*].

***p*-Acetylphenyl phosphate, potassium salt.** Purified by dissolving in the minimum volume of hot water (60°) and adding EtOH, with stirring, then left at 0° for 1h. Crystals were filtered off and recrystd from water until free of Cl^- and SO_4^{2-} ions. Dried in a vacuum over P_2O_5 at room temperature. [Milsom et al. *BJ* **128** 331 *1972*].

S-Acetylthiocholine bromide *[25025-59-6]* **M 242.2, m 217-223°(dec).** It is a *hygroscopic* solid which can be recrystd from ligroin-EtOH (1:1), dried and kept in a vacuum desiccator. Crystn from C_6H_6-EtOH gave **m** 227° or from propan-1-ol the **m** was 213°. [*Acta Chem Scand* **11** 537 *1957*, **12** 1481 *1958*].

S-Acetylthiocholine chloride *[6050-81-3]* **M 197.7, m 172-173°** The chloride can be purified in the same way as the bromide, and it can be prepared from the iodide. A few milligrams dissolved in H_2O can be purified by applying onto a Dowex-1 Cl^- resin column (prepared by washing with N HCl followed by CO_3^{2-}—free H_2O until the pH is 5.8). After equilibration for 10min elution is started with CO_3^{2-}—free distilled H_2O and 3ml fractions are collected and their OD at 229nm measured. The fractions with appreciable absorption are pooled and lyophilised at 0-5°. Note that at higher temps decomposition of the ester is appreciable; hydrolysis is appreciable at pH >10.5/20°. The residue is dried *in vacuo* over P_2O_5, checked for traces of iodine (conc H_2SO_4 and heat, violet vapours are released), and recrystd from propan-1-ol. [*Clinica Chim Acta* **2** 316 *1957*].

S-Acetylthiocholine iodide *[1866-15-5]* **M 289.2, m 203-204°, 204°, 204-205°.** Recrystd from propan-1-ol (or *iso*-PrOH, or EtOH/Et_2O) until almost colourless and dried in a vacuum desiccator over P_2O_5. Solubility in H_2O is 1% w/v. A 0.075M (21.7mg/ml) solution in 0.1M phosphate buffer pH 8.0 is stable for 10-15 days if kept refrigerated. Store away from light. It is available as a 1% soln in H_2O. [*Biochemical Pharmacology* **7**, 88 *1961*; IR: Hansen *Acta Chem Scand* **13** 151 *1959*, **11** 537 *1957* ; *Clinica Chim Acta* **2** 316 *1957*; *Zhur Obshchei Khimii* **22** 267 *1952*].

Actinomycin C (Cactinomycin) *[805-16-2]* **M ~1255.** (A commercial mixture of Actinomycin C_1 ~5%, C_2 ~30% and C_3 ~65%). *Actinimycin C_1 (native)* crysts from EtOAc as red crystals, is sol in $CHCl_3$, C_6H_6 and Me_2CO and has **m** 246-247°(dec), $[\alpha]_D^{20}$ -328° (0.22, MeOH) and λ_{max} 443nm (ε 25,000) and 240nm (ε 34,000). *Actinimycin C_2 (native)* crysts as red needles from EtOAc and has **m** 244-246°(dec), $[\alpha]_D^{20}$ -325° (c 0.2, MeOH), λ_{max} 443nm (ε 25,300) and (ε 33,400). *Actinimycin C_3 (native)* recryst from cyclohexane, or C_6H_6/MeOH/cyclohexane as red needles **m** 238-241° (dec), $[\alpha]_D^{20}$ -321° (c 0.2, MeOH), λ_{max} 443nm (ε 25,000) and 240nm (ε 33,300). [Brockman and Lackner, *B* **101** 1312 *1968*]. It is *light sensitive.*

Actinomycin D (Dactinomycin) *[50-76-0]* **M 1255.5, m 241-243°(dec), $[\alpha]_D^{22}$ -296° (c 0.22, MeOH).** Crystallises as bright red rhombic crystals from absolute EtOH or from MeOH-EtOH (1:3). It will also crystallise from EtOAc-cyclohexane (**m** 246-247° dec), $CHCl_3$-pet ether (**m** 245-246° dec), and EtOAc-MeOH-C_6H_6 (**m** 241-243° dec). Its solubility in MeCN is 1mg/ml. $[\alpha]_D^{20}$ varies from -296° to -327° (c 0.2, MeOH). λ_{max} (MeOH) 445, 240nm (log ε 4.43, 4.49), λ_{max} (MeOH, 10N HCl, 1:1) 477nm (log ε 4.21) and λ_{max} (MeOH, 0.1N NaOH) 458, 344, 285 (log ε 3.05, 4.28, 4.13). It is *HIGHLY* **TOXIC,** light sensitive and antineoplastic. [Bullock and Johnson, *JCS* 3280 *1957*].

Acyl-coenzyme A Synthase [from beef liver] *[9013-18-7]* **M_r 57,000, [EC 6.2.1.2].** Purified by extraction with sucrose-HCO_3 buffer, protamine sulphate pptn, $(NH_4)_2SO_4$ (66-65%) pptn at pH 4.35 and a second $(NH_4)_2SO_4$ (35-60%) pptn at pH 4.35. It has Km 0.15mM (v_{rel} 1.0) for octanoate; 0.41mM (v_{rel} 2.37) for heptanoate and 1.59mM (v_{rel} 0.63). Km for ATP is 0.5mM all at pH 9.0 in ethylene glycol buffer at 38°. [Jencks et al. *JBC* **204** 453 *1953; Methods in Enzymology* **5** 467 *1962*].

Acyl-coenzyme A Synthase (from yeast) *[9012-31-1]* **[EC 6.2.1.1].** This enzyme has been purified by extraction into phosphate buffer pH 6.8-7.0 containing 2-mercaptoethanol and EDTA, protamine sulphate pptn, polyethylene glycol fractionation, Alumina γ gel filtration, concentration by $(NH_4)_2SO_4$ pptn, Bio-GelA-0.5m chromatography and DEAE-cellulose gradient chromatogarphy. It has M_r ~151,000, Km (apparent) 0.24mM (for acetate) and 0.035mM (for CoA); 1.2 mM (for ATP) and Mg^{++} 4.0mM. [Frenkel and Kitchens *Methods in Enzymology* **71** 317 *1981*].

Adenosine-5'-diphosphate [adenosine-5'-pyrophosphate, ADP] *[58-64-0]* **M 427.2, $[\alpha]_D^{25}$ -25.7° (c 2, H_2O).** Characterised by conversion to the *acridine salt* by addition of alcoholic acridine (1.1g in 50ml), filtering off the yellow salt and recrystallising from H_2O. The salt has **m** 215°(dec). λ_{max} 259nm (ε 15,400) in H_2O. [Baddiley and Todd *JCS* 648 *1947*, 582 *1949*, *cf* LePage *Biochemical Preparations* **1** 1 *1949*]. The acid has pKa^{25} values of 3.99 and 6.35 in 0.1 aqueous NaCl [Martell and Schwarzenbach *HCA* **39** 653 *1956*].

Adenosine-3'-monophosphoric acid [3'-adenylic acid, 3'-AMP] *[84-21-9]* **M 347.3, m 197°(dec, as dihydrate).** It crystallises from H_2O as needles but is not very soluble in boiling H_2O. Under acidic conditions it forms an equilibrium mixture of 2' and 3' adenylic acids *via* the 2',3'-cyclic phosphate. When heated with 20% HCl it gives a quantitative yield of furfural after 3hours, unlike 5'-adenylic acid which only gives traces of furfural. The yellow *monoacridine salt* has **m** 175°(dec) and the *diacridine salt* has **m** 177° (225°)(dec). [Brown and Todd *JCS* 44 *1952*; Takaku et al. *Chem Pharm Bull (Japan)* **21** 1844 *1973*; NMR: Ts'O et al. *Biochemistry* **8** 997 *1969*].

Adenosine-5'-monophosphoric acid monohydrate [5'-adenylic acid, 5'-AMP] *[18422-05-4]* **M 365.2, m 178°, 196-200°, 200° (sintering at 181°), $[\alpha]_D^{20}$ -47.5° (c 2, in 2% NaOH), -26.0° (c 2, 10% HCl), -38° (c 1, 0.5M Na_2HPO_4).** It has been recrystd from H_2O (fine needles) or H_2O-Me_2CO and is freely soluble in boiling H_2O. It has λ_{max} 259nm (ε 15,400) in H_2O at pH 7.0. It has

pKa^{25} values in H_2O of 3.89 and 6.49 and at 20° the values are 3.81 and 6.14 [Alberty et al. *JBC* **193** 425 *1951*; Martell and Schwarzenbach *HCA* **39** 653 *1956*]. The *acridinium salt* has **m** 208° [Baddiley and Todd *JCS* 648 *1947*; Pettit *Synthetic Nucleotides,* van Nostrand-Reinhold, NY, **vol 1** 252 *1972*; NMR: Sarma et al. *JACS* **96** 7337 *1974*; Norton et al. *JACS* **98** 1007 *1976*; IR of *diNa salt*: Miles *Biochem Biophys Acta* **27** 324 *1958*].

Adenosine 5"-[β-thio]diphosphate tri-lithium salt *[73536-95-5]* **M 461.1.** Purified by ion-exchange chromatography on DEAE-Sephadex A-25 using gradient elution with 0.1-0.5M triethylammonium bicarbonate. [*Biochem Biophys Acta* **276** 155 *1972*].

Adenosine 5"-[α-thio]monophosphate di-lithium salt *[19341-57-2]* **M 375.2.** Purified as for the diNa salt [Murray and Atkinson *Biochemistry* **7** 4023 *1968*]. Dissolve 0.3g in dry MeOH (7ml) and M LiI (6ml) in dry Me_2CO containing 1% of mercaptoethanol and the Li salt is ppted by adding Me_2CO (75ml). The residue is washed with Me_2CO (4 x 30ml) and dried at 55°/25mm. λ_{max} (HCl, pH 1.2) 257nm (ε 14,800); (0.015M NaOAc, pH 4.8) 259nm (ε 14,800); and (0.015M NH_4OH, pH 10.1) 259nm (ε 15,300).

Adenosine-5'-triphosphate See entry in Chapter 3.

S-(5'-Adenosyl)-L-homosysteine *[979-92-0]* **M 384.4, m 202°(dec), 204°(dec), 205-207°(dec), $[\alpha]_D^{25}$ +93° (c 1, 0.2N HCl), $[\alpha]_D^{23}$ +44° (c 0.1, 0.05N HCl).** It has been recrystd several times from aqueous EtOH or H_2O to give small prisms. The *picrate* has **m** 170°(dec) from H_2O and has λ_{max} 260nm in H_2O. [Baddiley and Jameison *JCS* 1085 *1955*; de la Haba and Cantoni *JBC* **234** 603 *1959*; Borchardt et al. *JOC* **41** 565 *1976*; NMR: Follmann et al. *Eur J Biochem* **47** 187 *1974*].

(-)-S-Adenosyl-L-methionine chloride (SAM hydrochloride) *[24346-00-7]* **M 439.9.** Purified by ion exchange on Amberlite IRC-150, and eluting with 0.1-4M HCl. [Stolowitz and Minch *JACS* **103** 6015 *1981*]. It has been isolated as the tri-reineckate salt by adding 2 volumes of 1% solution of ammonium reineckate in 2% perchloric acid. The reineckate salt separates at once but is kept at 2° overnight. The salt is collected on a sintered glass funnel, washed with 0.5% of ammonium reineckate, dried (all operations at 2°) and stored at 2°. To obtain adenosylmethionine, the reineckate is dissolved in a small volume of methyl ethyl ketone and centrifuged at room temp to remove a small amount of solid. The clear dark red supernatant is extracted (in a separating funnel) with a slight excess of 0.1 N H_2SO_4. The aqueous phase is re-extracted with fresh methyl ethyl ketone until it is colourless. [Note that reineckates have UV absorption at 305nm (ε 15,000), and the optical density at 305nm is used to detect the presence of reineckate ions]. Methyl ethyl ketone is removed from the aqueous layer containing adenosylmethyionine sulphate, the pH is adjusted to 5.6-6.0 and extracted with two volumes of Et_2O. The *sulphate* is obtained by evaporating the aqueous layer in *vacuo*. The *hydrochloride* can be obtained in the same way but using HCl instead of H_2SO_4. SAM-HCl has a solubility of 10% in H_2O. The salts are stable in the cold at pH 4-6 but decompose in alkaline media. [Cantoni *Biochemical Preparations* **5** 58 *1957*]. The purity of SAM can be determined by paper chromatography [Cantoni *JBC* **204** 403 *1953*; *Methods in Enzymology* **3** 601 *1957*], and electrophoretic methods or enzymic analysis [Cantoni and Vignos *JBC* **209** 647 *1954*].

L-Adrenaline [L-epinephrine, l-(3,4-dihydroxyphenyl)-2-methylaminoethanol] *[51-43-4]* **M 183.2, m 210°(dec), 211°(dec), 211-212°(dec), 215°(dec), $[\alpha]_D^{20}$ -52° (c 2, 5% HCl).** It has been recrystd from EtOH + AcOH + NH_3 [Jensen *JACS* **57** 1765 *1935*]. It is sparingly soluble in H_2O, readily in acidic or basic solns but insoluble in aqueous NH_3, alkali carbonate solns, EtOH, $CHCl_3$, Et_2O or Me_2CO. It is readily oxidised in air and turns brown on exposure to light and air. Store in the dark under N_2. Its pKa values in H_2O are 8.88 and 9.90 [Lewis *Brit J Pharmacol Chemotherapy* **9** 488 *1954*]. The *hydrogen oxalate salt* has **m** 191-192°(dec, evac capillary) after recrystn from H_2O or EtOH [Pickholz *JCS* 928 *1945*].

Adrenolone hydrochloride [3',4'-dihydroxy-2-methylaminoacetophenone hydrochloride] *[62-13-5]* **M 217.7, m 244-249°(dec), 248°(dec), 256°(dec).** It was purified by recrystn from EtOH or aqueous EtOH. It has a pKa value of 5.5. [Gero *JOC* **16** 1222 *1951*; Kindler and Peschke *Archiv der Pharmazie* **269** 581, 603 *1931*].

ADP-Ribosyl transferase (from human placenta). Purified by making an affinity absorbent for ADP-ribosyltransferase by coupling 3-aminobenzamide to Sepharose 4B. [Burtscher et al. *AB* **152** 285 *1986*].

Agglutinin (from peanuts) [*Arachis hypogaea*]. [1393-62-0] Purified by affinity chromatography on Sepharose-ζ-aminocaproyl-ß-D-galactopyranosylamine. [Lotan et al. *JBC* **250** 8518 *1974*].

Alamethicin (from *Tricoderma viridae*). Recrystd from MeOH. [Panday et al. *JACS* **99** 8469 *1977*].

Albumin (bovine and human serum) *[9048-46-8]* **M ~67 000 (bovine), 69 000 (human), UV: $\varepsilon^{1\%}_{280nm}$ 6.6 (bovine) and 5.3 (human) in H_2O, $[\alpha]^{25}_{546}$ -78.2° (H_2O).** Purified by soln in conductivity water and passage at 2-4° through two ion-exchange columns, each containing a 2:1 mixture of anionic and cationic resins (Amberlite IR-120, H-form; Amberlite IRA-400, OH-form). This treatment removed ions and lipoid impurities. Care was taken to exclude CO_2, and the soln was stored at -15°. [Möller, van Os and Overbeek *TFS* **57** 312 *1961*]. More complete lipid removal was achieved by lyophilising the de-ionised soln, covering the dried albumin (human serum) with a mixture of 5% glacial acetic acid (v/v) in iso-octane (previously dried with Na_2SO_4) and allowing to stand at 0° (without agitation) for upwards of 6h before decanting and discarding the extraction mixture, washing with iso-octane, re-extracting, and finally washing twice with iso-octane. The purified albumin was dried under vacuum for several hours, then dialyzed against water for 12-24h at room temperature, lyophilised, and stored at -10°C [Goodman *Science* **125** 1296 *1957*]. It has be recrystd in high (35%) and in low (22%) EtOH solutions from Cohn's Fraction V.

The **high EtOH recrystn** was as follows: To 1 Kg of Fraction V albumin paste at -5° was added 300ml of 0.4 M pH (pH 5.5) acetate buffer in 35% EtOH pre-cooled to -10° and 430 ml of 0.1 M NaOAc in 25% EtOH also at -10°. Best results were obtained by adding all of the buffer and about half of the NaOAc and stirring slowly for 1hour. The rest of the NaOAc was added when all the lumps had disintegrated. The mixture was set aside at -5° for several days to crystallise. 35% EtOH (1 L) was then added to dilute the crystalline suspension and lower the ionic strength prior to centrifugation at -5° (yield 80%). The crystals were further dissolved in 1.5 volumes of 15% EtOH-0.02M NaCl at -5° and clarified by filtration through washed, calcined, diatomaceous earth. This soln may be recrystd by re-adjusting to the conditions in the first crystallisation, or it may be recrystd at 22% EtOH with the aid of a very small amount of decanol (enough to give a final concn of 0.02%). Note that crystn from lower EtOH gave better purification (i.e. by removing globulins and carbohyrates) and producing a more stable product.

The **low EtOH recrystn** was as follows: To 1 Kg of Fraction V at -10° to -15° was added 500ml of 15% EtOH at -5°, stirred slowly until a uniform suspension was formed. 15% EtOH (500ml) and sufficient 0.2M $NaHCO_3$ soln at 0° to bring the pH (1:10 diln) to 5.3. This required 125- 150ml . Some temp rise occurs and care must be taken to keep the temp < -5°. If the albumin is incompletely dissolved a small amount of H_2O was added (100ml at a time at 0°, allowing 15min between additions). Undissolved albumin can be easily distinguished from small amounts of undissolved globulins, or as the last albumin dissolves, the appearance of the soln changes from milky white to hazy grey-green in colour. Keep the soln at -5° for 12hours and filter best by suspending in it 15g of washed fine calcined diatomaceous earth, and thus filtering using a Büchner funnel precoated with coarser diatomaceous earth. The filtrate may require two or more similar filtrations to give a clear soln. To crystallise the filtrate add through a capillary pipette, and with careful stirring, 1/100volume of a soln containing10% decanol and 60% EtOH (at -10°), and seeded with the needle-type albumin crystals. After 2-3 days crystn is complete. The crystals are centrifuged off. These are suspended with gentle mechanical stirring in one third their weight of 0.005 M NaCl pre-cooled to 0°. With careful stirring, H_2O (at 0°) is added slowly in an amount equal to 1.7 times the weight of the crystals. At this stage there is about 7% EtOH and the temp cannot be made lower than -2.5° to -1°. Clarify and collect as above. [Cohn et al. *JACS* **69** 1753 *1947*].

Human serum albumin has been purified similarly with 25% EtOH and 0.2% decanol. The isoelectric points of bovine and human serum albumins are 5.1 and 4.9.

Alkaline phosphatase see **phosphatase alkaline** (below).

Amethopterin (Methotrexate, 4-amino-4-deoxy-N^{10}-methylpteroyl-L-glutamic acid) *[59-05-2]* **M 454.4, m 185-204°(dec), $[\alpha]^{20}_{D}$ +19° (c 2, 0.1N aq NaOH).** Commonest impurities are 10-methyl pteroylglutamic acid, 4-amino-10-methylpteroylglutamic acid, aminopterin and pteroylglutamic acid. Purified by chromatography on Dowex-1 acetate, followed by filtration through a mixture of cellulose and

charcoal. It has been recrystd from aqueous HCl or by dissolution in the minimum volume of N NaOH and acidified until pptn is complete, filter or collect by centrifugation, wash with H_2O (also by centrifugation) and dry at 100°/3mm. It has UV λ_{max} at 244 and 307nm (ε 17300 and 19700) in H_2O at pH 1; 257, 302 and 370nm (ε 23000, 22000 and 7100) in H_2O at pH 13. [Momle *Biochemical Preparations* **8** 20 *1961*; Seeger et al. *JACS* **71** 1753 *1949*]. It is a potent inhibitor of dihydrofolate reductase and used in cancer chemotherapy. [Blakley *The Biochemistry of Folic Acid and Related Pteridines* (North-Holland Publ Co., Amsterdam, NY) pp157-163 *1969*]. It is **CARCINOGENIC, HANDLE WITH EXTREME CARE.**

α-Amino acids see Chapter 3 if not included in this chapter.

9-Aminoacridine hydrochloride monohydrate (Acramine yellow, Monacrin) *[52417-22-8]* **M 248.7, m >355°.** Recrystd from boiling H_2O (charcoal; 1g in 300 ml) to give pale yellow crystals with a neutral reaction. It has pKa values in H_2O of 9.99 and 4.7. It is one of the most fluorescent substances known. At 1:1000 dilution in H_2O it is pale yellow with only a faint fluorescence but at 1:100,000 dilution it is colourless with an intense blue fluroescence. [Albert and Ritchie *Org Synth* Coll Vol III 53 *1955*; Falk and Thomas *Pharm J* **153** 158 *1944*]. See entry in Chapter 3 for the free base.

Aminopterin [4-amino-4-deoxypteroyl-L-glutamic acid) *[54-62-6]* **M 440.4, m 230-235°(dec), $[\alpha]_D^{20}$ +18° (c 2, 0.1N aq NaOH).** Purified by recrystn from H_2O, and has properties similar to those of methotrexate, and is **CARCINOGENIC.** It has UV at λ_{max} 244, 290 and 355nm (ε 18600, 21300 and 12000) in H_2O at pH 1; 260, 284 and 370nm (ε 28500, 26400 and 8600) in H_2O at pH 13. [Seeger et al. *JACS* **71** 1753 *1949*; Angier and Curran *JACS* **81** 2814 *1959*; Blakley *The Biochemistry of Folic Acid and Related Pteridines* (North-Holland Publ Co., Amsterdam, NY) pp157-163 *1969*].

3-Aminopyridine adenine dinucleotide. Purified by ion exchange chromatography [Fisher et al. *JBC* **248** 4293 *1973*].

7-Amino-4-(trifluoromethyl)coumarin, *[53518-15-3]* **M229.2, m 222°.** Purified by column chromatography on a C18 column, eluted with acetonitrile/0.01M aq HCl (1:1), and crystd from isopropanol. Alternatively, it is eluted from a silica gel column with CH_2Cl_2, or by extracting a CH_2Cl_2 solution (4g/L) with 1M aq NaOH (3 x 0.1L), followed by drying ($MgSO_4$), filtration and evapn. [Bissell *JOC* **45** 2283 *1980*].

Amylose *[9005-82-7]* $(C_6H_{10}O_5)_n$ ***(for use in iodine complex formation).*** Amylopectin was removed from impure amylose by dispersing in aqueous 15% pyridine at 80-90° (concn 0.6-0.7%) and leaving the soln stand at 44-45° for 7 days. The ppte was re-dispersed and recrystd during 5 days. After a further dispersion in 15% pyridine, it was cooled to 45°, allowed to stand at this temperature for 12hours, then cooled to 25° and left for a further 10hours. The combined ppte was dispersed in warm water, ppted with EtOH, washed with absolute EtOH, and vacuum dried [Foster and Paschall *JACS* **75** 1181 *1953*].

Angiotensin (from rat brain) *[70937-97-2]* **M 1524.8.** Purified using extraction, affinity chromatography and HPLC [Hermann et al. *AB* **159** 295 *1986*].

Angiotensinogen (from human blood serum) *[64315-16-8].* Purified by chromatography on Blue Sepharose, Phenyl-Sepharose, hydroxylapatite and immobilised 5-hydroxytryptamine [Campbell et al. *BJ* **243** 121 *1987*].

ß-Apo-4'-carotenal *[12676-20-9]* **M 414.7, m 139°, $\varepsilon_{1cm}^{1\%}$ 2640 at 461nm,**
ß-Apo-8'-carotenal *[1107-26-2]* **M 414.7.** Recrystd from $CHCl_3$/EtOH mixture or *n*-hexane. [Bobrowski and Das *JOC* **91** 1210 *1987*].

ß-Apo-8'-carotenoic acid ethyl ester *[1109-11-1]* **M 526.8, m 134-138°, $\varepsilon_{1cm}^{1\%}$ 2550 at 449nm, ß-Apo-8'-carotenoic acid methyl ester** *[16266-99-2]* **M 512.7, m 136-137°, $\varepsilon_{1cm}^{1\%}$ 2575 at 446nm and 2160 at 471nm, in pet ether.** Crystd from pet ether or pet ether/ethyl acetate. Stored in the dark in an inert atmosphere at -20°.

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Apocodeine *[641-36-1]* **M 281.3, m 124°.** Crystd from MeOH and dried at 80°/2mm.

Apomorphine *[50-00-4]* **M 267.3, m 195°(dec).** Crystd from $CHCl_3$ and pet ether.

Aureomycin *[57-62-5]* **M 478.5, m 172-174°(dec), $[\alpha]_D^{23}$ -275° (MeOH).** Dehydrated by azeotropic distn of its soln with toluene. On cooling anhydrous material crystallises out and is recrystd from C_6H_6, then dried under vacuum at 100° over paraffin wax. (If it is crystd from MeOH, it contains MeOH which is not removed on drying.) [Stephens et al. *JACS* **76** 3568 *1954*].

Aureomycin hydrochloride *[64-72-2]* **M 514.0, m 234-236°(dec), $[\alpha]_D^{25}$ -23.5° (H_2O).** Purified by dissolving 1g rapidly in 20ml of hot water, cooling rapidly to 40°, treating with 0.1ml of 2M HCl, and chilling in an ice-bath. The process is repeated twice [Stephens et al. *JACS* **76** 3568 *1954*].

Avidin (from egg white) *[1405-69-2]* **M_r ~70,000.** Purified by chromatography of an ammonium acetate soln on CM-cellulose [Green *BJ* **101** 774 *1966*]. Also purified by affinity chromatography on 2-iminobiotin-6-aminohexyl-Sepharose 4B [Orr *JBC* **256** 761 *1981*]. It is a biotin binding protein.

Azurin (from *Pseudomonas aeruginosa*) *[12284-43-4]* **M_r 30,000.** Material with $A_{625/A280}$ = 0.56 was purified by gel chromatography on G-25 Sephadex with 5mM phosphate pH 7 buffer as eluent [Cho et al. *JPC* **91** 3690 *1987*]. It is a blue Cu protein used in biological electron transport and its reduced form is obtained by adding a slight excess of $Na_2S_2O_4$. [Fee *Structure and Bonding* Springer Verlag, Berlin **23** 1 *1975*].

Bacitracin (Altracin, Topitracin) *[1405-87-4]* M 1422.7, $[\alpha]_D^{23}$ +5° (H_2O).

It has been purified by carrier displacement using *n*-heptanol, *n*-octanol and *n*-nonanol as carriers and 50% EtOH in 0.1 N HCl. The pure material gives one spot with R_F ~0.5 on paper chromatography using AcOH:*n*-BuOH: H_2O (4:1:5). [Porath *Acta Chem Scand* **6** 1237 *1952*]. It has also been purified by ion-exchange chromatography. It is a white powder soluble in H_2O and EtOH but insoluble in Et_2O, $CHCl_3$ and Me_2CO. It is stable in acidic soln but unstable in base. (Abraham and Bewton *BJ* **47** 257 *1950*; Synthesis: Munekata et al. *Bull Chem Soc Japan* **46** 3187, 3835 *1973*].

N^6-Benzyladenine *[1214-39-7]* **M 225.3, m 231-232°, 232.5°, 234-234°(dec).** Purified by recrystn from aqueous EtOH. It has λ_{max} at 207 and 270nm (H_2O), 268 nm (pH 6), 274nm (0.1 N HCl) and 275nm (0.1 N NaOH). [Daly *JOC* **21** 1553 *1956*; Bullock et al. *JACS* **78** 3693 *1956*].

N^6-Benzyladenosine *[4294-16-0]* **M 357.4, m 177-179°, 185-187°, $[\alpha]_D^{25}$ -68.6° (c 0.6, EtOH).** Purified by recrystn from EtOH. It has λ_{max} 266nm (aq EtOH-HCl) and 269 nm (aqueous EtOH-NaOH). [Kissman and Weiss *JOC* **21** 1053 *1956*].

***N*-Benzylcinchoninium chloride (9*S*-benzyl-9-hydroxycinchonanium chloride)** *[69221-14-3]* **M 421.0, $[\alpha]_D^{20}$ +169° (c 0.4, H_2O).** Recrystd from isoPrOH, toluene or small volumes of H_2O. Good chiral phase transfer catalyst [Julia et al. *JCS Perk Trans 1* 574 *1981*; Hughes et al. *JACS* **106** 446 *1984*; Hughes et al. *JOC* **52** 4745 *1987*].

***R*-(-)-*N*-Benzylcinchonidinium chloride** *[69257-04-1]* **M 421.0, m 212-213° (dec), $[\alpha]_D^{20}$ -175.4°, -183° (c 5, 0.4, H_2O).** Dissolve in minimum volume of H_2O and add absolute Me_2CO. Filter off and dry in a vacuum. Also recrystd from hot EtOH or EtOH-Et_2O. (A good chiral phase transfer catalyst - see above) [Colonna et al. *JCS Perk Trans 1* 547 *1981*, Imperali and Fisher *JOC* **57** 757 *1992*].

***N*-Benzylpenicillin sodium salt** *[69-57-8]* **M 356.37, m 215° (charring and dec), 225° (dec), $[\alpha]_D^{20}$ +269° (c 0.7, MeOH), $[\alpha]_D^{25}$ +305° (c 1, H_2O).** Purified by dissolving in a small volume of MeOH (in which it is more soluble than EtOH) and treating gradually with ~5 volumes of EtOAc. This gives

an almost colourless crystalline solid (rosettes of clear-cut needles) and recrystallising twice more if slightly yellow in colour. The salt has also been conveniently recrystd from the minimum amount of 90% Me_2CO and adding an excess of absolute Me_2CO. A similar procedure can be used with wet *n*-BuOH. If yellow in colour then dissolve (~3.8g) in the minimum volume of H_2O (3ml), add *n*-BuOH and filter through a bed of charcoal. The salt forms long white needles on standing in a refrigerator overnight. More crystals can be obtained on concentrating the mother liquors *in vacuo* at 40°. A further recrystn (without charcoal) yields practically pure salt. A good preparation has ~600 Units/mg. The presence of H_2O in the solvents increases the solubility considerably. The solubility in mg/100ml at 0° is 6.0 (Me_2CO), 15.0 (Me_2CO + 0.5% H_2O), 31.0 (Me_2CO + 1.0% H_2O), 2.4 (methyl ethyl ketone), 81.0 (*n*-butanol) and 15.0 (dioxane at 14°). Alternatively it is dissolved in H_2O (solubility is 10%), filtered if necessary and ppted by addition of EtOH and dried in a vacuum over P_2O_5. A sample can be kept for 24h at 100° without loss of physiological activity. It has a pKa^{25} of 2.76 in H_2O and 4.84 in 80% EtOH. [IR: *AC* **19** 620 *1947*; *The Chemistry of Penicillin* [Clarke, Johnson and Robinson eds]. Princeton University Press, Princeton NJ, **Cha V** 85 *1949*].
Other salts, e.g. the **potassium salt** can be prepared from the Na salt by dissolving it (147mg) ice-cold in H_2O acidified to pH 2, extracting with Et_2O (~50ml), wash once with H_2O, and extract with 2ml portions of 0.3% $KHCO_3$ until the pH of the extract rose to ~6.5 (~7 extractns). The combined aqueous extracts are lyophilised and the white residue is dissolved in *n*-BuOH (1ml, absolute) with the addition of enough H_2O to effect soln. Remove insoluble material by centrifugation and add absolute *n*-BuOH to the supernatant. Crystals should separate on scratching, and after 2.5h in a refrigerator they are collected, washed with absolute *n*-BuOH and EtOAc and dried (yield 51.4mg). The *potassium salt* has **m** 214-217° (dec) (block preincubated at 200°; heating rate of 3°/min) and $[\alpha]_D^{22}$ +285° (c 0.748, H_2O). The *free acid* has **m** 186-187° (MeOH-Me_2CO), 190-191° (H_2O) $[\alpha]_D^{25}$ +522°.

(+)-Bicuculin [*R*-6(5,6,7,8-tetrahydro-6-methyl-1,3-dioxolo[4,5-*g*]isoquinolon-5-yl)-furo[3,4-*c*]-1,3-benzodioxolo-8(6*H*)-one] *[485-49-4]* **M 367.4, m 177°, 193-195°, 193-197°, 215°, $[\alpha]_D^{20}$ +126° (c 1, $CHCl_3$).** Recrystallises from $CHCl_3$-MeOH as plates. Crystals melt at 177° then solidify and re-melt at 193-195° [Manske *Canad J Research* **21B** 13 *1943*]. It is soluble in $CHCl_3$, C_6H_6, EtOAc but sparingly soluble in EtOH, MeOH and Et_2O. [Stereochem: Blaha et al. *Coll Czech Chem Commun* **29** 2328 *1964*; Snatzke et al. *TET* **25** 5059 *1969*; Pharm activity: Curtis et al. *Nature* **266** 1222 *1970*].

L-*erythro*-Biopterin (2-amino-4-hydroxy-6-[{1*R*,2*S*}-1,2-dihydroxypropyl]pteridine) *[36183-24-1]* **M 237.2, m >300°(dec), $[\alpha]_{546}^{20}$ -65° (c 2.0M HCl).** Purified by chromatography on Florisil washed thoroughly with 2M HCl, and eluted with 2M HCl. The fractions with the UV-fluorescent band are evapd *in vacuo* and the residue recrystd. Biopterin is best recrystd (90% recovery) by dissolving in 1% aq NH_3 (*ca* 100 parts), and adding this soln dropwise to an equal vol of M aq formic acid at 100° and allowing to cool at 4° overnight. It is dried at 20° to 50°/01mm in the presence of P_2O_5. [Schircks, Bieri and Viscontini *HCA* **60** 211 *1977*; Armarego, Waring and Paal *Australian J Chem* **35** 785 *1982*]. Also crystd from *ca* 50 parts of water or 100 parts of hot 3M aq HCl by adding hot 3M aq NH_3 and cooling. It has pKa^{25} values of 2.23 and 7.89 in H_2O and UV: λ_{max} at 212, 248 and 321nm (log ε 4.21, 4.09 and 3.94) in H_2O at pH 0.0; 223infl, 235.5, 274.5 and 345nm (log ε 4.07infl, 4.10, 4.18 and 3.82) in H_2O at pH 5.0; 221.5, 254.5 and 364nm (log ε 3.92, 4.38 and 3.84) in H_2O at pH 10.0 [Sugimoto and Matsuura *Bull Chem Soc Japan* **48** 3767 *1875*].

D-(+)-Biotin (hexahydro-2-oxo-1*H*-thieno[3,4-d]imidazole-4-pentanoic acid) *[58-85-5]* **M 244.3, m 229-231°, 230.2°(dec), 230-231°, 232-234°(dec), $[\alpha]_{546}^{20}$ +108°, $[\alpha]_D^{20}$ +91.3° (c 1,0.1N NaOH).** Crystd from hot water in fine long needles with a solubility of 22 mg/100ml at 25°. Its solubility in 95% EtOH is 80 mg/100 ml at 25°. Its isoelectric point is at pH 3.5. Store solid and solutions under sterile conditions because it is susceptible to mould growth. [Confalone *JACS* **97** 5936 *1975*; Wolf et al. *JACS* **67** 2100 *1945*; Synthesis: Ohuri and Emoto *TET LETT* 2765 *1975*; Harris et al. *JACS* **66** 1756 *1944*]. The *(+)-methyl ester* has **m** 166-167° (from MeOH-Et_2O), $[\alpha]_D^{22}$ +57° (c 1, $CHCl_3$) [du Vigneaud et al. *JBC* **140** 643, 763 *1941*]; the *(+)-S-oxide* has **m** 200-203°, $[\alpha]_D^{20}$ +130° (c 1.2, 0.1N NaOH) [Melville *JBC* **208** 495 *1954*]; the *SS-dioxide* has **m** 274-275°(dec, 268-270°) and the *SS-dioxide methyl ester* has **m** 239-241° (from MeOH-Et_2O) [Hofmann et al. *JBC* **141** 207, 213 *1941*].

D-(+)-Biotin hydrazide *[66640-86-6]* **M 258.4, m 238-240°, 245-247°, $[\alpha]_D^{20}$ +66° (c 1, Me_2NCHO).** Wash the material with H_2O, dry, wash with MeOH then Et_2O, dry, and recrystallise from hot H_2O (clusters of prisms) [Hofmann et al. *JBC* **144** 513 *1942*].

D-(+)-Biotin *N*-hydroxysuccinimide ester (+-biotin *N*-succinimidyl ester) *[35013-72-0]* **M 342.4, m 210°, 212-214°, $[\alpha]_D^{20}$ +53° (c 1, Me_2NCHO).** Recrystd from refluxing isoPrOH and dried in a vacuum over P_2O_5 + KOH. [Jasiewicz et al. *Experimental Cell Biology* **100** 213 *1976*].

D-(+)-Biotin 4-nitrophenyl ester *[33755-53-2]* **M 365.4, m 160-163°, 163-165°, $[\alpha]_D^{25}$ +47° (c 2, Me_2NCHO containing 1% AcOH).** It has been recrystd by dissolving 2g in 95% EtOH (30ml), heated to dissolve, then cooled in an ice-water bath. The crystals are collected, washed with ice-cold 95% EtOH (5ml) and dried over P_2O_5. The R_F on silica plates ($CHCl_3$:MeOH-19:1) is 0.19 [Bodanszky and Fagan *JACS* **99** 235 *1977*].

***N*-(+)-Biotinyl-4-aminobenzoic acid** *[6929-40-4]* **M 363.4, m 295-297°, 295-300°, $[\alpha]_D^{23}$ +56.55° (c 0.5, 0.1N NaOH).** Dissolve in $NaHCO_3$ soln, cool and ppte by adding N HCl. Collect the solid, dry at 100° and recrystallise from MeOH. Note that it is hydrolysed by aq 3M, 1M and 0.2M HCl at 120°, but can be stored in 5% aq $NaHCO_3$ at -20° without appreciable hydrolysis [Knappe et al. *Biochem Zeitschrift* **338** 599 *1963*; *JACS* **73** 4142 *1951*; Bayer and Wilchek *Methods in Enzymology* **26** 1 *1980*]

***N*-Biotinyl-6-aminocaproic *N*-succinimidyl ester** *[72040-63-2]* **M 454.5, m 149-152°.** Dissolve ~400mg in dry propan-2-ol (~25ml) with gentle heating. Reduce the volume to ~10ml by gentle boiling and allow the soln to cool. Decant the supernatant carefully from the white crystals, dry the crystals in a vacuum over P_2O_5 at 60° overnight. Material gives one spot on TLC. [Costello et al. *Clin Chem* **25** 1572 *1979*; Kincaid et al. *Methods in Enzymology* **159** 619 *1988*].

***N*-(+)-Biotinyl-6-aminocaproyl hydrazide (biotin-6-aminohexanoic hydrazide)** *[1109276-34-8]* **M 371.5, m 189-191°, 210°, $[\alpha]_D^{20}$ +23° (c 1, Me_2NCHO).** Suspend in ice-water (100mg/ml), allow to stand overnight at 4°, filter and dry the solid in a vacuum. Recrystd from isoPrOH. R_F 0.26 on SiO_2 plate using $CHCl_3$-MeOH (7:3) as eluent. [O'Shannessy et al. *AB* **163** 204 *1987*].

***N*-(+)-Biotinyl-L-lysine (Biocytin)** *[576-19-2]* **M 372.5, m 228.5°, 228-230° (dec), 241-243°, 245-252° (dec, sintering at 227°), $[\alpha]_D^{25}$ +53° (c 1.05, 0.1 N NaOH).** Recrystd rapidly from dilutw MeOH or Me_2CO. Also recrystd from H_2O by slow evaporation or by dissolving in the minimum volume of H_2O and adding Me_2CO until solid separates. It is freely soluble in H_2O and AcOH but insoluble in Me_2CO. [Wolf et al. *JACS* **76** 2002 *1952*, **72** 1048 *1050*]. It has been purified by chromatography on superfiltrol-Celite, Al_2O_3 and by countercurrent distribution and then recrystd [IR: Peck et al. *JACS* **74** 1991 *1952*]. The *hydrochloride* can be recrystd from aqueous Me_2CO + HCl and has **m** 227° (dec).

2-(4-Biphenylyl)-5-phenyl-1,3,4-oxadiazole *[852-38-0]* **M 298.4, m 166-167°, 167-170°.** Recrystd from toluene. It is a good scintillation material [Brown et al. *Discussion Faraday Soc* **27** 43 *1959*].

2,5-Bis(4-biphenylyl)-1,3,4-oxadiazole (BBOD) *[2043-06-3]* **M 374.5, m 229-230°, 235-238°.** Recrystd from heptane or toluene. It is a good scintillant. [Hayes et al. *JACS* **77** 1850 *1955*].

4,4-Bis(4-hydroxyphenyl)valeric acid [diphenolic acid] *[126-00-1]* **M 286.3, m 168-171°, 171-172°.** When recrystd from C_6H_6 the crystals have 0.5 mol of C_6H_6 (**m** 120-122°) and when recrystd from toluene the crystals have 0.5 mol of toluene. Purified by recrystn from hot H_2O. It is sol in Me_2CO, AcOH, EtOH, propan-2-ol, methyl ethyl ketone. It is also recrystallised from AcOH, heptane-Et_2O or Me_2CO + C_6H_6. It has λ_{max} 225 and 279nm in EtOH. The *methyl ester* has **m** 87-89° (aqueous MeOH to give the trihydrate). [Bader and Kantowicz *JACS* **76** 4465 *1954*].

Bis(2-mercaptoethyl)sulphone (BMS) M 186.3, m 57-58°. Recrystd from hexane as white fluffy crystals. Large amounts are best recrystd from de-oxygenated H_2O (charcoal). It is a good alternative to dithiothreitol and has pKa^{25} values of 7.9 and 9.0 in H_2O. Its IR (film) has ν 2995, 2657, 1306, 1248, 1124

and 729 cm^{-1}. The synthetic intermediate *thioacetate* has **m** 82-83° (white crystals from CCl_4). The *disulphide* was purified by flash chromatography on SiO_2 and elution with 50% EtOAc-hexane and recrystd from hexane, **m** 137-139°. [Lamoureux and Whitesides *JOC* **58** 633 *1993*].

Bis(2-nitrophenyl) disulphide *[1155-00-6]* **M 308.3, m 192-195°, 195°, 194-197°, 198-199°.** Purified by recrystn from glacial AcOH or from C_6H_6 and the yellow needles are dried in an oven at 100° until the odour of the solvent is absent. It is sparingly soluble in EtOH and Me_2CO. [Bogert and Stull *Org Synth* Coll Vol I 220 *1941*; Bauer and Cymerman *JCS* 3434 *1949*].

Bombesin (2-L-glutamin-3-6-L-asparaginealytesin) *[31362-50-2]* **M 619.9.** Purified by gel filtration on a small column of Sephadex G-10 and eluted with 0.01 M AcOH. This procedure removes lower molecular weight contaminants which are retarded on the column. The procedure should be repeated twice and the material should now be homogeneous on electrophoresis, and on chromatography gives a single active spot which is negative to ninhydrin but positive to Cl_2 and iodoplatinate reagents. R_F on paper chromatography (*n*-BuOH-pyridine-AcOH-H_2O (37.5: 25:7.5: 30) is 0.55 for Bombesin and 0.65 for Alytin. [Bernardi *Experientia* **B 27** 872 *1971*; **A 27** 166 *1971*]. The *hydrochloride* has **m** 185°(dec) (from EtOH) $[\alpha]_D^{24}$ -20.6° [c 0.65, Me_2NCHO-$(Me_2N)_3PO$ (8:2)].

Bradykinin [ArgProProGlyPheSerProPheArg] *[5979-11-3]* **M_r 1,240.4.** Purified by ion-exchange chromatography on CMC (*O*-carboxymethyl cellulose) and partition chromatography on Sephadex G-25. Purity was checked by paper chromatography using Bu:AcOH:H_2O (4:1:5) as eluent. [Park et al. *Canad J Biochem* **56** 92 1978; ORD and CD: Bodanszky et al. *Experientia* **26** 948 *1970*; activity: Regoli and Barabé *Pharmacological Reviews* **32** 1 *1980*].

Brefeldin A [1-*R*-2*c*,15*c*-dihydroxy-7*t*-methyl-(1*r*,13*t*)-6-oxa-bicyclo[11.3.0]hexadeca-3*t*,11*t*-dien-5-one, Decumbin] *[20350-15-6]* **M 280.4, m 200-202°, 204°, 204-205°, $[\alpha]_D^{22}$ +95° (c 0.81, MeOH).** Isolated from *Penicillium brefeldianum* and recrystd from aqueous MeOH-EtOAc or MeOH. Solubility in H_2O is 0.6mg/ml, 10mg/ml in MeOH and 24.9mg/ml in EtOH. The *O-acetate* recrystallises from Et_2O-pentane and has **m** 130-131°, $[\alpha]_D^{22}$ +17° (c 0.95, MeOH). [Sigg *HCA* **47** 1401 *1964*; UV and IR: Härri et al. *HCA* **46** 1235 *1963;* total synthesis: Kitahara et al. *TET* 3021 *1979*; X-ray : Weber et al. HCA **54** 2763 *1971*].

Bromelain (anti-inflammatory Ananase from pineapple) *[37189-34-7]* **M_r ~33 000, [EC 3.4.33.4].** This protease has been purified *via* the acetone powder, G-75 Sephadex gel filtratn and Bio-Rex 70 ion-exchange chromatography and has $A_{1cm}^{1\%}$ 20.1 at 280nm. The protease from pineapple hydrolyses benzoyl glycine ethyl ester with a Km (app) of 210mM and k_{cat} of 0.36 sec^{-1}. [Murachi *Methods in Enzymology* **19** 273 *1970*; Balls et al. *Ind Eng Chem* **33** 950 *1941*].

6-Bromo-2-naphthyl-α-D-galactopyranoside *[25997-59-5]* **M 385.2, m 178-180°, 224-226°, 225°, $[\alpha]_D^{28}$ +60° (c 1.2, pyridine).** It was prepared from penta-*O*-acetyl-D-galactoside and 6-bromo-2-naphthol and $ZnCl_2$. The resulting tetra-acetate (2g) was hydrolysed by dissolving in 0.3N KOH (100ml) and heated until the soln was clear, filtered and cooled to give colourless crystals of the α-isomer which are collected and recrystd twice from hot MeOH. The high specific rotation is characteristic of the α-isomer. The *tetra-acetate* has **m** 155-156° $[\alpha]_D^{20}$ +60° (c 1, $CHCl_3$) [Dey and Pridham *BJ* **115** 47 *1969*] [reported **m** 75-85°, $[\alpha]_D^{24}$ +94° (c 1.3, dioxane), Monis et al. *J Histochem Cytochem* **11** 653 *1963*].

5-Bromouridine *[957-75-5]* **M 323.1, m 215-217°, 217-218°, $[\alpha]_D^{25}$ -4.1° (c 0.1, H_2O).** Recrystd from 96% EtOH. UV λ_{max} 279nm (log ε 3.95) ιν H_2O pH 1.9. R_F in *n*-BuOH:AcOH:H_2O (4:4:1) is 0.49; in *n*-BuOH:EtOH:H_2O (40:11:9) is 0.46 and in isoPrOH:25%NH_3:H_2O (7:1:2) is 0.53 using Whatman No 1 paper. [Prystas and Sorm *Coll Czech Chem Commmun* **29** 2956 *1964*].

Brucine (H_2O) *[5892-11-5]* **M 430.5, m 178-179°, $[\alpha]_{546}^{20}$ -149.9° (anhydrous; c 1, in $CHCl_3$).** Crystd once from water, as tetrahydrate, then suspended in $CHCl_3$ and shaken with anhydrous Na_2SO_4 (to dehydrate the brucine, which then dissolves). Ppted by pouring the soln into a large bulk of dry pet

ether (b 40-60°), filtered and heated to 120° in a high vacuum [Turner *JCS* 842 *1951*]. See also entry in Chapter 3.

α-Brucine sulphate (hydrate) *[4845-99-2]* **M 887.0, m 180°(dec).** Crystd from water.

Butyryl choline iodide [(2-butyryloxyethyl)trimethyl ammonium iodide] *[2494-56-6]* **M 301.7, m 85-89°, 87°, 93-94°.** Recrystd from isoPrOH or Et_2O. [Tammelin *Acta Chem Scand* **10** 145 *1956*]. The *perchlorate* has **m** 72° (from isoPrOH). [Aldridge *BJ* **53** 62 *1953*].

S-Butyryl thiocholine iodide [(2-butyrylmercaptoethyl)trimethyl ammonium iodide] *[1866-16-6]* **M 317.2, m 173°, 173-176°.** Recrystd from propan-1-ol and dried *in vacuo*; store in the dark under N_2. The *bromide* has **m** 150° (from Me_2CO) or **m** 140-143° (from butan-1-ol). [Gillis *Chemistry and Industry* (*London*) 111 *1957*; Hansen *Acta Chem Scand* **11** 537 *1957*].

L-Canavanine sulphate (from jackbean, *O*-guanidino-L-homoserine) *[2219-31-0]* M 274.3, m 160-165°(dec), 172°(dec), $[\alpha]_D^{18.5}$ +19.8° (c 7, H_2O).

Recrystd by dissolving (~1g) in H_2O (10ml), and adding with stirring 0.5 to 1.0 vols of 95% EtOH whereby crystals separate. These are collected, washed with Me_2CO-EtOH (1:1) and dried over P_2O_5 in a vacuum. [Hunt and Thompson *Biochemical Preparations* **13** 416 *1971*; Feacon and Bell *BJ* **59** 221 *1955*].

Carbonic anhydrase (carbinate hydrolyase) *[9001-03-0]* **M_r 31,000 (EC. 4.2.1.1].** Purified by hydroxylapatite and DEAE-cellulose chromatography [Tiselius et al. *Arch Biochem Biophys* **65** 132 *1956*, *Biochim Biophys Acta* **39** 218 *1960*], and is then dialysed for crystn. A 0.5 to 1% soln of the enzyme in 0.05 M Tris-HCl pH 8.5 was dialysed against 1.75 soln of $(NH_4)_2SO_4$ in the same buffer, and this salt soln was slowly increased in salt concn by periodic removal of small amounts of dialysate and replacement with an equal volume of 3.5M $(NH_4)_2SO_4$. The final salt concn in which the DEAE-cellulose fractions which gave beautiful birefringent suspensions of crystals ranged from 2.4 to 2.7M, and appeared first as fine crystals then underwent transition to thin fragile plates. Carbonic anhydrase is a Zn enzyme which exists as several isoenzymes of varying degrees of activity [*JBC* **243** 6474 *1968*; crystal structure: *Nature, New Biology* 235 131 *1972*; see also P.D. Boyer ed, *The Enzymes* Academic Press NY, pp 587-665 *1971*].

Carboxypeptidase A. (from bovine pancreas, peptidyl-L-aminoacid lyase) *[11075-17-5]* **M_r 34,600, [EC. 3.4.17.1].** Purified by DEAE-cellulose chromatography, activation with trypsin and dialysed against 0.1M NaCl, yielding crystals. It is recrystd by dissolving in 20 ml of M NaCl and dialysed for 24hours each against the following salts present in 500ml of 0.02M sodium veronal pH 8.0: ,0.5M NaCl, 0.2M NaCl and 0.15M NaCl. The last dialysate usually induces crystn. If it does not crystallise then dialyse the last soln against 0.02M sodium veronal containing 0.10M NaCl. Only 2 or 3 recrystns are required to attain maximum activity. [Cox et al. *Biochemistry* **3** 44 *1964*]. Enzyme activity is measured by hydrolysing hippuryl-L-phenylalanine (or phenylacetic acid) and observing the rate of change of optical density at 254nm (reaction extinction coefficient is ~0.592 $cm^2/\mu mole$ at pH 7.5, [Bergmyer *Methods in Enzymatic Analysis* (Academic Press) **1** 436 *1974*].

Carminic acid (7-α-D-glucopyranosyl-9,10-dihydro-3,5,6,8-tetrahydroxy-1-methyl-9,10-dioxo-2-anthracene carboxylic acid, Neutral Red 4: CI 75470) *[1260-17-9]* **M 492.4, m 120°(dec), $[\alpha]_{654}^{15}$ +51.6° (H_2O).** Forms red prisms from EtOH. It gives a red colour in Ac_2O and yellow to violet in acidic solution. UV: λ_{max} (H_2O) 500nm (ε 6,800); (0.02N HCl) 490-500nm (ε 5,800) and (0.0001N NaOH) 540nm (ε 3,450). IR: ν_{max} (Nujol) 1708s, 1693s, 1677m,1648m, 1632m, 1606s, 1566s, 1509 cm^{-1}. Periodate oxidation is complete after 4h at 0° with the consumption of 6.2 mols. The *tetra-O-methyl carminate* has **m** 186-188° (yellow needles from C_6H_6 + pet ether). [IR: Ali and Haynes *JCS* 1033 *1959*; Bhatia and Venkataraman *Indian J Chem* **3** (2) 92 *1965*; Synthesis: Davis and Smith *Biochemical Preparations* **4** 38 *1955*].

L-Carnosine (β-alanyl-L-histidine) *[305-84-0]* **M 226.2, m 258-260°(dec), 260°(capillary tube), 262°(dec), $[\alpha]_D^{25}$ +20.5° (c 1.5, H_2O).** Likely impurities: histidine, β-alanine. Crystd from water by adding EtOH in excess. Recrystd from aqueous EtOH by slow addition of EtOH to a strong aqueous soln of the dipeptide. Its solubility in H_2O is 33.3% at 25°, and has pKa values of 2.64, 6.83 and 9.51. [Vinick and Jung *JOC* **48** 392 *1983*; Turner *JACS* **75** 2388 *1953*; Sifford and du Vigneaud *JBC* **108** 753 *1935*].

α-Carotene *[74488-99-5]* **M 536.9, m 184-188°, λ_{max} 422, 446, 474 nm, in hexane, $\varepsilon^{1\%}_{1cm}$ 2725 (at 446nm), 2490 (at 474nm).** Purified by chromatography on columns of calcium hydroxide, alumina or magnesia. Crystd from CS_2/MeOH, toluene/MeOH, ethyl ether/pet ether, or acetone/pet ether. Stored in the dark, under inert atmosphere at -20°.

***all-trans*-β-Carotene** *[7235-40-7]* **M 536.9, m 178-179°, 179-180°, 180°, 181°, 183° (evac capillary), $\varepsilon^{1\%}_{1cm}$ 2590 (450nm), 2280 (478nm), in hexane.** It forms purple prisms when crystd from C_6H_6-MeOH and red rhombs from pet ether. Its solubility in hexane is 0.1% at 0°. It is **oxygen sensitive** and should be stored under N_2 at -20° in the dark. It gives a deep blue colour with $SbCl_3$ in $CHCl_3$. UV: (C_6H_6) 429infl, λ_{max} 454 and 484nm. The principal peak at 454nm has $E^{1\%}_{1cm}$ 2000. [Synthesis: Surmatis and Ofner *JOC* **26** 1171 *1961*; Milas et al. *JACS* **72** 4844 *1950*]. β-Carotene was also purified by chromatography (Al_2O_3 activity I-II) - it was dissolved in pet ether-C_6H_6 (10:1), applied to the column and eluted with pet ether-EtOH, the desired fraction was evaporated and the residue recrystd from C_6H_6-MeOH as violet-red plates. [UV: Inhoffen et al. *A* **570** 54,68 *1950*; Review: Fleming *Selected Organic Synthesis* (J Wiley, Lond) pp 70-74 *1973*]. Alternatively it can be purified by chromatography on a magnesia column, thin layer of kieselguhr or magnesia. Crystd from CS_2/MeOH, Et_2O/pet ether, acetone/pet ether or toluene/MeOH. Stored in the dark, under inert atmosphere, at -20°. Recrystd from 1:1 EtOH/$CHCl_3$ [Bobrowski and Das *JPC* **89** 5079 *1985*; Johnston and Scaiano *JACS* **108** 2349 *1986*].

γ-Carotene *[10593-83-6]* **M 536.9, $\varepsilon^{1\%}_{1cm}$ 2055 (437nm), 3100 (462nm), 2720 (494nm) in hexane.** Purified by chromatography on alumina or magnesia columns. Crystd from C_6H_6/MeOH (2:1). Stored in the dark, under inert atmosphere, at 0°.

ξ-Carotene *[38894-81-4]* **M 536.9, m 38-42°, λ_{max} 378, 400, 425nm, $\varepsilon^{1\%}_{1cm}$ 2270 (400nm), in pet ether.** Purified by chromatography on 50% magnesia-HyfloSupercel, developing with hexane and eluting with 10% EtOH in hexane. It was crystd from toluene/MeOH. [Gorman et al. *JACS* **107** 4404 *1985*]. Stored in the dark under inert atmosphere at -20°.

λ–Carrageenan *[9064-57-7]*. Ppted from a soln of 4g in 600ml of water containing 12g of potassium acetate by addition of EtOH. The fraction taken, ppted between 30 and 45% (v/v) EtOH. [Pal and Schubert *JACS* **84** 4384 *1962*].

(-)-Caryophyllene oxide (1-*S*-5*c*-6*t*-epoxy-6*c*,10,10-trimethyl-2-methylene-1*r*,9*t*-bicyclo[7.2.0]undecane *[1139-30-6]* **M 220.4, m 62-63°, 63.5-64°, 64°, b 114-117°/1.8mm, 141-142°/11mm, d_4^{20} 0.9666, n_D^{20} 1.49564, $[\alpha]_D^{20}$-79° (c 2,$CHCl_3$), $[\alpha]_D^{20}$-68° (supercooled melt).** Purified by TLC on silica gel with EtOAc-pet ether (b 60-80°) (15:85), and recrystallised from MeOH or C_6H_6. [NMR: Warnhoff *Canad J Chem* **42** 1664 *1964*, Ramage and Whitehead *JCS* 4336 *1954*].

Catechin *[7295-85-4]* **M 272.3, m 177° (anhyd).** Crystd from hot water. Dried at 100°.

Catechol *[120-80-9]* **M 110.1, m 105°.** Crystd from benzene or toluene. Sublimed under vacuum. [Rozo et al. *AC* **58** 2988 *1986*].

Cation exchange resins. Conditioned before use by successive washing with water, EtOH and water, and taken through two H^+-Na^+-H^+ cycles by successive treatment with M NaOH, water and M HCl then washed with water until neutral. (Ion exchange resins, BDH Handbook, 5th edn 1971).

(+)-Cedrol (octahydro-3,6,8,8-tetramethyl-1-3a,7-methanoaazulen-6-ol, 8a*S*-6*c*-hydroxy-3*c*,6*t*,8,8-tetramethyl[8a*r*-*H*)-octahydro-3*H*,3a*t*,7*t*-methanoazulene) *[77-53-2]* **M 222.4, m 82-86°, 86-87°, $[\alpha]_D^{28}$ +10.5° (c 5,$CHCl_3$), $[\alpha]_D^{18}$ +13.1° (c 5.5, EtOH), $[\alpha]_D^{18}$ +14.3° (c 10, dioxane).** Purified by recrystn from aqueous MeOH. It is estimated colorimetrically with H_3PO_4 in EtOH followed by vanillin and HCl

Cathepsin B (from human liver) *[9025-22-7]* **[EC 3.4.22.1].** Purified by affinity chromatography on the semicarbazone of Gly-Phe-glycinal-linked to Sepharose 4B, with elution by 2,2'-dipyridyl disulphide [Rich et al. *BJ* **235** 731 *1986*].

Cathepsin D (from bovine spleen) *[9025-26-7]* **[EC 3.4.23.5].** Purified on a CM column after ammonium sulphate fractionation and dialysis, then starch-gel electrophoresis and by ultracentrifugal analysis. Finally chromatographed on a DEAE column [Press et al. *BJ* **74** 501 *1960*].

Cephalosporin C potassium salt *[28240-09-7]* **M 453.5, $[\alpha]_D^{20}$ +103° (H_2O).** Purified by dissolving in the minimum volume of H_2O (filter) and adding EtOH until separation of solid is complete. A soln is stable in the pH range 2.5-8. It has pK_a values of <2.6, 3.1 and 9.8 in H_2O, and the UV λ_{max} is 260nm (log ε 3.95) in H_2O. The Ba salt has $[\alpha]_D^{20}$ +80° (c 0.57, H_2O) [Woodward et al. *JACS* **88** 852 *1966;* Abraham and Newton *BJ* **79** 377 *1961*; Hodgkin and Maslen *BJ* **79** 402 *1961*; see also *Quart Reviews Chem Soc* London **21** 231 *1967*].

Ceruloplasmin (from human blood plasma) *[9031-37-2].* Purified by precipitation with polyethylene glycol 4000, batchwise adsorption and elution from QAE-Sephadex, and gradient elution from DEAE-Sepharose CL-6B. Ceruloplasmin was purified 1640-fold. Homogeneous on anionic polyacrylamide gel electrophoresis (PAGE), SDS-PAGE, isoelectric focusing and low speed equilibrium centrifugation. [Oestnuizen *AB* **146** 1 *1985*].

Chlorambucil [4-{bis(2-chloroethyl)amino}benzene)butyric acid] *[305-03-3]* **M 304.2, m 64-66°.** It is recrystd from pet ether (flat needles) and has a solubility at 20° of 66% in EtOH, 40% in $CHCl_3$, 50% in Me_2CO but is insoluble in H_2O. Its pKa^{66} in 50% aqueous Me_2CO is 6. **CARCINOGEN.** [Everett et al. *JCS* 2386 *1953*].

Chloramphenicol [Amphicol, 1*R*,2*R*-(-)-2-{2,2-dichloroacetylamino}-1-{4-nitrophenyl}-propan-1,3-diol] *[56-75-7]* **M 323.1, m 149-151°, 150-151°, 151-152°, $[\alpha]_D^{20}$ +20.5° (c 3,EtOH), $[\alpha]_D^{25}$ -25.5° (EtOAc).** Purified by recrystn from H_2O or ethylene dichloride as needles or long plates and by sublimation at high vacuum. It has $A_{1cm}^{1\%}$ 298 at λ_{max}278nm and it is slightly soluble in H_2O (0.25%) and propylene glycol (1.50%) at 25° but is freely soluble in MeOH, EtOH, BuOH, EtOAc and Me_2CO. [Relstock et al. *JACS* **71** 2458 *1949*; Confroulis et al. *JACS* **71** 2463 *1949*; Long and Troutman *JACS* **71** 2469, 2473 *1949*, Ehrhart et al. *B* **90** 2088 *1957*].

2-Chloroadenosine *[146-77-0]* **M 301.7, m 145-146°(dec), 147-149°(dec).** Purified by recrystn from H_2O (~1% in cold) and has λ_{max} at 264 nm (pH 1 and 7) and 265 nm (pH 13) in H_2O. [Brown and Weliky *JOC* **23** 125 *1958*; Schaeffer and Thomas *JACS* **80** 3738 *1958*; IR: Davoll and Lewy *JACS* **74** 1563 *1952*].

Chlorophylls *a* and *b* see entries in Chapter 3.

6-Chloropurine riboside (6-chloro-9-β-D-ribofuranosyl-9*H*-purine) *[2004-06-0]* **M 286.7, m 158-162°(dec), 165-166°(sintering At 155°), 168-170°(dec), $[\alpha]_D^{26}$ -45° (c 0.8, H_2O).** Purified by suspending the dry solid (~12 g) in hot MeOH (130 ml) and then adding enough hot H_2O (~560 ml) to cause solution, filter and set aside at 5° overnight. The colourless crystals of the riboside are filtered off, washed with Me_2CO, Et_2O and dried at 60°/0.1mm. More material can be obtained from the filtrate by evapn to dryness and recrystn of the residue from MeOH-H_2O (2:1) (15ml/g). It has λ_{max} 264nm (ε 9140) in H_2O. [Robins *Biochemical Preparations* **10** 145 *1963*; Baker et al. *JOC* **22** 954 *1957*].

7-Chlorotetracycline hydrochloride *[64-72-2]* **M 515.4, m 210-215°(dec), 220°(sintering at 252°), $[\alpha]_D^{25}$ -338° (c 0.5, Me_2NCHO).** Recrystd from Me_2NCHO + Me_2CO. It has pKa values of 7.1 and 9.5 in 50% aqueous Me_2NCHO. [Stephens et al. *JACS* **76** 3568 *1954*; UV: McCormick et al. *JACS* **79** 2849 *1975*].

α-Chymotrypsin *[9004-07-3]* **M_r ~25,000, [EC 3.4.21.1].** Crystd twice from four-tenths saturated ammonium sulphate soln, then dissolved in 1mM HCl and dialysed against 1mM HCl at 2-4°. The soln was stored at 2° [Lang, Frieden and Grunwald *JACS* **80** 4923 *1958*].

Cinchonidine and **Cinchonine** see entries in Chapter 3.

Citric acid cycle components (from rat heart mitochondria). Resolved by anion-exchange chromatography [LaNoue et al. *JBC* **245** 102 *1970*].

Clonidine hydrochloride [Catapres, 2(2,6-dichloroanilino)-2-imidazoline hydrochloride) *[4205-91-8]* **M 266.6, m 305°.** It is recrystd from EtOH-Et_2O and dried in a vacuum (solubility in H_2O is 5%). It has a pKa of 5.88. The *free base* has **m** 124-125° and is recrystallised from hexane. [Jen et al. *J Medicinal Chem* **18** 90 *1975*; NMR: Jackman and Jen *JACS* **97** 2811 *1975*].

Clostripain *[9028-00-6]* **[EC 33.4.22.8] M_r ~55,000.** Isolated from *Clostridium histolyticum* callogenase by extraction in pH 6.7 buffer, followed by hydroxylapatite chromatography with a 0.1-0.2 M phosphate gradient, then Sephadex G-75 gel filtration with 0.05M phosphate pH 6.7, dialysis and a second hydroxylapatite chromatography (gradient elution with 0.1M → 0.3M phosphate, pH 6.7). It has proteinase and esterase activity and is assayed by hydrolysing *n*-benzoyl-L-arginine methyl ester. [Mitchell and Harrington *JBC* **243** 4683 *1968*, *Methods in Enzymology* **19** 635 *1970*].

Cloxacillin sodium salt (sodium 3-*o*-chlorophenyl-5-methyl-4-isoxazolyl penicillin monohydrate) *[642-78-4]* **M 457.9, m 170°, $[\alpha]_D^{20}$ +163° (H_2O pH 6.0-7.5).** Purified by dissolving in isoPrOH containing 20% of H_2O, and diluting with isoPrOH to a water content of 5% and chilled, and recrystd again in this manner. The sodium salt is collected and dried at 40° in air to give the colourless monohydrate. It is soluble in H_2O (5%), MeOH, EtOH, pyridine and ethylene glycol. [Doyle et al. *JCS* 5838 *1963*; Naylor et al. *Nature* **195** 1264 *1962*].

Cocarboxylase *[532-40-1]* **M 416.8, m 195°(dec).** Crystd from EtOH slightly acidified with HCl.

Cocarboxylase tetrahydrate (aneurine pyrophosphoric acid tetrahydrate, thiamine pyrophosphoric acid tetrahydrate) *[136-09-4]* **M 496.4, m 220-222°(sinters at 130-140°), 213-214°.** Recrystd from aqueous Me_2CO. [Wenz et al. *A* **618** 210 *1958*; UV: Melnick *JBC* **131** 615 *1939*; X-ray: Carlisle and Cook *Acta Cryst (B)* **25** 1359 *1969*]. The *hydrochloride salt* has **m** 242-244°(dec), 241-243°(dec) or 239-240°(dec) and is recrystd from aqueous HCl + EtOH, EtOH containing HCl or HCl + Me_2CO. [Weijlard *JACS* **63** 1160 *1941*; Synthesis: Weijlard and Tauber *JACS* **60** 2263 *1938*].

Coenzyme A trihydrate *[85-61-0]* **M 821.6.** White powder best stored in an inert atmosphere in the dark in sealed ampoules after drying *in vacuo* over P_2O_5 at 34°. It has pKa values of 4.0 (adenine NH_2), 6.5 (phosphate) and 9.6 (SH group). It has UV: λ_{max} 259 nm (ε 16,800) in H_2O. [Buyske et al. *JACS* **76** 3575 *1954*]. It is sol in H_2O but insol in EtOH, Et_2O and M_2CO. It is readily oxidised in air and is best kept as the more stable *trilithium salt* [Moffat and Khorana *JACS* **83** 663 *1961*; see also Beinert et al. *JBC* **200** 384 *1953*; De Vries et al. *JACS* **72** 4838 *1950*; Gregory et al. *JACS* **74** 854 *1952* and Baddiley *Advances in Enzymology* **16** 1 *1955*].

Coenzyme Q_0 (2,3-Dimethoxy-5-methyl-1,4-benzoquinone, 3,4-dimethoxy-2,5-toluquinone, fumigatin methyl ether) *[605-94-7]* **M 182.2, m 56-58°, 58-60°, 59°.** It crystallises in red needles from pet ether (b 40-60°) and can be sublimed in high vacuum with a bath temperature of 46-48° [Ashley, Anslow and Raistrick *JCS* 441 *1938*; UV in EtOH: Vischer *JCS* 815 *1953*; UV in cyclohexane: Morton et al. *HCA* **41** 2343 *1858*; Aghoramurthy et al. *Chemistry and Industry London* 1327 *1954*].

Coenzyme Q_4 (Ubiquinone-4, 2,3-dimethoxy-5-methyl-6-[3,7,11,15-tetramethyl-hexadeca-2*t*,6*t*,10*t*,14-tetraenyl]-[1,4]benzoquinone *[4370-62-1]* **M 454.7.** A red oil purified by TLC chromatography on SiO_2 and eluted with Et_2O-hexane. Purity can be checked by HPLC (silica column using 7% Et_2O-hexane). It has λ_{max} 270 nm (ε 14,800) in pet ether. [NMR and MS: Naruta *JOC* **45** 4097 *1980;* cf Morton *Biochemical Spectroscopy* (Adam Hilger, London, 1975) p 491].

Coenzyme Q_9 (Ubiquinone-9, 2,3-dimethoxy-5-methyl-6-[3,7,11,15,19,23,27,31,35-nonamethyl-hexatriaconta-2*t*,6*t*,10*t*,14*t*,18*t*,22*t*,26*t*,30*t*,34-nonaenyl]-[1,4]benzoquinone) *[303-97-9]* **M 795.3, m 40.5-42.5°, 44-45°, 45°.** Yellow crystals purified by recrystn from pet ether and by TLC chromatography on SiO_2 and eluted with Et_2O-hexane. Purity can be checked by HPLC (silica column using 7% Et_2O-hexane). It has λ_{max} 270nm (ε 14,850) in pet ether. [NMR and MS: Naruta *JOC* **45** 4097 *1980;* Le et al. *Biochem Biophys Acta* **32 497** *1958*; cf Morton *Biochemical Spectroscopy* (Adam Hilger, London, 1975) p 491; IR: Lester et al. *Biochim Biophys Acta* **33** 169 *1959*; UV: Rüegg et al. *HCA* **42** 2616 *1959*; Shunk *JACS* **81** 5000 *1959*].

Coenzyme Q_{10} (Ubiquinone-10, 2,3-dimethoxy-5-methyl-6-[3,7,11,15,19,23,27,31,35,-39-decamethyl-tetraconta-2*t*,6*t*,10*t*,14*t*,18*t*,22*t*,26*t*,30*t*,34*t*,38-decaenyl]-[1,4]benzoquinone) *[303-98-0]* **M 795.3, m 48-49°,49°, 49.5-50.5°, 50°.** Purified by recrystn from EtOH, EtOH + Me_2CO or Et_2O-EtOH and by chromatography on silica gel using isoPrOH-Et_2O (3:1) to give orange crystals. It has λ_{max} 270nm (ε 15,170) in pet ether. [Terao et al. *JOC* **44** 868 *1979*; NMR and MS: Naruta et al. *JOC* **45** 4097 *1980*; IR: Lester et al. *Biochem Biophys Acta* **42** 1278 *1959*, NMR: Planta et al. *HCA* **42** 1278 *1959*; cf Morton *Biochemical Spectroscopy* (Adam Hilger, London, 1975) p 491].

Colcemide (Demecocine) *[477-30-5]* **M 371.4, m 182-185°, 183-185°, 186°, $[\alpha]_D^{20}$ -129° (c 1, $CHCl_3$).** It has been purified by chromatography on silica and eluting with $CHCl_3$-MeOH (9:1) and recrystn from EtOAc-Et_2O and forms yellow prisms. UV in EtOH has λ_{max} 243nm (ε 30,200) and 350nm (ε 16,3000). [Synthesis, IR, NMR, MS: Capraro and Brossi *HCA* **62** 965 *1979*].

Colchicine *[64-86-8]* **M 399.5, m 155-157°(dec), $[\alpha]_{546}^{20}$ -570° (c 1, H_2O).** Commercial material contains up to 4% desmethylcolchicine. Purified by chromatography on alumina, eluting with $CHCl_3$ [Ashley and Harris *JCS* 677 *1944*]. Alternatively, an acetone solution on alkali-free alumina has been used, and eluting with acetone [Nicholls and Tarbell *JACS* **75** 1104 *1953*].

Colchicoside *[477-29-2]* **M 547.5, m 216-218°.** Crystd from EtOH.

Colicin E (from *E.coli*) *[11032-88-5].* Purified by salt extraction of extracellular-bound colicin followed by salt fractionation and ion-exchange chromatography on a DEAE-Sephadex column, and then by CM-Sephadex column chromatography [Schwartz and Helinski *JBC* **246** 6318 *1971*].

Collagenase (from human polymorphonuclear leukocytes) [EC 3.4.24.7]. Purified by using *N*-ethylmaleimide to activate the enzyme, and wheat germ agglutinin-agarose affinity chromatography [Callaway et al. *Biochemistry* **25** 4757 *1986*].

Compactin *[73573-88-3]* **M 390.5, m 151-153°, 152°, $[\alpha]_D^{22}$ +283° (c 0.48, M_2CO).** Purified by recrystn from aqueous EtOH. UV: λ_{max} 230, 237 and 246nm (logε 4.28, 4.30 and 4.11); IR (KBr): ν 3520, 1750 (lactone CO) and 1710 (CO ester) cm^{-1}. [Clive et al. *JACS* **110** 6914 *1988*; Synthesis review: Rosen and Heathcock *TET* **42** 4909 *1986*; IR, NMR, MS: Brown et al. *JCS Perkin Trans I* 1165 *1976*].

Convallatoxin *[508-75-8]* **M 550.6, m 238-239°.** Crystd from ethyl acetate.

Copper-zinc-superoxide dismutase (from blood cell haemolysis) *[9054-89-1]* **M_r ~32,000 [EC 1.15.1.1].** Purified by DEAE-Sepharose and copper chelate affinity chromatography. The preparation was homogeneous by SDS-PAGE, analytical gel filtration chromatography and by isoelectric focusing [Weselake et al. *AB* **155** 193 *1986*; Fridovich *JBC* **244** 6049 *1969*].

Coproporphyrin I *[531-14-6]* **M 654.7, λ_{max} 591, 548, 401nm in 10% HCl.** Crystd from pyridine/glacial acetic acid.

Corticosterone (11β, 21-dihydroxypregn-4-en-3,20-dione) *[50-22-6]* **M 346.5, m 180-181°, 180-182°, 181-184°, $[\alpha]_D^{15}$ +223° (c 1.1, EtOH), $[\alpha]_D^{23-25}$ +194° (c 0.1, dioxane).** Purified by recrystn from M_2CO (trigonal plates), EtOH or isoPrOH. UV λ_{max} at 240nm, and gives an orange-yellow soln with strong fluorescence on treatment with concentrated H_2SO_4. Insoluble in H_2O but soluble in organic solvents. [Reichstein and Euw *HCA* **21** 1197 *1938*, **27** 1287 *1944*; Mason et al. *JBC* **114** 613 *1936*; ORD: Foltz et al. *JACS* **77** 4359 *1955*; NMR: Shoolery and Rogers *JACS* **80** 5121 *1958*]. The *21-O-benzoyl* derivative has **m** 201-202° [Reichstein *HCA* **20** 953 *1937*].

Corticotropin *[92307-52-3]* **polypeptide M_r ~4697.** Extract separated by ion-exchange on CM-cellulose, desalted, evapd and lyophilised. Then run on gel filtration (Sephadex G-50) [Lande et al. *Biochemical Preparations* **13** 45 *1971*; Esch et al. *BBRC* **122** 899 *1984*].

Cortisol *[50-23-7]* **M 362.4, m 217-220°, λ_{max} 242nm (log ε 4.20).** Crystd from EtOH.

Cortisone *[53-06-5]* **M 360.5, m 230-231°, $[\alpha]_{546}^{20}$ +225° (c 1, in EtOH).** Crystd from 95% EtOH or acetone.

Cortisone-21-acetate *[50-04-4]* **M 402.5, m 242-243°, $[\alpha]_{546}^{20}$ +227° (c 1, in $CHCl_3$).** Crystd from acetone.

Creatine (H_2O) *[6020-87-7]* **M 131.1, m 303°.** Likely impurities are creatinine and other guanidino compounds. Crystd from water as monohydrate. Dried under vacuum over P_2O_5 to give anhydrous material.

Creatinine *[60-27-5]* **M 113.1, m 260°(dec).** Likely impurities are creatine and ammonium chloride. Dissolved in dilute HCl, then neutralised by adding ammonia. Recrystd from water by adding excess of acetone.

Crotaline (monocrotaline, 12,13-dihydroxy-(13β-14β*H*)-14,19-dihydro-20-norcrotalanan-11,15-dione) *[315-22-0]* **M 325.4, m 196-197°(dec), 197-198°(dec), 203°(dec), $[\alpha]_D^{20}$ -55° (c 1, EtOH).** It forms prisms from absolute EtOH and recrystallises also from $CHCl_3$. UV in 96% EtOH has λ_{max} 217nm (log ε 3.32). [Adams et al. *JACS* **74** 5612 *1952*; Culvenor and Smith *Australian J Chem* **10** 474 *1957*]. The *hydrochloride* has **m** 212-214° (from MeOH-Et_2O) and $[\alpha]_D^{28}$ -38.4° (c 5, H_2O) [Adams and Gianturco *JACS* **78** 1922 *1956*]. The *picrate* has **m** 230-231.5°(dec) [Adams et al. *JACS* **74** 5614 *1952*].

α-Cyclodextrin (H_2O) *[10016-20-3]* **M 972.9, m >280°(dec), $[\alpha]_{546}$ +175° (c 10, H_2O).** Recrystd from 60% aq EtOH, then twice from water, and dried for 12hours in a vacuum at 80°. Also purified by pptn from water with 1,1,2-trichloroethylene. The ppte was isolated, washed and resuspended in water. This was boiled to steam distil the trichloroethylene. The soln was freeze-dried to recover the cyclodextrin. [Armstrong et al. *JACS* **108** 1418 *1986*].

ß-Cyclodextrin (H_2O) *[7585-39-9]* **M 1135.0, m >300°(dec), $[\alpha]_{546}$ +170° (c 10, H_2O).** Recrystd from water and dried for 12hours in a vacuum at 110°, or 24hours in a vacuum at 70°. The purity was assessed by TLC on cellulose with a fluorescent indicator. [Taguchi, *JACS* **108** 2705 *1986*; Tabushi et al. *JACS* **108** 4514 *1986*; Orstam and Ross *JPC* **91** 2739 *1987*].

D-(*R-natural*) and L-(*S*-non-natural) Cycloserine (2-amino-3-isoxazolidone) *[R- 68-41-7 and S- 339-72-0]* **M 102.1, m 145-150° (dec), 154-155°, 155-156° (dec), 156° (dec), $[\alpha]_D^{25}$ ±137° (c 5, 2N NaOH).** Purified by recrystn from aqueous EtOH or MeOH or aqueous NH_3 + EtOH or isoPrOH. An aqueous soln buffered to pH 10 with Na_2CO_3 can be stored in a refrigerator for 1 week without decomposition. UV: λ_{max} 226nm ($\varepsilon_{1cm}^{1\%}$ 4.02). They have pKa values in H_2O of 4.50 and 7.74 at 10° and 4.44 and 7.20 at 50°. The *tartrate salt* has **m** 165-166° (dec), 166-168° (dec), and $[\alpha]_D^{24}$ -41° (c 0.7, H_2O). [Stammer et al. *JACS* **79** 3236 *1959*; UV: Kuehl *JACS* **77** 2344 *1955*].

Cystamine dihydrochloride (2,2'-diaminodiethylene disulphide dihydrochloride, 2,3'-dithiobis(ethylamine) dihydrochloride *[56-17-7]* **M 225,2, m 217-220°(dec), 219-220°(dec).** Recrystd by dissolving in EtOH containing a few drops of dry EtOH-HCl, filtering and adding dry Et_2O. The solid is dried in a vacuum and stored in dry and dark atmosphere. It has been recrystd from EtOH (solubility: 1g in 60ml of boiling EtOH) or MeOH (plates). The *free base* has **b** 90-100°/0.001mm, 106-108°/5mm and 135-136°/atm, d_4^{20} 1.1559, n_D^{20} 1.5720. [Verly and Koch *BJ* **58** 663 *1954*]. It has pKa values in H_2O of 8.82 and 9.58 at 30° [Gonick et al. *JACS* **76** 4671 *1954*; Jackson and Block *JBC* **113** 137 *1936*]. The *dihydrobromide* has **m** 238-239° (from EtOH-Et_2O) [Viscontini *HCA* **36** 835 *1953*].

***S,S*-(L,L)-Cystathionine (*S*-2-amino-2-carboxyethyl-L-homocysteine, L-2-amino-4[(2-amino-2-carboxyethyl)thio]butyric acid)** *[56-88-2]* **M 222.3, m >300°, dec at 312° with darkening at 270°, $[\alpha]_D^{20}$ +23.9° (c 1, M HCl).** Could be converted to the *HCl* salt by dissolving in 20% HCl and carefully basifying with aqueous NH_3 until separation is complete. Filter off and dry in a vacuum. It forms prisms from H_2O. The *dibenzoyl* derivative has **m** 229° (from EtOH). [IR: Greenstein and Winitz *Chemistry of the Amino Acids (J Wiley)* **vol 3** 2690 *1961* and Tallan et al. *JBC* **230** 707 *1958*; Synthesis: du Vigneaud et al. *JBC* **143** 59 *1942*; Anslow et al. *JBC* **166** 39 *1946*]. [Prepn: Weiss and Stekol *JACS* **73** 2497 *1951*; see also du Vigneaud et al. *JBC* **143** 60 *1942*; Biological synthesis: Greenberg *Methods in Enzymology* **5** 943 *1962*].

Cysteamine (2-aminoethanethiol, 2-mercaptoethylamine) *[60-23-1]* **M 77.2, m 97-98.5°, 98-99°, 99-100°.** Soluble in H_2O giving an alkaline reaction and it has a disagreeable odour. Likely impurity is the disulphide, cystamine which is not soluble in alkaline solution. Under a N_2 atmosphere dissolve in EtOH, evaporate to dryness and wash the white residue with dry pet ether, then sublime at 0.1mm and store under N_2 (out of contact with air) at 0-10° in the dark. Its pKa values in H_2O are 9.15 and 11.93 at 0°, and 8.42 and 10.83 at 30°. Its *$HgCl_2$ (2:3) complex* has **m** 181-182° (from H_2O), and its *picrate* has **m** 125-126°. [Mills and Bogert *JACS* **57** 2328 *1935*, **62** 1173 *1940*; Baddiley and Thain *JCS* 800 1952; Shirley *Preparation of Organic Intermediates (J. Wiley)* **vol 3** 189 *1951*].

Cysteamine hydrochloride *[156-57-0]* **M 113.6, m 70.2-70.7°, 70-72°.** Purified by recrystn from EtOH. It is freely soluble in H_2O and should be stored in a dry atmosphere. [Mills and Bogert *JACS* **62** 1177 *1940*]. The *picrate* has **m** 125-126°, see previous entry for *free base*.

(±)-Cysteic acid (3-sulphoalanine, 1-amino-3-sulphopropionic acid) *[3024-83-7]* **M 169.2, m 260°(dec),**
***S*-Cysteic acid (H_2O)** *[498-40-8]* **M 187.2, m 275-280° (dec), 289°, $[\alpha]_D^{20}$ +8.66° (c 7.4, H2O, pH 1) and + 1.54° (H_2O pH 13).** Likely impurities are cystine and oxides of cysteine. Crystd from water by adding 2 volumes of EtOH. When recrystd from aqueous MeOH it has **m** 264-266°, and the anhydrous acid has **m** ~260°(dec). It has pKa values of 1.9 (SO_3H, acidic), 8.7 (CO_2H, acidic) and 12.7 (NH_3^+) at 25°. [Chapeville and Formageot *Biochim Biophys Acta* **26** 538 *1957*; *JBC* **72** 435 *1927*].

D-(*S*)- and L-(*R*)- Cysteine (*S*- and *R*-2-amino-3-mercaptopropionoic acid) *[S-: 921-01-7* and *R-: 52-90-4]* **M 121.2, m 230°, 240° (dec), $[\alpha]_D^{20}$ ±7.6° (c 2, M HCl) and ±10.1° (c 2, H_2O, pH 10).** Purified by recrystn from H_2O (free from metal ions) and dried in a vacuum. It is soluble in H_2O, EtOH, Me_2CO, EtOAc, AcOH, C_6H_6 and CS_2. Acidic solns can be stored under N_2 for a few days without deterioration. They have pKa values of 1.71, 8.33 and 10.78 in H_2O. [For synthesis and Spectra see Greenstein and Winitz *Chemistry of the Amino Acids (J. Wiley)* **vol 3** p1879 *1961*].

L-Cysteine hydrochloride (H_2O) *[52-89-1]* **M 157.6, m 175-178° (dec), $[\alpha]_D^{25}$ +6.53° (5M HCl).** Likely impurities are cystine and tyrosine. Crystd from MeOH by adding ethyl ether, or from hot 20% HCl. Dried under vacuum over P_2O_5. *Hygroscopic.*

(±)-Cysteine hydrochloride *[10318-18-0]* **M 157.6.** Crystd from hot 20% HCl; dried under vacuum over P_2O_5.

L-Cystine *[56-89-3]* **M 240.3, $[\alpha]_D^{18.5}$-229° (c 0.92 in M HCl).** Cystine disulphoxide was removed by treating an aqueous suspension with H_2S. The cystine was filtered off, washed with distilled water and dried at 100° under vacuum over P_2O_5. Crystd by dissolving in 1.5M HCl, then adjusting to neutral pH with ammonia. Likely impurities are D-cystine, meso-cystine and tyrosine.

Cytidine *[65-46-3]* **M 243.2, m 210-220°(dec), 230° (dec), 251-252° (dec), $[\alpha]_{546}^{20}$ +37° (c 9, H_2O), $[\alpha]_D^{20}$+29° (c 9, H_2O).** Crystd from 90% aqueous EtOH. Also has been converted to the *sulphate* by dissolving (~200mg) in a soln of EtOH (10ml) containing H_2SO_4 (50mg), whereby the salt crystallises out. It is collected, washed with EtOH and dried for 5hours at 120°/0.1mm. The *sulphate* has **m** 225°. The *free base* can be obtained by shaking with a weak ion-exchange resin, filtering, evaporating and recrystallising the residue from EtOH as before. It has a pKa of 3.85 in H_2O. [Fox and Goodman *JACS* **73** 3256 *1956*; Fox and Shugar *Biochim Biophys Acta* **9** 369 *1952*; see Prytsas and Sorm in *Synthetic Procedures in Nucleic Acid Chemistry* (Zorbach and Tipson eds) **vol 1** 404 *1973*].

Cytisine see entry in Chapter 3.

Cytochalasin B (from dehydrated mould matte) *[14930-96-3]* **M 479.6.** Purified by MeOH extraction, reverse phase C18 silica gel batch extraction, selective elution with 1:1 v/v hexane/tetrahydrofuran, crystn, subjected to TLC and recrystallised [Lipski et al. *AB* **161** 332 *1987*].

Cytochrome c_1 (from horse, beef or fishes' heart, or pigeon breast muscle) *[9007-43-6]* **M ~ 13,000.** Purified by chromatography on CM-cellulose (CM-52 Whatman) [Brautigan et al. *Methods in Enzymology* **53D** 131 *1978*]. It has a high PI and has been purified further by adsorption onto an acidic cation exchanger, e.g. Amberlite IRC-50 (polycarboxylic) or in ground form Amberlite XE-40 (100-200 mesh) or Decalso-F (aluminium silicate), where the non-cytochrome protein is not adsorbed and is readily removed. The cytochrome is eluted using a soln containing 0.25g ions/L of a univalent cation at pH 4.7 adsorbed onto the NH_4^+ salt of Amberlite IRC-50 at pH 7, washed with H_2O and then with 0.12M NH_4OAc to remove non-cytochrome protein. When the cytochrome begins to appear in the eluate then the NH_4OAc concn is increased to 0.25 M. The fractions with *ca* Fe = 0.465—0.467 are collected, dialysed against H_2O and adsorbed onto a small IRC-50 column and eluted with 0.5M NH_4OH, then dialysed and lyophilised. (A second fraction (II) can be eluted from the first resin with 0.5M NH_4OH but is discarded). [Keilin and Hartree *Biochemical Preparations* **1** 1 *1952*; Margoliash *Biochemical Preparations* **8** 33 *1957*].
Cytochrome c has been recrystd as follows: The above eluate (*ca* 100ml) is dialysed against H_2O (10 vols) at 4° for 24 h (no more), then passed through an XE-40 column (2 x 1 cm above) which is equilibrated with 0.1M NH_4OAc pH 7.0. The column is washed with 0.1% $(NH_4)_2SO_4$ pH 8.0 and the dark red resin in the upper part of the column is collected and in 0.1% $(NH_4)_2SO_4$ pH 8.0 transferred to another column (7 mm diameter) and the cytochrome c is eluted with 5% $(NH_4)_2SO_4$ pH 8.0. More than 98% of the red colour is collected in a volume of *ca* 4ml in a weighed centrifuge tube. Add a drop of octanol, 0.43g of $(NH_4)_2SO_4$/gm of soln. When the salt has dissolved ascorbic acid (5mg), add a few drops of 30% NH_3 and keep the soln at 10° for 10min (turns lighter colour due to reduction). Then add finely powdered $(NH_4)_2SO_4$ in small portions (stir with a glass rod) until the soln becomes turbid. Stopper the tube tightly, and set aside at 15-25° for 2 days while the cytochrome c separates as fine needles or rosettes. Further $(NH_4)_2SO_4$ (20mg) are added per ml of suspension and kept in the cold for a few days to complete the crystallisation. The crystals are collected by centrifugation (5000xg), suspended in saturated $(NH_4)_2SO_4$ (pH 8.0 at 10°) then centrifuged again. For recrystn the crystals are dissolved in the least volume of H_2O, one drop of ammonia and 1 mg of ascorbic acid are added and the above process is repeated. The yield of twice recrystd cytochrome c from 2Kg of muscle is *ca* 200 mg but this varies with the source and freshness of the muscle used. The crystals are stored as a solid after dialysis against 0.08M NaCl or 0.1M sodium buffer and lyophilising, or as a suspension in saturated $(NH_4)_2SO_4$ at 0°. [Hagihara et al. *Biochemical Preparations* **6** 1 *1958*]. *Purity of cytochrome c:* This is checked by the ratio of the absorbance at 500nm (reduced form) to 280nm (oxidised form), i.e. $\varepsilon_{500}/\varepsilon_{280}$ should be between 1.1 and 1.28, although values of up to 1.4 have been obtained for pure preparations.
For the preparation of the *reduced form* see Margoliash *Biochemical Preparations* **5** 33 *1957* and Yonetani *Biochemical Preparations* **11** 19 *1966*.
Cytochrome from *Rhodospirillum rubrum.* ($\varepsilon_{270}/\varepsilon_{551}$ 0.967). Purified by chromatography on a column of CM-Whatman cellulose [Paleus and Tuppy *Acta Chem Scand* **13** 641 *1959*].

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Cytochrome c oxidase (from bovine heart mitochondria). *[9001-16-5]* **M_r 100,000/haeme, [EC 1.9.3.1].** Purified by selective solubilisation with Triton X-100 and subsequently with lauryl maltoside; finally by sucrose gradient centrifugation [Li et al. *BJ* **242** 417 *1978*].
Also purified by extraction in 0.02 M phosphate buffer (pH 7.4) containing 2% of cholic acid (an inhibitor which stabilises as well as solubilises the enzyme) and fractionated with $(NH_4)_2SO_4$ collecting the 26-33% saturation cut and refractionating again and collecting the 26-33% saturation fraction. The pellet collected at 10,000xg appears as an oily paste. The cholate needs to be removed to activate the enzyme as follows: The ppte is dissolved in 10ml of 0.1M phosphate buffer pH 7.4, containing 1% of Tween-80 and dialysed against 1L of 0.01 M PO_4 buffer (pH 7.4) containing 1% of Tween-80 for 10 h at 0° and aliquoted. The enzyme is stable at 0° for 2 weeks and at -15° for several months. It is assayed for purity (see reference) by oxidation of reduced cytochrome c (Km 10μM). [Yonetani *Biochemical Preparations* **11** 14 *1966*; *JBC* **236** 1680 *1961*].

Cytosine *[71-30-7]* **M 111.1, m 320-325° (dec).** Crystd from water.

Cytosine-1-β-*O*-arabinofuranoside (Cytarabin) *[147-94-4]* **M 243.2, m ~220°(dec), 212-213.5°, $[\alpha]_D^{20}$ +155° (c 1, H_2O).** Purified by recrystn from aqueous EtOH. It has a pKa value of 4.1 (H_2O, and λ_{max} 212 and 279nm at pH 2 and 272nm at pH 12. [Walwick et al. *Proc Chem Soc (London)* 84 *1959*].

N-Decanoyl-*N*-methylglucamine (Mega-10, *N*-D-glucidyl-*N*-methyl decon-amide) *[85261-20-7]* M 349.5, m 91-93°, 92°.

Possible impurities are decanoic acid and *N*-methylglycamine. The former is removed by grinding the solid with Et_2O and then with pet ether and dried over P_2O_5. Twice recrystd from MeOH-Et_2O by dissolving in the minimum volume of MeOH and adding Et_2O and drying in a vacuum. To remove the glycamine the solid (800mg) is dissolved in hot H_2O (10ml) and set aside. Mega-10 crystallises in colourless needles. These are filtered off and dried in a vacuum to constant weight. It is a good non-ionic non-hygroscopic detergent with a critical micelle concentration (CMC) of 7.4mM (0.26%) in 0.1M Tris-HCl pH 7.4 at 25°. [Hildreth *BJ* **207** 363 *1982*].

Demeclocycline hydrochloride (7-chloro-6-demethyltetracycline hydrochloride, Clortetrin) *[64-73-3]* **M 501.3, m 174-178°(dec, for sesquihydrate), $[\alpha]_D^{25}$ -258° (c 0.5, 0.1N H_2SO_4).** Crystd from EtOH-Et_2O or H_2O and dried in air, It has a pKa value of 4.45 in H_2O-Me_2NCHO (1:1). [McCormick et al. *JACS* **79** 4561 *1957*; Dobrynin et al. *TET LETT* 901 *1962*].

2'-Deoxyadenosine (adenine 2'-deoxyriboside) *[16373-93-6]* **M 269.3, m 187-188°, 187-189°, 189-191°, $[\alpha]_D^{20}$ -25° (c 0.5, H_2O), $[\alpha]_{589}^{25}$ -26°, $[\alpha]_{310}^{25}$ -206° (c 0.5, H_2O).** Purified by recrystn from H_2O (as hydrated crystals; solubility of mono-hydrate is 1.1% in H_2O at 20°). It has λ_{max} 258nm (pH 1), 260nm (pH 7) and 261nm (pH 13). [Ness and Fletcher *JACS* **81** 4752 *1959*; Walker and Butler *Canad J Chem* **34** 1168 *1956*]. The *3',5'-O-diacetyl derivative* has **m** 151-152° (recrystd from EtOAc-pet ether).

3'-Deoxyadenosine (Cordycepin, adenine 3'-deoxyriboside) *[73-03-0]* **M 251.2, m 225-226°, 225-229°, $[\alpha]_D^{20}$ -47° (H_2O).** It forms needles from EtOH, *n*-BuOH and *n*-PrOH, and from H_2O as the mono-hydrate. It has λ_{max} 260nm (ε 14,600) in EtOH. The *picrate* has **m** 195°(dec, yellow crystals from H_2O). Kaczka et al. *Biochim Biophys Acta* **14** 456 *1964*; Todd and Ulbricht *JCS* 3275 *1960*; Lee et al. *JACS* **83** 1906 *1961*; Walton et al. *JACS* **86** 2952 *1964*].

11-Deoxycorticosterone acetate (21-acetoxy-4-pregnen-3,20-dione) *[56-47-3]* **M 372.5, m 154-159°, 154-160°, 155-157°, 155-161°, $[\alpha]_D^{20}$ +174° (c 1, dioxane), $[\alpha]_D^{22-24}$ +196° (c 1, $CHCl_3$).** Recrystallises from EtOH as needles or Me_2CO-hexane, and sublimes at high vacuum. Partly soluble in MeOH, Me_2CO, Et_2O and dioxane but insoluble in H_2O. [Romo et al. *JACS* **79** 5034 *1957*; NMR: Shoolery and Rogers *JACS* **80** 5121 *1959*].

2'-Deoxycytidine monohydrate *[951-77-9]* **M 245.2, m 119-200°, 207-209°, 213-215°,** $[\alpha]_D^{25}$ **+78° (c 0.4, N NaOH),** $[\alpha]_D^{23}$ **+57.6° (c 2, H_2O).** Purified by recrystn from MeOH-Et_2O or EtOH and dried in air. [NMR: Miles *JACS* **85** 1007 *1963*; UV: Fox and Shugar *Biochim Biophys Acta* **9** 369 *1952*]. The *hydrochloride* crystallises from H_2O-EtOH and has **m** 174°(dec, 169-173°) [Walker and Butler *Canad J Chem* **34** 1168 *1956*]. The *picrate* has **m** 208°(dec). [Fox et al. *JACS* **83** 4066 *1961*].

2'-Deoxycytidine 5'-monophosphoric acid (deoxycytidylic acid) *[1032-65-1]* **M 307.2, m 170-172°(dec), 183-184°(dec), 183-187°(dec),** $[\alpha]_D^{21}$ **+35° (c 0.2, H_2O).** Recrystd from H_2O or aqueous EtOH and dried in a vacuum. [Volkin et al. *JACS* **73** 1533 *1951*; UV: Fox et al. *JACS* **75** 4315 *1953*; IR: Michelson and Todd *JCS* 3438 *1954*].

2'-Deoxyguanosine monohydrate (9-[2-deoxy-β-D-ribofuranosyl]guanidine) *[961-07-9]* **M 285.3, m** *ca* **200°(dec),** $[\alpha]_D^{20}$ **+37.5° (c 2, H_2O),** $[\alpha]_D^{14}$ **-47.7° (c 0.9, N NaOH).** Recrystd from H_2O as the monohydrate. [Brown and Lythgoe *JCS* 1990 *1950*; Levene and London *JBC* **81** 711 *1929*, **83** 793 *1929*]; UV: Hotchkiss *JBC* **175** 315 *1948*; ORD: Levendahl and James *Biochim Biophys Acta* **26** 89 *1957*]. The *3',5'-di-O-acetyl derivative* crystd from aqueous EtOH has **m** 222°(dec), $[\alpha]_D^{18}$ -38° (c 0.3, 10% aq EtOH) [Hayes et al. *JCS* 808, 813 *1955*].

2'-Deoxyinosine *[890-38-0]* **M 252.2, m 206°(dec), 218-220°(dec),** $[\alpha]_D^{25}$ **-21° (c 2, N NaOH),** $[\alpha]_D^{21.5}$ **(c 1, H_2O).** Purified by recrystn from H_2O. [Brown and Lythgoe *JCS* 1990 *1950*; UV: : MacNutt *BJ* **50** 384 *1952*].

5-Deoxy-5-(methylthio)adenosine *[2457-80-9]* **M 297.3, m 210-213°(dec), 211°, 212°, 213-214°,** $[\alpha]_D^{20}$ **-23.7° (c 0.02, pyridine),** $[\alpha]_D^{20}$ **-8° (c 1, 5% aq NaOH),** $[\alpha]_D^{25}$ **+15° (c 0.4-1.0, 0.3N aq AcOH).** It has been recrystd from H_2O and sublimed at 200°/0.004mm. [v.Euler and Myrbäck *Z physiol Chem* **177** 237 *1928*; Weygand and Trauth *B* **84** 633 *1951*; Baddiley et al. *JCS* 2662 *1953*]. The *hydrochloride* has **m** 161-162° [Kuhn and Henkel *Z physiol Chem* **269** 41 *1941*]. The *picrate* has **m** 183°(dec) (from H_2O).

Deoxyribonucleic acid (from plasmids). Purified by two buoyant density ultracentrifugations using ethidium bromide-CsCl. The ethidium bromide was extracted with Et_2O and the DNA was dialysed against buffered EDTA and lyophilised. [Marmur and Doty *J Mol Biol* **5** 109 *1962*; Guerry et al. *J Bacteriol* **116** 1064 *1973*]. See also p. 457,458.

3'-Deoxythymidine (2',3'-dideoxythymidine, 1-[(2*r*)-5*c*-hydroxymethyltetrahydro(2*r*)-furyl-5-methylpyrimidine-2,4-dione) *[3416-05-5]* **M 226.2, m 145°, 149-151°,** $[\alpha]_D^{26}$ **+18° (c 1, H_2O).** Recrystd from Me_2CO + MeOH. [Michelson and Todd *JCS* 816 *1955*].

2'-Deoxyuridine (1-[β-D-*erythro*-2-deoxypentofuranosyl]-1*H*-pyrimidine-2,4-dione) *[951-78-0]* **M 228.2, m 163°, 163-163.5°, 165-167° 167°,** $[\alpha]_D^{26}$ **+30° (c 2, H_2O),** $[\alpha]_D^{22}$ **+50° (c 1, N NaOH).** Forms needles from absolute EtOH or 95% EtOH. It has a pKa value of 9.3 (acidic) in H_2O. [Dekker and Todd *Nature* **166** 557 *1950*; Brown et al. *JCS* 3035 *1958*; NMR Jardetzky *JACS* **83** 2919 *1961*; Fox and Shugar *Biochim Biophys Acta* **9** 369 *1952*; UV: MacNutt *BJ* **50** 384 *1952*].

3'-Deoxyuridine (1-[(2*R*)-5*c*-hydroxymethyltetrahydro[2*r*]furyl-5-methylpyrimidin-2,4-dione, 2'.3'-dideoxythymidine) *[3416-05-5]* **M 226.2, m 145°, 149-151°,** $[\alpha]_D^{20}$ **+18° (c 1, H_2O).** Recrystd from Me_2CO + MeOH and dried in a vacuum. [Michelson and Todd *JCS* 816 *1955*].

Dermatan sulphate (condroitin sulphate B from pig skin). Purified by digestion with papain and hyaluronidase, and fractionation using aqueous EtOH. [Gifonelli and Roden *Biochemical Prepreparations* **12** 1 *1968*].

Dextran. Solutions keeps indefinitely at room temperature if 0.2ml of Roccal (10% alkyldimethylbenzylammonium chloride) or 2mg phenyl mercuric acetate are added per 100ml solution. [Scott and Melvin *AB* **25** 1656 *1953*].

Diacetone-D-Glucose (1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranoside) *[582-52-5]* **M 260.3, m 107-110°, 110.5°, 111-113°, 112°, $[\alpha]_D^{15}$-18.4° (c 1, H_2O).** It crystallises from Et_2O, (needles), pet ether or C_6H_6 and sublimes *in vacuo*. It is sol in 7 vols of H_2O and 200 vols of pet ether at their boiling points. The solubility in H_2O at 17.5° is 4.3%. It pptes from aq solns on basification with NaOH. [Schmid and Karrer *HCA* **32** 1371 *1949*; Fischer and Rund *B* **49** 90, 93 *1916*; IR: Kuhn *AC* **22** 276 *1950*].

***N,N'*-Diacetylchitobiose (2-acetyl-*O*^{4}-[2-acetylamino-2-deoxy-β-D-glucopyranosyl]-2-deoxy-D-glucose)** *[35061-50-8]* **M 424.4, m 245-247°(dec), 251.5-252.5°, 260-262°, $[\alpha]_D^{25}$ +39.5° (extrapolated) → +18.5° (after 60 min, c 1, H_2O).** Recrystd from aqueous MeOH or aqueous EtOH + 1,2-dimethoxyethane. [Zilliken et al. *JCS* **77** 1296 *1955*].

1,8-Diazafluorenone (cyclopenta[1.2-*b*:4,3-*b'*]dipyridin-9-one) *[54078-29-4]* **M 182.2, m 205°, 229-231°.** Recrystd from Me_2CO. The *oxime* has **m** 119-200°. [Druey and Schmid *HCA* **33** 1080 *1950*].

Di- and tri-carboxylic acids. Resolution by anion-exchange chromatography. [Bengtsson and Samuelson *Analyt Chim Acta* **44** 217b *1969*].

Dihydrofolate reductase (from *Mycobacterium phlei*). Purified by ammonium sulphate pptn, then fractionated on Sephadex G-75 column, applied to a Blue Sepharose column and eluted with 1mM dihydrofolate. [Al Rubeai and Dole *BJ* **235** 301 *1986*].

7,8-Dihydrofolic acid (7,8-dihydropteroyl-L-glutamic acid, DHFA) *[4.033-27-6]* **M 443.4.** Best purified by suspending (1g mostly dissolved)) in ice-cold sodium ascorbate (300ml of 10% at pH 6.0 [prepared by adjusting the pH of 30g of sodium ascorbate in 150ml of H_2O by adding 1N NaOH dropwise using a glass electrode till the pH is 6.0]). This gave a clear solution with pH ~5. While stirring at 0° add N HCl dropwise slowly (0.1ml/min) until the pH drops to 2.8 when white birefringent crystals separate. These are collected by centrifugation (1000xg for 5min), washed 3x with 0.001N HCl by centrifugation and decantation. The residue is then dried in a vacuum (0.02mm) over P_2O_5 (change the P_2O_5 frequently at first) and KOH at 25° in the dark. After 24hours the solid reaches constant weight.
For the assay of *dihydrofolate reductase* (see below): suspend ~66.5mg of DHFA in 10ml of 0.001M HCl containing 10mM dithiothreitol (DTT stock made from 154mg in 10ml H_2O making 0.1M), shake well and freeze in 400µl aliquots. Before use mix 400µl of this suspension with 0.1M DTT (200µl, also made in frozen aliquots), and the mixture is diluted with 200µl of 1.5M Tris-HCl pH 7.0 and 1.2ml of H_2O (making a total volume of ~2ml) to give a clear solution. To estimate the concentration of DHFA in this solution, dilute 20µl of this solution to 1ml with 0.1M Tris-HCl pH 7.0 and read the OD at 282nm in a 1cm pathlength cuvette. ε at 282nm is 28,000$M^{-1}cm^{-1}$. [Reyes and Rathod *Methods in Enzymology* **122** 360 *1986*].

Dihydropteridine reductase (from sheep liver) M_r 52,000 [EC 1.6.99.7]. Purified by fractionation with ammonium sulphate, dialysed *versus* tris buffer, adsorbed and eluted from hydroxylapatite gel. Then run through a DEAE-cellulose column and also subjected to Sephadex G-100 filtration. [Craine et al. *JBC* **247** 6082 *1972*].

Dihydropteridine reductase (from human liver) M_r 52,000 [EC 1.6.99.7]. Purified to homogeneity on a naphthoquinone affinity adsorbent, followed by DEAE-Sephadex and CM-Sephadex chromatography. [Firgaira, Cotton and Danks, *BJ* **197** 31 *1981*]. [For other dihydropteridine reductases see Armarego et al. *Medicinal Research Reviews* **4**(3) 267 *1984*].

DL-*erythro*-Dihydroshingosine (dl-*erythro*-2-aminooctadecan-1,3-diol) *[3102-56-5]* **M 301.5, m 85-86°, 85-87°.** Purified by recrystn from pet ether-EtOAc or $CHCl_3$. The (±)-*N-dichloroacetyl* derivative has **m** 142-144° (from MeOH). [Shapiro et al. *JACS* **80** 2170 *1958*; Shapiro and Sheradsky *JOC* **28** 2157 *1963*]. The D-isomer crystallises from pet ether-Et_2O and has **m** 78.5-79°, $[\alpha]_{546}^{28}$ +6° ($CHCl_3$ + MeOH, 10:1). [Grob and Jenny *HCA* **35** 2106 *1953*, Jenny and Grob *HCA* **36** 1454 *1953*].

Dihydrostreptomycin sesquihydrate *[5490-27-7]* **M 461.4, m 250°(dec), 255-265°(dec), $[\alpha]_D^{20}$ -92.4° (c 1,H_2O).** It crystallises from H_2O with MeOH, *n*-BuOH or methyl ethyl ketone. The crystals are not hygroscopic like the amorphous powder, however both forms are soluble in H_2O but the amorphous solid is about 10 times more soluble than the crystals. The *free base* also crystallises from H_2O-Me_2CO and has $[\alpha]_D^{26}$ -92° (aqueous solution pH 7.0). [Solomons and Regina *Science* **109** 515 *1949*; Wolf et al. *Science* **109** 515 *1949*; McGilveray and Rinehart *JACS* **87** *4003* 1956].

3-(3,4-[dihydroxyphenyl)-L-alanine (DOPA, EUODOPA) *[59-92-7]* **M 197.2, m 275°(dec), 267-268°(dec), 284-286°(dec), ~295°(dec), $[\alpha]_D^{13}$ -13.1° (c 5.12, N HCl).** Recryst from H_2O as colourless white needles; Soluble in H_2O (0.165%), but is insoluble in EtOH, C_6H_6, $CHCl_3$, and EtOAc. It is rapidly oxidised in air when moist, and darkens. Dry in a vacuum at 70° in the dark, and store in a dark container preferably under N_2. λ_{max} 220.5nm (log ε 3.79) and 280nm (log ε 3.42) in 0.001N HCl. [Yamada et al. *Chem Pharm Bull Japan* **10** 693 *1962*; Bretschneider et al. *HCA* **56** 2857 *1973*; NMR: Jardetzky and Jardetzky *JBC* **233** 383 *1958*].

***N*-(3-Dimethylaminopropyl)-*N*-ethylcarbodiimide hydrochloride** see **ethyl-3-(3-dimethylaminopropyl) carbodiiomide hydrochloride** (below).

3,4-Dihydroxyphenylalanine-containing proteins. Boronate affinity chromatography is used in the selective binding of proteins containing 3,4-dihydroxyphenylalanine to a *m*-phenylboronate agarose column and eluting with 1M NH_4OAc at pH 10. [Hankus et al. *AB* **150** 187 *1986*].

3-(3,4-Dihydroxyphenyl)-2-methyl-L-alanine (methyldopa, 2-amino-3-[3,4-dihydroxyphenyl)-2-methylrpopionic acid) *[555-30-6]* **M 238.2, m >300°, 300-301°(dec).** Recrystd from H_2O. [Reinhold et al. *JOC* **33** 1209 *1968*]. The L-*isomer* forms a sesquihydrate from H_2O **m** 302-304° (dec), and the anhydrous crystals are *hygroscopic*, $[\alpha]_D^{23}$ -4.0° (c 1, 0.1N HCl), $[\alpha]_{546}$ +154.5° (c 5, $CuSO_4$ solution). It has λ_{max} 281nm (ε 2780). Solubility in H_2O at 25° is ~10mg/ml and the pH of an aqueous solution is ~5.0. It is almost insoluble in most organic solvents. [Stein et al. *JACS* **77** 700 *1955*].

(±)-7-(2,3-Dihydroxypropyl)theophylline (Diprophylline, Dyphylline) *[479-18-5]* **M 254.3, m 155-158°, 158°, 160-164°, 161°, 161-164°.** Recrystd from EtOH or H_2O. Solubility in H_2O is 33% at 25°, in EtOH it is 2% and in $CHCl_3$ it is 1%. λ_{max} (H_2O) 273nm (ε 8,855). [Roth *Arch Pharm* **292** 234 *1959*]. The *4-nitrobenzoyl* derivative has **m** 178° [Oshay *JCS* 3975 *1956*].

3,5-Diiodo-L-thyroxine (3,5-diiodo-4-[4-hydroxyphenoxy]-1-phenylalanine) *[1041-01-6]* **M 525.1, m 255°(dec), 255-257°(dec), $[\alpha]_D^{22}$ +26° [2N HCl-EtOH (1:2)].** Recrystd from EtOH. [Chambers et al. *JCS* 3424 *1949*].

3,5-Diiodo-L-tyrosine dihydrate *[300-39-0]* **M 469.0, m 199-210°, 202°(dec), $[\alpha]_D^{20}$ +2.89° (c 4.9, 4% HCl).** It forms crystals from H_2O [solubility (g/L): 0.204 at 0°, 0.62 at 25°, 1.86 at 50°, 5.6 at 75° and 17.0 at 100°]. Also recrystallises from 50% EtOH. When boiled in EtOH the crystals swell and on further boiling a gelatinous ppte is formed. It has pKa values of 2.12, 6.48 and 7.82. [Harrington *BJ* **22** 1434 *1928* ; Jurd *JACS* **77** 5747 *1955*].

1,2-Dilauroyl-sn-glycero-3-phosphoethanolamine (±-dilauroyl-α-kephalin, 3-sn-phosphatidylethanolamine 1,2-didodecanoyl) *[559752-57-7]* **M 579.8, m 210°.** Recrystd from EtOH or tetrahydrofuran. [Bevan and Malkin *JCS* 2667 *1951*; IR: Bellamy and Beecher *JCS* 728 *1953*].

1,2-Dimyristoyl-sn-glycero-3-phosphocholine monohydrate (dimyristoyl-L-α-lecithin) *[18194-24-6]* **M 696.0, $[\alpha]_D^{24}$ +7° (c 8, EtOH-$CHCl_3$ 1:1 for α_1 form).** Three forms α_1, α_2 and β'. Recrystd from aqueous EtOH or EtOH-Et_2O. Solubility at 22-23° in Et_2O is 0.03%, in Me_2CO it is 0.06% and in pyridine it is 1.3%. [Baer and Kates *JACS* **72** 942 *1950*; Baer and Maurakas *JACS* **74** 158 *1952*; IR: Marinetti and Stotz *JACS* **76** 1347 *1954*]. The *S-isomer* with 1 H_2O is recrystd from 2,6-dimethylheptan-4-one and has **m** 226-227° (sintering at 90-95°), and $[\alpha]_D$ -7° (c 6, MeOH-$CHCl_3$ 1:1). [Baer and Martin *JBC* **193** 835 *1951*].

(±)-1,2-Dimyristoyl-sn-glycero-3-phosphoethanolamine (dimyristoyl-α--kephalin) *[998-07-2]* **M 635-9, m 207°.** Recrystd from EtOH [Bevan and Malkin *JCS* 2667 *1951*]. The *R-isomer* has **m** 195-196° (sintering at 130-135°) after recrystn from $CHCl_3$-MeOH, $[\alpha]_D^{26}$ +6.7° (c 8.5, $CHCl_3$-AcOH 9:1). [Baer *Canad J Biochem Physiol* **35** 239 *1957*; Baer et al. *JACS* **74** 152 *1952*].

***S*-1,2-Dipalmitin** *[761-35-3]* **M 568-9, m 68-69° $[\alpha]_D^{20}$-2.9° (c 8, $CHCl_3$), $[\alpha]_{546}^{20}$ +1.0° (c 10, $CHCl_3$/MeOH, 9:1).** Crystd from chloroform/pet ether.

***R*-Dipalmitoyl-sn-glycero-3-phosphatidic acid** *[7091-44-3]* **M 648-9, $[\alpha]_D^{26}$ +4° (c 10, $CHCl_3$).** Recrystd from Me_2CO at low temp. At 21° it is soluble in C_6H_6 (4.2%), pet ether (0.01%), MeOH (2%), EtOH (2.5%), AcOH (1.3%), Me_2CO (1.76%), and Et_2O (1.5%). [Baer *JBC* **189** 235 *1951*].

***R*-1,2-Dipalmitoyl-sn-glycero-3-phosphocholine monohydrate (dipalmitoyl-α-L-lecithin)** *[63-89-8]* **M 752.1, sinters at 120°, $[\alpha]_D^{25}$ +7.0° (c 5.6, abs $CHCl_3$).** It has three crystn forms α_1, α_2 and β' which change at 60-70° and at 229° respectively. In order to obtain a fine powder, ~2 g are dissolved in $CHCl_3$ (15ml) and pet ether (b 35-60°) is added and the soln evaporated to dryness *in vacuo* <20°, and then dried at 0.1mm over $CaCl_2$. [Baer and Maurukas *JACS* **74** 158 *1952*; Baer and Kates *JBC* **185** 615 *1950*].

***d,l*-βγ-Dipalmitoylphosphatidyl choline** *[2797-68-4]* **M 734.1, m 230-233°.** Recrystd from chloroform and dried for 48h at 10^{-5} torr [O'Leary and Levine *JPC* **88** 1790 *1984*].

Dipeptidyl aminopeptidase (from rat brain). Purified about 2000-fold by column chromatography on CM-cellulose, hydroxylapatite and Gly-Pro AH-Sepharose. [Imai et al. *J Biochem (Tokyo)* **93** 431 *1983*].

1,2-Distearoyl-sn-glycerol *[1429-59-0]* **M 625.0.** The dl-form recrystallises from $CHCl_3$-pet ether (b 40-60°), **m** 59.5° (α form) and 71.5-72.5° (β form). Recrystn from solvents (e.g. EtOH, MeOH, toluene, Et_2O) gives the higher melting form and resolidification gives the lower melting forms. [IR: Chapman *JCS* 4680 *1958*, 2522 *1956*;]. The *S-isomer* is recrystd from $CHCl_3$-pet ether and has **m** 76-77°, $[\alpha]_D^{24}$ -2.8° (c 6, $CHCl_3$). [Baer and Kates *JACS* **72** 942 *1950*].

1,2-Distearoyl-sn-glycero-3-phosphoethanolamine (distearoyl-α-kephalin) *[1069-79-0]* **M 748.1, m 180-182° (*R*-form, sintering at 130-135°), m 196° (± form).** The *R*-form is recrystd from $CHCl_3$-MeOH and the ±-form is recrystd from EtOH. [Bevan and Malkin *JCS* 2667 *1951*; Baer *Canad J Biochem Physiol* **81** 1758 *1959*].

Dolichol (from pig liver) *[11029-02-0]*. Cryst 6 times from pet ether/EtOH at -20°C. Ran as entity on a paper chromatogram on paraffin impregnated paper, with acetone as the mobile phase. [Burgos *BJ* **88** 470 *1963*].

Domoic acid *[14277-97-5]* **M 311.3, m 215°, 217°, $[\alpha]_D^{20}$ -108° (c 1,H_2O).** The acid (~300 mg) is purifed on a Dowex 1 column (3.5 x 40 mm,200-400 mesh, acetate form), washed with H_2O until neutral, then eluted with increasing concentrations of AcOH (8L) from 0 to 0.25M. The fraction containing domoic acid (in 50ml) is collected, evaporated to dryness under reduced pressure and recrystd from aqueous EtOH. [Impellizzeri et al. *Phytochemistry* **14** 1549 *1975*; Takemoto and Diago *Arch Pharm* **293** 627 *1960*].

Dopamine-β-hydroxylase (from bovine adrenal medulla) *[9013-38-1]* **M_r ~290,000 [EC. 1.14.17.1].** The Cu-containing glycoprotein enzyme has been isolated by two procedures. The first is an elaborate method requiring extraction, two $(NH_4)_2SO_4$ fractionations, calcium phosphate gel filtration, EtOH fractionation, DEAE-cellulose chromatography followed by two Sephadex-G200 gel filtrations giving enzyme with a specific activity of 65 Units/mg. [Friedman and Kaufman *JBC* **240** 4763 *1965*; Rush et al. *BBRC* **61** 38 *1974*]. The second procedure is much gentler and provides good quality enzyme. Sedimented chromaffin vesicles were lysed in 10 volumes of 5mM K-phosphate buffer pH 6.5 using a loosely fitting Teflon-glass homogeniser. The mixture is centrifuged at 40,000xg/0.5 h and the supernatant is diluted with an equal volume of 100mM phosphate buffer (pH 6.5) containing 0.4M NaCl. This lysate is applied to a concanavelin A-

Sepharose column (4 x 0.7cm) which had been equilibrated with 50 mM of phosphate buffer (pH 6.5 + 0.2M NaCl) with a flow rate of ~ 0.3 ml/min. The column is washed thoroughly with the buffer until OD_{280nm} is 0.005. The enzyme is then eluted with the same buffer containing 10% α-methyl-D-mannoside (flow rate 0.1 ml/min) and the enzyme is collected in twenty column volumes. The pooled eluate is concentrated by ultrafiltration in an Amicon Diaflo stirrer cell using an XM100A membrane. The concentrated enzyme is dialysed against 50 mM phosphate buffer (pH 6.5) containing 0.1% NaCl. The enzyme gives one band (+ two very weak band) on disc gel electrophoresis indicating better than 93% purity (67% fold purification) and has a specific activity of 5.4Units/mg. [Rush et al. *BBRC* **57** 1301 *1974*; Stewart and Klinman *Ann Reviews of Biochemistry* **57** 551 *1988*].

Ellipticine **(5,11-dimethylpyrido[4,3:*b*]carbazole)** *[519-23-3]* **M 246.3, m 311-315°(dec), 312-314°(dec).** This DNA intercalator is purified by recrystn from $CHCl_3$ or MeOH and dried *in vacuo*. The UV λ_{max} values in aqueous EtOH-HCl are at 241, 249, 307, 335 and 426nm. It has a pKa value of 5.78 in 80% aqueous methoxyethanol [Marini-Bettolo and Schmutz *HCA* **42** 2146 *1959*]. The *methiodide* has **m** 360°(dec), with UV λ_{max} (EtOH-KOH) 223, 242, 251, 311, 362 and 432nm. [Goodwin et al. *JACS* **81** 1903 *1959*].

(-)-Ephedrine (1*R*,2*S*-2-methylamino-1-phenylpropanol) *[299-42-3]* **M 165.2, m ~34°, 36°, 38.1°, b 126-129°/7mm, 225-227°/760mm, d^{22} 1.0085, $[\alpha]_D^{26}$ -42° (c 4, 3% HCl), $[\alpha]_D^{22.5}$ +15.1° (c 0.8, H_2O), -9.36° (c 3, MeOH).** Purified by vacuum distn and forms waxy crystals or granules, and may pick up 0.5 H_2O. The presence of H_2O raises its **m** to 40°. [Moore and Taber *J Amer Pharm Soc* **24** 211 *1935*]. It gradually decomposes on exposure to light and is best stored in an inert atmosphere in the dark (preferably at -20°). Sol in H_2O is 5%, in EtOH it is 1% and it is soluble in $CHCl_3$, Et_2O and oils. It has pKa values in H_2O of 10.25 (0°) and 8.69 (60°) [Everett and Hyne *JCS* 1136 *1958*]; pKa^{22} in H_2O is 9.58 [Prelog and Häflinger *HCA* **33** 2021 *1950*] and pKa^{25} 8.84 in 80% aqueous methoxyethanol [Simon *HCA* **41** 1835 *1958*]. The *hydrochloride* has **m** 220° (from EtOH-Et_2O) and $[\alpha]_D^{20}$ -38.8° (c 2, EtOH). [IR: Chatten and Levi *Analyt Chem* **31** 1581 *1959*].

(+)-Ephedrine hydrochloride (1*S*-2*R*-2-methylamino-1-phenylpropan-1-ol hydrochloride) *[24221-86-1]* **M 201.7, m 216-219°, $[\alpha]_D^{20}$ +34° (c 11.5, H_2O).** Recrystd from EtOH-Et_2O. The *free base* recrystallises from C_6H_6 with **m** 40-41° (Skita et al. *B* **66** 974 *1933*].

Erythromycin A *[114-07-8]* **M 733.9, m 133-135°(dec), 135-140°, 137-140°, $[\alpha]_D^{20}$ -75° (c 2, EtOH).** It recrystallises from H_2O to form hydrated crystals which melt at *ca* 135-140°, resolidifies and melts again at 190-193°. The **m** after drying at 56°/8mm is that of the **anhydrous** material at 137-140°. Its solubility in H_2O in ~2mg/ml. The *Hydrochloride* has **m** 170°, 173° (from aq EtOH, EtOH-Et_2O). [Flynn et al. *JACS* **76** 3121 *1954*; constitution : Wiley et al. *JACS* **79** 6062 *1957*].

β-Estradiol (1,3,5-estratrien-3,17β-diol) *[50-28-2]* **M 272.4, m 173-179°, 176-178°, $[\alpha]_D^{20}$ +76° to +83° (c 1, dioxane).** Purified by chromatohraphy on SiO_2 (toluene-EtOAc 4:1) and recrystd from $CHCl_3$-hexane or 80% EtOH. It is stable in air and insoluble in H_2O and is ppted by digitonin. UV λ_{max} at 225 and 280 nm. [Oppolzer and Roberts *HCA* **63** 1703 *1980*].

β-Estradiol-6-one (1,3,5-estratriene-3,17β-diol-6-one) *[571-92-6]* **M 359.4, m 278-280°, 281-283°, $[\alpha]_D^{20}$ +4.2° (c 0.7, EtOH).** It forms plates from EtOH. The *3,17-diacetate* has **m** 173-175° after recrystn from aqueous EtOH. [Longwell and Wintersteiner *JBC* **133** 219 *1940*]. The UV has λ_{max} 255 and 326nm in EtOH [Slaunwhite et al. *JBC* **191** 627 *1951*].

Ethoxyquin (1,2-dihydro-6-ethoxy-2,2,4-trimethylquinoline) *[91-53-2]* **M 217.3, b 169°/12-13mm, d_4^{20} 1.000.** Purified by fractional distn *in vacuo* and solidifies to a glass. [Knoevenagel *B* **54** 1723, 1730 *1921*]. The *methiodide* has **m** 179° (from EtOH) and the *1-phenylcarbamoyl* derivative has **m** 146-147° (from EtOH). [Beaver et al. *JACS* **79** 1236 *1957*].

Ethyl-3-(3-dimethylaminopropyl) carbodiiomide hydrochloride (*N*-[3-Dimehylamino-propyl]-*N*-ethylcarbodiimide hydrochloride) *[25952-53-8]* **M 191.7, m 113.5-114.5°, 114-116°.** An excellent H_2O-soluble peptide coupling reagent. It is purified by dissolving (*ca* 1g) in CH_2Cl_2 (10ml) at room temperature and then add dry Et_2O (~110 ml) dropwise and the crystals that separate are collected, washed with dry Et_2O and recrystd from CH_2Cl_2-Et_2O and dried in a vacuum over P_2O_5. It is important to work in a dry atmosphere or work rapidly and then dry the solid as soon as possible. Material is moderately *hygroscopic* but once it becomes wet it reacts slowly with H_2O. Store away from moisture and at -20° to slow down the hydrolysis process. The *free base* has **b** 47-48°/0.27mm, 53-54°/0.6mm, n_D^{25} 1.4582. The *methiodide* is recrytstallised from $CHCl_3$-EtOAc, the crystals are filtered off, washed with dry Et_2O and recrystd from $CHCl_3$-Et_2O, and dried *in vacuo* over P_2O_5, **m** 93-95°, 94-95°. [Sheehan et al. *JACS* **87** 2492 *1965*; Sheehan and Cruickshank *Org Synth* Coll Vol V 555 *1973*].

17-α-Ethynylestradiol *[57-63-6]* **M 296.4, m 141-146°, 145-146°, $[\alpha]_D^{20}$ +4° (c 1, $CHCl_3$).** It forms a hemihydrate on recrystn from MeOH-H_2O. It dehydrated on melting and re-melts on further heating at **m** 182-184°. UV λ_{max} at 281nm (ε 2040) in EtOH. Solubility is 17% in EtOH, 25% in Et_2O, 20% in Me_2CO, 25% in dioxan and 5%in $CHCl_3$. [Petit and Muller *Bull Soc Chim France* 121 *1951*]. The *diacetyl* derivative has **m** 143-144° (from MeOH) and $[\alpha]_D^{20}$ +1° (c 1, $CHCl_3$) [Mills et al. *JACS* **80** 6118 *1958*].

Eucaliptol (1,8-cineol, 1,8-epoxy-*p*-menthane, 1,3,3-trimethyl-2-oxabicyclo[2.2.2]-octane) *[470-82-6]* **M 154.2, m 1.3°, 1.5°, b 39-39.3°/4mm, 176-176.4°/760mm, d_4^{20} 0.9232, n_D^{20} 1.4575.** Purified by fractional distn. Insoluble in H_2O but soluble in organic solvents. [IR: Kome et al. *J Chem Soc Japan* (Pure Chem Sect) **80** 66 *1959*; Chem Abstr 603 *1961*].

Eugenol (4-allyl-2-methoxyphenol) *[97-53-0]* **M 164.2, b 253°/760mm, 255°/760mm, d_4^{20} 1.066, n_D^{20} 1.540.** Fractional distn gives a pale yellow liquid which darkens and thickens on standing in air. Should be stored under N_2 at -20°. [Waterman and Priedster *Rec Trav Chim Pays Bas* **48** 1272 *1929*].

Eugenol methyl ether (4-allyl-1,2-dimethoxybenzene) *[93-15-2]* **M 178.2, m -4°, b 127-129°/11mm, 146°/30mm, 154.7°/760mm, d_4^{20} 1.0354, n_D^{20} 11.53411.** Recrystd from hexane at low temp and redistd (preferably *in vacuo*). [Hillmer and Schorning *ZPC* [A] **167** 407 *1934*; Briner and Fliszár *HCA* **42** 2063 *1959*].

Farnesol

(*trans-trans*-3,7,11-trimethyl-2,6,10-dodecatrien-1-ol) *[106-28-5]* **M 222.4, b 111°/0.35mm, 126-127°/0.5mm, 142-143°/2mm, d_4^{20} 0.8871, n_D^{25} 1.4870.** Main impurity is the *cis-trans* isomer. Purified by gas chromatography using a 4ft x 0.125in 3%OV-1 column at 150°. [Corey et al. *JACS* **92** 6637 *1970*; Popjak et al. *JBC* **237** 56 *1962*]. Also purifed through a 14-in Podbielniak column at 11°/0.35mm. Alternatively it has been purified by gas chromatography using SF96 silicone on Fluoropak columns or Carbowax 20M on Fluoropak or base-washed 30:60 firebrick (to avoid decomp of alcohol, prepared by treating the firebrick with 5N NaOH in MeOH and washed with MeOH to pH 8) at 210° with Helium carrier gas at 60 ml/min flow rate. The *diphenylcarbamoyl* derivative has **m** 61-63° (from MeOH) and has IR band at 3500 cm^{-1}. [Bates et al. *JOC* **28** 1086 *1963*].

Fibrinogen (from human plasma) *[9001-32-5]* **M_r 341,000.** A protein made up of 2Aα,2Bβ and 2γ subunits connected by disulphide bridges. Possible impurity is plasminogen. Purified by glycine pptn [Mosesson and Sherry *Biochemistry* **5** 2829 *1966*] to obtain fractions 1-2, then further purified [Blombäck and Blombäck *Arkiv Kemi* **10** 415 *1956*] and contaminating plasminogen is removed by passage through a lysine-Sepharose column. Such preparations were at least 95% clottable as determined by Mosesson and Sherry's method (above ref.) in which the OD_{280} was measured before and after clotting with 5 Units/ml of thrombin (> 3000U/mg). All fibrinogen preps were treated with calf intestinal alkaline phosphatase to convert any fibrinogen peptide-AP to fibrinogen peptide-A by removing serine-bound phosphate. Solutions are then lyophilised and stored at -20°. [Higgins and Shafer *JBC* **256** 12013 *1981*]. It is sparingly soluble in H_2O. Aqueous solns are viscous with isoelectric point at pH 5.5. Readily denatured by heating above 56° or by

chemical agents, e.g. salicyl aldehyde, naphthoquinone sulphonates, ninhydrin or alloxan. [Edsall et al. *JACS* **69** 2731 *1947*; Purification: Cama et al. *Naturwiss* **48** 574 *1961*; Lorand and Middlebrook *Science 118* 515 *1953*; *cf.* Fuller in *Methods in Enzymology* **163** 474 *1988*].
For plasminogen-deficient fibrinogen from blood plasma, the anticoagulated blood was centrifuged and the plasma was frozen and washed with saline solution. Treated with charcoal and freeze-thawed. Dialysed *versus* Tris/NaCl buffer. [Maxwell and Nikel *Biochemical Preparations* **12** 16 *1968*].

Fibronectin (from human plasma) *[86088-83-7]* **M_r ~220,000.** This glycoprotein contains 5-12% of carbohydrate. It has been purified by glycine fractionation and DEAE-cellulose chromatography. Material is dissolved in 0.25M Tris-phosphate buffer pH 7.0, diluted to 20% and glycine added gradually till 2.1M when the temperature falls to below 15°. The ppte contains mainly fibrinogen. The supernatant is discarded and the ppte is treated with an equal volume of H_2O, cooled (to 0°) and ppted by adding EtOH to 16% (v/v) at -4°. The ppte contains some CI globulin, fibronectin and small quantities of other proteins. To remove these the ppte is dissolved in 0.25M Tris-phosphate buffer (pH 7.0) *ca* 0.5% and purified by DEAE-cellulose chromatography after diluting the buffer to 0.05M buffer. [Morrison et al. *JACS* **70** 3103 *1948*; Mosesson and Umfleet *JBC* **245** 5728 *1970*; Mosesson and Amrani *Blood* **56** 145 *1980*; Akiyama and Yamada *Advances in Enzymology* **59** 51 *1987*].

Flavin adenine dinucleotide (diNa, $2H_2O$ salt, FAD) *[146-14-5]* **M 865.6, $[\alpha]_{546}$ -54° (c 1, H_2O).** Small quantities, purified by paper chromatography using *tert*-butyl alcohols/water, cutting out the main spot and eluting with water. Larger amounts can be ppted from water as the uranyl complex by adding a slight excess of uranyl acetate to a soln at pH 6.0, dropwise and with stirring. The soln is set aside overnight in the cold, and the ppte is centrifuged off, washed with small portions of cold EtOH, then with cold, peroxide-free ethyl ether. It is dried in the dark under vacuum over P_2O_5 at 50-60°. The uranyl complex is suspended in water and, after adding sufficient 0.01M NaOH to adjust the pH to 7, the ppte of uranyl hydroxide is removed by centrifugation [Huennekens and Felton *Methods in Enzymology* **3** 954 *1957*]. It can also be crystd from water. Should be kept in the dark. More recently it was purified by elution from a DEAE-cellulose (Whatman DE 23) column with 0.1M phosphate buffer pH 7, and the purity was checked by TLC. [Holt and Cotton, *JACS* **109** 1841 *1987*].

Flavin mononucleotide (Na, $2H_2O$ salt, FMN) *[130-40-5]* **M 514.4.** Purified by paper chromatography using *tert*-butanol-water, cutting out the main spot and eluting with water. Also purified by adsorption onto an apo-flavodoxin column, followed by elution and freeze drying [Mayhew and Strating *Eur J Biochem* **59** 539 *1976*].

Ferritin (from human placenta). Purified by homogenisation in water and precipitating with ammonium sulphate, repeating the cycle of ultracentrifuging and molecular sieve chromatography through Sephadex 4B column. Isoelectric focusing revealed a broad spectrum of impurities which were separated by ion-exchange chromatography on Sephadex A-25 and stepwise elution. [Konijn et al. *AB* **144** 423 *1985*].

Fluorescamine see **Fluram.**

4-Fluoro-7-nitrobenzofurazan (4-fluoro-7-nitrobenzo-2-oxa-1,3-diazole) *[29270-56-2]* **M 183.1, m 52.5-53.5°, 53-56°, 53.5-54.5°.** Purified by repeated recrystn from pet ether (b 40-60°). On treatment with MeONa in MeOH it gave *4-methoxy-7-nitrobenzo-2-oxa-1,3-diazole* **m** 115-116°. [Nunno et al. *JCS (C)* 1433 *1970*]. It is a very good fluorophore for amino acids [Imai and Watanabe *Analyt Chim Acta* **130** 377 *1981*], as it reacts with primary and secondary amines to form fluorescent adducts with λ_{ex} 470nm and λ_{em} 530nm. It gives a *glycine derivative* with **m** 185-187° [Miyano et al. *Analyt Chim Acta* **170** 81 *1985*].

4-Fluoro-3-nitrophenylazide *[28166-06-5]* **M 182.1, m 53-55°, 54-56°.** Dissolve in Et_2O, dry over $MgSO_4$, filter, evaporate and recryst the residue from pet ether (b 20-40°) to give orange needles. Store in a stoppered container at ~0°. The NMR has δ 7.75 (m 1H) and 7.35 (m 2H) ppm in $CDCl_3$. [Hagedorn et al. *JOC* **43** 2070 *1978*].

2-Fluorophenylalanine *[R-: 97731-02-7; S-: 19883-78-4]* **M 183.2, m 226-232°, 231-234°, $[\alpha]_D^{25}$ ±15° (c 2, H_2O pH 5.5).** Recryst from aqueous EtOH. The *hydrochloride* has **m** 226-231°(dec), 224-228°(dec) and the *N-acetyl* derivative has **m** 147-149° (from aqueous EtOH). [Bennett and Nieman *JACS* **72** 1800 *1950*].

4-Fluorophenylalanine *[R-: 18125-46-7; S-: 1132-68-9]* **M 183.2, m 227-232°, $[\alpha]_D^{25}$ ±24° (c 2, H_2O).** It is recrystd from aqueous EtOH. The R-*N-acetyl* derivative has **m** 142-145°, $[\alpha]_D^{25}$ -38.6° (c 8, EtOH). [Bennett and Nieman *JACS* **72** 1800 *1950*].

5-Fluoro-L-tryptophan monohydrate *[16626-02-1]* **M 240.2, m >250°(dec), $[\alpha]_D^{20}$ +5.5° (c 1, 0.1N HCl).** Recrystd from aqueous EtOH.

5-Fluorouridine (5-fluoro-1-β-D-ribofuranosyl-1*H*-pyrimidine-2,4-dione) *[316-46-1]* **M 262.2, m 180-182°, 182-184°, $[\alpha]_D^{20}$ +18° (c 1, H_2O).** Recrystd from EtOH-Et_2O and dried at 100° in a vacuum. UV: λ_{max} 269nm (pH 7.2, H_2O), 270nm (pH 14, H_2O). [Liang et al. *Molecular Pharmacology* **21** 224 *1982*].

5-Fluorouracil (5-fluoropyrimidinedi-2,4-[1*H*,3*H*]-one) *[51-21-8]* **M 130.1, m 282-283°(dec), 282-286°(dec).** Recrystd from H_2O or MeOH-Et_2O, and sublimed at 190-200°/0.1mm or 210-230°/0.5mm. UV: λ_{max} 265-266nm (ε 7070). [Barton et al. *JOC* **37** 329 *1972*; Duschinsky and Pleven *JACS* **79** 4559 *1957*].

Fluram (Fluorescamine, 4-phenyl-spiro[furan-2(3*H*)-1-phthalan]-3,3'-dione) *[38183-12-9]* **M 278.3, m 153-155°, 154-155°.** A non-fluorescent reagent that reacts with primary amines to form highly fluorescent compounds. Purified by dissolving (~1g) in Et_2O-C_6H_6 (1:1, 180 ml), wash with 1% aq $NaHCO_3$ (50ml), dry (Ma_2SO_4), evaporate in a vacuum. Dissolve the residue in warm CH_2Cl_2 (5ml), dilute with Et_2O (12ml) and refrigerate. Collect the solid and dry in a vacuum. IR ($CHCl_3$): ν 1810, 1745, 1722, 1625 and 1600 cm^{-1}, and NMR ($CDCl_3$): δ 8.71 (s, -OC=). [Weigele et al. *JACS* **94** 5927 *1972*, *JOC* **41** 388 *1976*; *Methods in Enzymology* **47** 236 *1977*].

Folic acid (pteroyl-S-glutamic acid) *[75708-92-8]* **M 441.4, m >250°(dec), $[\alpha]_D^{25}$ +23° (c 0.5, 0.1N NaOH).** If paper chromatography indicates impurities then recrystallise from hot H_2O or from dilute acid [Walker et al. *JACS* **70** 19 *1948*]. Impurities may be removed by repeated extraction with *n*-BuOH of a neutral aqueous solns of folic acid (by suspending in H_2O and adding N NaOH till the solid dissolves then adjusting the pH to ~7.0-7.5) followed by pptn with acid, filtration, and recrystn form hot H_2O. [Blakley *BJ* **65** 331 *1975*; Kalifa, Furrer, Bieri and Viscontini *HCA* **61** 2739 *1978*]. Chromatography on cellulose followed by filtration through charcoal has also been used to obtain pure acid. [Sakami and Knowles *Science* **129** 274 *1959*]. UV: λ_{max} 247 and 296nm (ε 12800 and 18700) in H_2O pH 1.0; 282 and 346nm (ε 27600 anf 7200) in H_2O pH 7.0; 256, 284 and 366nm (ε 24600, 24500 and 8600) in H_2O pH 13 [Rabinowitz in *The Enzymes* (Boyer et al. **2** 185 *1960*].

Follicle Stimulating Hormone (FSH, follitropin) *[9002-68-0]* **M_r ~36,000.** Purified by Sephadex G100 gel filtration followed by carboxymethyl-cellulose with NH_4OAc pH 5.5. The latter separates luteinising hormone from FSH. Solubility in H_2O is 0.5%. It has an isoelectric point of 4.5. A soln of 1mg in saline (100ml) can be kept at 60° for 0.5h. Activity is retained in a soln at pH 7-8 for 0.5h at 75°. The activity of a 50% aq EtOH soln is destroyed at 60° in 15 min. [Bloomfield et al. *Biochim Biophys Acta* **533** 371 *1978*; Hartree *BJ* **100** 754 *1966*; Pierce and Parsons *Ann Review Biochem* **50** 465 *1981*].

6-Furfurylaminopurine (Kinetin) *[525-79-1]* **M 215.2, m 266-267°, 269-271°, 270-272°, 272° (sealed capillary).** Platelets from EtOH and sublimes at 220°, but is best done at lower temperatures in a good vacuum. It has been extracted from neutral aqueous solns with Et_2O. [Miller et al *JACS* **78** 1375 *1956*; Bullock et al. *JACS* **78** 3693 *1956*].

Fusaric acid (5-*n*-butylpyridine-2-carboxylic acid) *[536-69-6]* **M 179.2, m 96-98°, 98°, 98-100°, 101-103°.** Dissolve in $CHCl_3$, dry (Na_2SO_4), filter, evaporate and recrystallise the residue from 50

parts of pet ether (b 40-60°) or EtOAc, then sublime *in vacuo*. The *copper salt* forms bluish violet crystals from H_2O and has **m** 258-259°. It has pKa values of 5.70 and 6.16 in 80% aqueous 2-methoxyethanol. [Hardegger and Nikles *HCA* **39** 505 *1956*; Schreiber and Adam *B* **93** 1848 *1960*; NMR and MS: Tschesche and Führer *B* **111** 3500 *1978*].

Fuschin (Magenta I, rosaniline HCl) *[632-99-5]* **M 337.9, m >200°(dec).** Purified by dissolving in EtOH, filtering and adding H_2O. Filter or centrifuge and wash the ppte with Et_2O and dry in air. Crystals have a metallic green lustre. UV max in EtOH is at 543nm (ε 93,000). Solubility in H_2O is 0.26%. A carmine red colour is produced in EtOH. [Scalan *JACS* **57** 887 *1937*].

D-Galactal *[21193-75-9]* M 146.2, m 100°, 100-102°, 104°, 103-106°, $[\alpha]_D^{20}$ -21.3° (c 1, MeOH).

Recryst from EtOAc, EtOH or EtOAc + MeOH. [Overend et al. *JCS* 675 *1950*; Wood and Fletcher *JACS* **79** 3234 *1957*; Distler and Jourdian *JBC* **248** 6772 *1973*].

ß-Galatosidase (from bovine testes). Purified 600-fold by ammonium sulphate precipitation, acetone fractionation and affinity chromatography on agarose substituted with terminal thio-ß-galactopyranosyl residues. [Distlern and Jourdian *JBC* **248** 6772 *1973*].

Gangcyclovir [9-{(1,3-dihydroxy-2-propoxy)methyl}guanine; 2-amino-1,9-{(2-hydroxy-1-hydroxymethyl)-ethoxymethyl}-6*H*-purin-6-one; Cytovene; Cymeva(e)n(e)] *[82410-32-0]* **M 255.2, m >290°(dec), >300°(dec), monohydrate m 248-249°(dec).** Recryst from MeOH. Alternatively dissolve ~90g of reagent in 700ml of distilled H_2O, filter and cool (*ca* 94% recovery). UV: λ_{max} in MeOH 254nm (ε 12,880), 270sh nm (ε 9040), solubility in H_2O at 25° is 4.3mg/ml at pH 7.0. **ANTIVIRAL.** [Ogilvie et al. *Canad J Chem* **60** 3005 *1982*; Ashton et al. *BBRC* **108** 1716 *1982*; Martin et al. *J Medicinal Chem* **26** 759 *1983*].

Gitoxigenin (3β,14,16β,21-tetrahydroxy-20(22)norcholenic acid lactone) *[545-26-6]* **M 390.5, m 223-226°, 234°, 239-240° (anhydrous by drying at 60°), $[\alpha]_D^{20}$ +30° (c 1, MeOH).** Recrystn from aqueous EtOH produces plates of the sesquihydrate which dehydrate on drying at 100° *in vacuo*. It has also been recrystd from Me_2CO-MeOH and from EtOAc the crystals contain 1 mol of EtOAc with $[\alpha]_D^{21}$ +24.8° (c 1, dioxane). It has UV has λ_{max} at 310, 485 and 520nm in 96% H_2SO_4. On heating with ethanolic HCl it yields *digitaligenin* with loss of H_2O. [Smith *JCS* 23 *1931*].

Gliotoxin (3*R*-6*t*-hydroxy-3-hydroxymethyl-2-methyl-(5*at*)-2,3,6,10-tetrahydro-5*aH*-3,10*ac*-epidisulphido[1,2-*a*]-indol-1,4-dione) *[67-99-2]* **M 326.4, m 191-218°(dec), 220°(dec), 221°(dec), $[\alpha]_D^{20}$ -254° (c 0.6, $CHCl_3$), $[\alpha]_D^{25}$ -270° (c 1.7, pyridine).** Purified by recrystn from MeOH. Its solubility in $CHCl_3$ is 1%. The *dibenzoyl* derivative has **m** 202° (from $CHCl_3$-MeOH). [Glister and Williams *Nature* 153 651 *1944*; Elvidge and Spring *JCS* suppl 135 *1949*; Johnson et al. *JACS* **65** 2005 *1943*; Bracken and Raistrick *BJ* **41** 569 *1947*].

Glucose oxidase (from *Aspergillus niger*). Purified by dialysis against deionized water at 6° for 48hours, and by molecular exclusion chromatography with Sephadex G-25 at room temperature. [Holt and Cotton *JACS* **109** 1841 *1987*].

Glucose-6-phosphate dehydrogenase *[9001-40-5]* **M_r 128,000 (from Baker's yeast), 63,300 (from rat mammary gland) [EC 1.1.1.49].** The enzyme is useful for measuring pyridine nucleotides in enzyme recycling. The enzyme from Baker's yeast has been purified by $(NH_4)_2SO_4$ fractionation, Me_2CO pptn, a second $(NH_4)_2SO_4$ fractionation, concentration by DEAE-SF chromatography, a third $(NH_4)_2SO_4$ fractionation and recrystn. Crystn is induced by addition of its coenzyme NADP, which in its presence causes rapid separation of crystals at $(NH_4)_2SO_4$ concentration much below than required to ppte the amorphous enzyme. To recryst, the crystals are dissolved in 0.01M NADP (pH 7.3) with $(NH_4)_2SO_4$ at 0.55 saturation and the crystals appear within 10 to 60 min. After standing for 2-3 days (at 4°) the $(NH_4)_2SO_4$ is increased to 0.60

of saturation and more than 80% of the activity in the original crystals is recovered in the fresh crystals. [Noltmann et al. *JBC* **236** 1255 *1961*]. Large amounts can be obtained from rat livers. The livers are extracted with 0.025M phosphate buffer (pH 7.5), and ppted with 3M $(NH_4)_2SO_4$ (70% of activity). The ppte is dissolved in 3volumes of 0.025M phosphate (pH 7.5), dialysed against this buffer + 0.2mM EDTA at 4° for 5h, then diluted to 1% protein and the nucleic acids ppted by addition of 0.4volumes of 1% protamine sulphate. $(NH_4)_2SO_4$ is added to a concentration of 2M (pH adjusted to 7.0 with NH_3), the ppte is discarded and the supernatant is adjusted to 2.8M $(NH_4)_2SO_4$, dialysed, protein adjusted to 1% and treated with $Ca_3(PO_4)_2$ gel. The gel is added in three steps (1.5ml of 0.4% gel/ml per step) and the gel is removed by centrifugation after each addn. The third gel adsorbed 50% of the activity. The gel is eluted with 0.2M phosphate (pH 7.4, 40ml/g of gel; 60% recovery). The extract is ppted in 3volumes with $(NH_4)_2SO_4$ (adjusted to 4M) to give enzyme with an activity of 30μmoles/mg of protein x hour. [Lowry et al. *JBC* **236** 2746 *1961*]. Km values for the yeast enzyme are 20μM for G-6P and 2μM for NADP (Tris pH 8.0, 10^{-2} M $MgCl_2$, 38°) [Noltmann and Kuby *The Enzymes* **VII** 223 *1963*].

L-Glutathione (reduced form, γ-L-glutamyl-l-cysteinyl-glycine) *[70-18-8]* **M 307.3, m 188-190°(dec), 190°(dec), $[\alpha]_D^{20}$ -20.1° (c 1, H_2O).** Recrystd from aqueous EtOH under N_2, and stored dry in a sealed container below 4°. It is soluble in H_2O and has pKa^{25} values in H_2O of 9.46 and 9.70. [Weygand and Geiger *B* **90** 634 *1957*; Martin and Edsall *Bull Soc Chim France* **40** 1763 *1958*].

L-Glutathione (oxidised) *[27025-41-8]* **M 612.6, m 175-195°, 195°, $[\alpha]_D^{20}$ -98° (c 2, H_2O).** Purified by recrystn from 50% aqueous EtOH. Its solubility in H_2O is 5%. It has pKa values of 3.15, 4.03, 8.57 and 9.54. Store at 4°. [Li et al. *JACS* **76** 225 *1954*; Berse et al. *Canad J Chem* **37** 1733 *1959*].

Glutathione S-transferase (from human liver). Purified by affinity chromatography using a column prepared by coupling glutathione to epoxy-saturated Sepharose. After washing contaminating proteins the pure transferase is eluted with buffer containing reduced glutathione. The solution is then concentrated by ultrafiltration, dialysed against phosphate buffer at pH ~7 and stored in the presence of dithiothreitol (2mM) in aliquots at <-20°. [Simons and Vander Jag *AB* **52** 334 *1977*].

Glyceraldehyde-3-phosphate dehydrogenase *[9001-50-7]* **M_r 144,000 [EC. 1.2.1.12].** Purified from rabbit muscle by extraction with 0.03N KOH and ppted with $(NH_4)_2SO_4$ (0.52 of saturation). The clear supernatant was adjusted to pH 7.5 and NH_3 was added dropwise to pH 8.2-8.4. Crystals appear sometimes even without seeding. The crystals are dissolved in H_2O, filtered to remove suspended material and 2 volumes of saturated $(NH_4)_2SO_4$ at pH 8.2-8.4 is added. After 1hour the crystals appear. Recrystallise in the same way. [Cori et al. *JBC* **173** 605 *1948*; Furfine and Velick *JBC* **240** 844 *1965, The Enzymes* **7** 243 *1963*; Lui and Huskey *Biochemistry* **31** 6998 *1992*]. The Km values are: NADH (3.3μM) and 1,3-diphosphoglycerate ($8x10^{-7}$M) in pH 7.4 imidazole buffer at 26°, NAD (13μM), glyceraldehyde-3-P (90μM), P_i ($2.9x10^{-4}$M), and arsenate (69μM) in 8.6 $NaHCO_3$ buffer at 26°. [Orsi and Cleland *Biochemistry* **11** 102 *1972*].

Glycerol kinase (from *Candida mycoderma*, *E coli*, rat or pigeon liver glycerokinase) *[9030-66-4]* **M_r 251,000 [EC 2.7.1.30].** Commercial enzyme has been dialysed against 2mM Hepes, 5mM dithiothreitol and 0.3mM EDTA, followed by several changes of 20mM Hepes and 5mM dithiothreitol prior to storage under N_2 at -20°. [Knight and Cleland *Biochemistry* **28** 5728 *1989*]. The enzyme from pigeon liver was purified by acid-pptn (acetate buffer at pH 5.1), $(NH_4)_2SO_4$ fractionation, heat treatment (60°/ 1 h), calcium phosphate gel filtration, a second $(NH_4)_2SO_4$ fractionation, dialysis, elution of inert proteins and crystn. This was done by repeatedly extracting the ppte from the last step with 0.05M sodium pyrophosphate (pH 7.5) containing 1mM EDTA and 0.2M $(NH_4)_2SO_4$ was added. Careful addition of solid $(NH_4)_2SO_4$ to this soln lead to crystn of the enzyme. Recrystn was repeated. The enzyme is activated by Mg^{++} and Mn^{++} ions and is most stable in solns in the pH 4.5-5.5 range. The stability is greatly increased in the presence of glycerol. It has Km for glycerol of 60μM and for ATP 9μM in glycine buffer pH 9.8 and 25°. [Kennedy *Methods in Enzymology* **5** 476 *1962*].

L-Glycerol-3-phosphate dehydrogenase (GDH, from rabbit muscle) *[9075,65-4]* **M_4 78,000 [EC 1.1.1.8].** Recrystd by adding $(NH_4)_2SO_4$ till 0.45 saturation at pH 5.5 at 4° and the small amount of ppte is removed then satd $(NH_4)_2SO_4$ is added dropwise from time to time over several days in the cold room.

The crystals are collected and recrystd until they have maximum activity. The enzyme is stable in half saturated $(NH_4)_2SO_4$ for several weeks at 4°. The equilibrium [dihydroxyacetone][NADH][H^+]/[G-3-P][NAD] is 1.0 x 10^{-12}M in Tris buffer at 25°. It uses NAD ten times more efficiently than NADP. The Km for G-3-P is 1.1 x 10^{-4}M, for NAD it is 3.8 x 10^{-4}M and for dihydroxyacetone it is 4.6 x 10^{-4}M in phosphate buffer pH 7.0 and at 23.3°. Dihydroxyacetone phosphate and fructose-1,6-diphosphate are inhibitors. [Branowski *JBC* **180** 515 *1949*, *The Enzymes* **7** 85 *1963*; Young and Pace *Arch Biochem Biophys* **75** 125 *1958*; Walsh and Sallach *Biochemistry* **4** 1076 *1965*].

L-α-Glycerol phosphocholine (Cadmium Chloride)$_x$ complex *[64681-08-9]* **M 257.2 + (183.3)$_x$.** Glycerol phosphocholine is purified *via* the $CdCl_2$ complex which is purified by four recrystns from 99% EtOH by standing at 0° for 1h. The white ppte is collected, washed with EtOH, Et_2O and dried in a vacuum. The amorphous Cd complex can be converted to the crystalline form [$C_8H_{20}O_6NP.CdCl_2.3H_2O$] by dissolving 34.4g in H_2O (410ml) and 99% EtOH (1650ml total) added slowly with stirring and allowing the clear soln to stand at 25° for 12hours, then at 5° for 12hours. The crystallised complex is filteredd off, washed with cold 80% EtOH and dried in air. Glycerol phosphocholine can be recovered from the complex by dissolving in H_2O (2% soln), passing through an ion-exchange column (4.9 x 100cm, of 1vol IRC-50 and 2vol of IR-45). The effluent is concentrated to a thick syrup at 45°. It is dried further at 50°/P_2O_5/48h. The vitreous product (~8.25g) is dissolved in 99% EtOH (50ml) and the clear soln is cooled at 5°, whereby crystals appear, and then at -15° for 16h. The crystals are filtered off, washed with 99% EtOH, and Et_2O then dried at 50° in a vacuum over P_2O_5. It can be recrystd from 99.5% EtOH, long prisms) which are *hygroscopic* and must be handled in a H_2O-free atmosphere [Tattrie and McArthur *Biochemical Preparations* **6** 16 *1958*; Baer and Kates *JACS* **70** 1394 *1948* ; *Acta Cryst* **21** 79, 87 *1966*].

Glycine anhydride (2,5-diketopiperazine) *[106-57-0]* **M 114.1, m 311-312°(dec), ~315°(dec).** Recrystd from H_2O (plates) and can be sublimed (slowly) at 260° or at 140-170°/0.5mm. The *dihydrochloride* has **m** 129-130°, the *bis-1-naphthylurethane* has **m** 232°(dec), and the *diperchlorate* has **m** 117° (*hygroscopic*). [MS: Johnstone *JCS* Perkin Trans I 1297 *1975*; NMR: Blaha and Samek *Coll Czech Chem Commun* **32** 3780 *1967*; Sauborn *JPC* **36** 179 *1932*; Corey *JACS* **60** 1599 *1938*].

Glycocyamine (*N*-guanylglycine) *[352-97-6]* **M 117.1, m 280-284°(dec), >300°.** Recrystd from 15 parts of hot H_2O, or by dissolving in slightly more than the calculated amount of 2N HCl and ppting by adding an equivalent of 2N NaOH, filtering washing with cold H_2O and drying first *in vacuo* then at 60° *in vacuo*. It has pKa^{25} in H_2O of 2.86 (for NH_3^+). The *hydrochloride* has **m** 200°(dec) after recrystn from aqueous HCl as plates. The *picrate* forms needles from hot H_2O and has **m** 210°(dec). [Brand and Brand *Org Synth* Coll Vol III 440 *1955*; Failey and Brand *JBC* **102** 768 *1933*; King *JCS* 2375 *1930*].

Glycodeoxycholic acid monohydrate (*N*-[3α-12α-dihydroxy-5β-cholan-24-oyl]glycine) *[360-65-6]* **M 467.6, m 186-177°(dec), 187-188°, $[\alpha]_D^{23}$ +45.9° (c 1, EtOH).** Recrystallises from H_2O or aqueous EtOH with 1 mol of H_2O and dried at 100° *in vacuo*. Solubility in EtOH is 5%. [UV: Lindstedt and Sjövall *Acta Chem Scand* **11** 421 *1957*]. The *Na salt* is recrystd from EtOH/Et_2O, **m** 245-250°, $[\alpha]_D^{23}$ +41.2° (c 1, H_2O) [Wieland *Z physiol Chem* **106** 181 *1919*; Cortese *JACS* **59** 2532 *1937*].

D(+)-Glycogen *[9005-79-2]* **M 25,000-100,000, m 270-280°(dec), $[\alpha]_{546}$ +216° (c 5, H_2O).** A 5% aqueous soln (charcoal) was filtered and an equal volume of EtOH was added. After standing overnight at 3° the ppte was collected by centrifugation and washed with absolute EtOH, then EtOH/ethyl ether (1:1), and ethyl ether. [Sutherland and Wosilait *JBC* **218** 459 *1956*].

Glycogen synthase (from bovine heart) *[9014-56-6]* **[EC 2.4.1.11].** Purified by pptn of the enzyme in the presence of added glycogen by polyethylene glycol, chromatography on DEAE-Sephacel and high speed centrifugation through a sucrose-containing buffer. [Dickey-Dunkirk and Kollilea *AB* **146** 199 *1985*].

Gramicidin A (a pentadecapeptite from *Bacillus brevis*) *[11029-61-1]*. Purified by countercurrent distribution from C_6H_6-$CHCl_3$, MeOH-H_2O (15:15:23:7) with 5000 tubes. Fractions were examined by UV (280nm) of small aliquots. Separation from Gramicidin C and other material occurred after 999 transfers. [Gross and Witkop *Biochemistry* **4** 2495 *1965*; Bauer et al. *Biochemistry* **11** 3266 *1972*]. Purified finally by

recrystn from EtOH-H_2O and dried at 100°/10^{-2} mm over KOH and forms platelets **m** 229-230°. Almost insoluble in H_2O (0.6%) but soluble in lower alcohols, dry Me_2CO, dioxane, acetic acid and pyridine. The commercial material is more difficult to crystallise than the synthetic compound. [Sarges and Witkop *JACS* **86** 1861, **87** 2011,2020 *1965*]. It has characteristic $[\alpha]_D^{20}$ +27.3° (c 1.3, MeOH) and UV λ_{max} 282nm (ε 22,100). The *N-carbamoyldeformyl gramicidine A* pptes from EtOAc-pet ether (b 40-60°).

Gramicidin C (a pentadecapeptite from *Bacillus brevis*) *[9062-61-7].* Same as Gramicidin A since they are isolated together and separated. [Sarges and Witkop *Biochemistry* **4** 2491 *1965*; as well as references above for Gramicidin A].

***N*-Guanyltyramine hydrochloride** *[60-20-8]* **M 215.7 m 218°.** Purified on a phosphocellulose column and eluted with a gradient of aqueous NH_3 (0-10%). The second major peak has the characteristic tryptamine spectrum and is collected, lyphilised to give white crystals of the *dihydrate* which dehydrates at 100°. It has pKa values of 10.2 (phenolic OH) and 12.4 (guanidinoH$^+$), and UV λ_{max} at 274.5nm (ε 1310) in 0.1N NaOH and 274.5nm (ε 1330) at pH 7.0. Excitation λ_{max} is at 280nm and emission λ_{max} is at 330nm. [Mekalanos et al. *JBC* **254** 5849 *1979*].

Haemoglobin A (from normal human blood) *[9008-02-0].*

Purified from blood using CM-32 cellulose column chromatography. [Matsukawa et al. *JACS* **107** 1108 *1985*]. For the purification of the α and β chains see Hill et al. *Biochemical Preparations* **10** 55 *1963.*

Harmaline (7-methoxy-1-methyl-4,9-dihydro-3*H*-β-carboline, 4,9-dihydro-7-methoxy-1-methyl-3*H*-pyrido[3,4-*b*]indole) *[304-21-2]* **M 214.3, m 229-230°, 229-231°, 235-237° (after distn at 120-140°/10^{-3}).** Recrystd from MeOH and sublimed at high vacuum. It has a pKa value of 4.2 in H_2O. UV in MeOH has λ_{max} 218, 260 and 376nm (log ε 4.27, 3.90 and 4.02 respectively); IR (Nujol) ν 1620, 1600, 1570 and 1535cm^{-1} and in $CHCl_3$ ν 1470 and 1629cm^{-1}. [Spenser *Canad J Chem* **37** 1851 *1959*; Marion et al. *JACS* **73** 305 *1951*; UV Prukner and Witkop *A* **554** 127 *1942*]. The *hydrochloride dihydrate* has **m** 234-236°(dec), the *picrate* has **m** 228-229° (sinters at 215°) from aqueous EtOH, and the *N-acetate* forms needles **m** 204-205°.

Hematoporphyrin (3,3'-[7,12-bis-(1-hydroxyethyl)-3,8,13,17-tetramethyl-porphyrin-2,18-diyl]-dipropionic acid) *[14459-29-1]* **M 598.7.** Purified by dissolving in EtOH and adding H_2O or Et_2O to give deep red crystals. UV has λ_{max} at 615.5, 565, 534.4 and 499.5nm in 0.1 N NaOH, and 597, 619, 634,653, 683 and 701nm in 2 N HCl. [Falk *Porphyrins and Metalloporphyrins* Elsevier, NY, p 175 *1964*]. It is used in the affinity chromatographic purification of Heme proteins [Olsen *Methods in Enzymology* 123 324 *1986*]. The *O-methyl-dimethyl ester* has **m** 203-206° (from $CHCl_3$-MeOH) and the *O,O'-dimethyl-dimethyl ester* has **m** 145° (from $CHCl_3$-MeOH). [Paul *Acta Chem Scand* **5** 389 *1951*].

Hematoxylin (±-11*bc*-7,11*b*-dihydroindeno[2,1-*c*]-chromen-3,4-6*ar*-9,10-pentaol) *[517-28-2]* **M 302.3, m 200°(dec), 210-212°(dec).** Recrystd from H_2O (as trihydrate) in white-yellow crystals which become red on exposure to light and then melt at 100-120°. It has also been recrystd from Me_2CO-C_6H_6. Soluble in alkalies, borax and glycerol. Store in the dark below 0°. [Morsingh and Robinson *TET* **26** 182 *1970*; Dann and Hofmann *B* **98** 1498 *1955*].

Heme (ferriproptoporphyrin IX chloride) *[16009-14-5]* **M 652.0.** It is purified by recrystn. Heme (5g) is shaken in pyridine (25ml) till it dissolves, then $CHCl_3$ (40ml) is added, the container is stoppered and shaken for 5min (releasing the stopper occasionally). The soln is filtered under slight suction, and the flask and filter washed with a little $CHCl_3$ (15ml). During this period, AcOH (300ml) is heated to boiling and saturated aqueous NaCl (5ml) and conc HCl (4ml) are added. The $CHCl_3$ filtrate is poured in a steady stream, with stirring, into the hot AcOH mixture and set aside for 12hours. The crystals are filtered off, washed with 50% aqueous AcOH (50ml), H_2O (100ml), EtOH (25ml), Et_2O and dried in air. [Fischer *Org Synth* Coll Vol III 442 *1955*].

Heparin (from pig intestinal mucosa). Most likely contaminants are mucopolysaccharides including heparin sulphate and dermatan sulphate. Purified by pptn with cetylpyridinium chloride from saturated solutions of high ionic strength. [Cifonelli and Roden *Biochemical Preparations* **12** 12 *1968*].

Heparin (sodium salt) *[9041-08-1]* **M** ~ 3000 **(low Mol Wt, Bovine).** Dissolved in 0.1M NaCl (1g/100ml) and ppted by addition of EtOH (150ml).

Histones (from S4A mouse lymphoma). Purification used a macroprocess column, heptafluorobutyric acid as solubilising and ion-pairing agent and an acetonitrile gradient. [McCroskey et al. *AB* **163** 427 *1987*].

Hyaluronidase *[9001-54-1], [37326-33-3]* **[EC 3.2.1.35].** Purified by chromatography on DEAE-cellulose prior to use. [Distler and Jourdain *JBC* **248** 6772 *1973*].

Hydrocortisone (11β,17α,21-trihydroxy-pregn-4-ene-3,20-dione) *[50-23-7]* **M 362.5, m 212-213°, 214-217°, 218-221°, 220-222°, $[\alpha]_D^{22}$ +167° (c 1, EtOH).** Recrystd from EtOH or isoPrOH. It is bitter tasting and has UV λ_{max} at 242 nm ($E_{1cm}^{1\%}$ 445). Its solubility at 25° is: H_2O (0.28%), EtOH (1.5%), MeOH (0.62%), Me_2CO (0.93%), $CHCl_3$ (0.16%), propylene glycol (1.3%) and Et_2O (0.35%). It gives an intense green colour with conc H_2SO_4. [Wendler et al. *JACS* **72** 5793 *1950*].

Hydrocortisone acetate (21-acetoxy-11β,17α-trihydroxy-pregn-4-ene-3,20-dione) *[50-03-3]* **M 404.5, m 218-221.5°, 221-223°, 222-225°, $[\alpha]_D^{25}$ +166° (c 0.4, dioxane), +150.7° (c 0.5, Me_2CO).** Recrystd from Me_2CO-Et_2O or aqueous Me_2CO as somewhat *hygroscopic* monoclinic crystals. UV has λ_{max} 242 nm ($E_{1cm}^{1\%}$ 390) in MeOH. Its solubility at 25° is: H_2O (0.001%), EtOH (0.45%), MeOH (0.04%), Me_2CO (1.1%), $CHCl_3$ (0.5%), Et_2O (0.15%) and is very soluble in Me_2NCHO. [Wendler et al. *JACS* **74** 3630 *1952*; Antonucci et al. *JOC* **18** 7081 *1953*].

(+)-Hydroquinidine anhydrous (9*S*-6'-methoxy-10,11-dihydrocinchonan-9-ol) *[1435-55-8]* **M 326.4, m 168-169°, 169°, 169-170°, 171-172°, $[\alpha]_D^{20}$ +231° (c 2, EtOH), +299° (c 0.82, 0.1N H_2SO_4).** Forms needles from EtOH and plates from Et_2O. Slightly soluble in Et_2O and H_2O but readily soluble in hot EtOH. [Heidelberger and Jacobs *JACS* **41** 826 *1919*; King *JCS* 523 *1946*]. The *hydrochloride* has **m** 273-274°, $[\alpha]_D^{26}$ +184° (c 1.3, MeOH) and is very soluble in MeOH and $CHCl_3$, but less soluble in H_2O, EtOH and less soluble in dry Me_2CO. [Kyker and Lewis *JBC* **157** 707 *1945*; Emde *HCA* **15** 557 *1932*].

Hydroquinine *[522-66-7]* **M 326.4, m 168-171°, 171.5°, $[\alpha]_D^{16}$ +143° (c 1.087, EtOH).** Recrystd from EtOH. [Rabe and Schultz *B* **66** 120 *1933*].

19-Hydroxy-4-androsten-3,17-dione *[510-64-5]* **M 302.4, m 167-169°, 168-170°, 169-170°, 172-173°, $[\alpha]_D^{20}$ +190° (c 1, $CHCl_3$).** Recrystd from Me_2CO-hexane or Et_2O-hexane. It has UV λ_{max} at 242nm in EtOH or MeOH. The *19-acetoxy* derivative has $[\alpha]_D^{26}$ +185° ($CHCl_3$) and λ_{max} 237.5nm in EtOH. [Ehrenstein and Dünnenberger *JOC* **21** 774 *1956*].

3-Hydroxy butyrate dehydrogenase (from *Rhodopseudomonas spheroides*). Purified by two sequential chromatography steps on two triazine dye-Sepharose matrices. [Scavan et al. *BJ* **203** 699 *1982*].

25-Hydroxycholesterol (cholest-5-en-3β,25-diol) *[2140-46-7]* **M 402.7, m 177-179°, 178-180°, 181.5-182.5°, $[\alpha]_D^{25}$ -39° (c 1.05, $CHCl_3$).** Forms colourless needles from MeOH. [Schwartz *TET LETT* **22** 4655 *1981*]. The *3β–acetoxy derivative* has **m** 142-142.8° (from Me_2CO), $[\alpha]_D^{25}$ -40.4° (c 2, $CHCl_3$). The *3β,25-diacetyl derivative* has **m** 119-120.5° (from MeOH), $[\alpha]_D^{25}$ -35.5° ($CHCl_3$). [Dauben and Bradlow *JACS* **72** 4248 *1950*; Ryer et al. *JACS* **72** 4247 *1950*].

18-Hydroxy-11-deoxycorticosterone (18,21-dihydroxypregn-4-en-3,20-dione tautomeric with 18,20-epoxy-20,21-dihydroxypregn-4-en-3-one) *[379-68-0]* **M 346.5, m 168-170°, 171-173°, 191-195°, 200-205°, $[\alpha]_D^{20}$ +151° (c 1,$CHCl_3$).** Recrystn from Et_2O-Me_2CO gave crystals **m** 200-205°, when recrystd from M_2CO it had **m** 191-195°. It has UV λ_{max} at 240nm. The *21-O-acetoxy-18-*

hydroxy derivative has **m** 158-159° (from Et_2O-C_6H_6) and the *21-O-acetoxy-18,20-epoxy derivative* has **m** 149-154° (from Et_2O). [Kahnt et al. *HCA* **38** 1237 *1955*; Pappo *JACS* **81** 1010 *1959*].

***R*-(-)-2-Hydroxy-3,3-dimethyl-γ-butyrolactone (3-hydroxy-4,4-dimethyl-4,5-dihydrofuran-2-one, D-pantolactone)** *[599-04-2]* **M 130.1, m 89-91°, 90.5-91.5°, 91°, 92-93°, b 120-122°/15mm, $[\alpha]_D^{20}$ -28° (c 5, MeOH), $[\alpha]_D^{20}$ -51° (c 3, H_2O).** Recrystallise from Et_2O-pet ether, diisopropyl ether or C_6H_6-pet ether and sublime at 25°/0.0001mm. It racemises when heated from 145° to 240°. The *Brucine salt* has **m** 211-212° (from EtOH). [Kuhn and Wieland *B* **73** 1134 *1940*; and Stiller et al. *JACS* **62** 1779 *1940*; Bental and Tishler *JACS* **68** 1463 *1946*].

(±)-Ibotenic acid monohydrate (α-[3-hdyroxy-5-isoxazolyl]-glycine, α-amino-3-hydroxy-5-isoxazoleacetic acid) *[2552-55-8]*M 176.1, m 144-146° (monohydrate), 151-152° (anhydrous), 148-151°.

It has been converted to the ammonium salt (**m** 121-123° dec) dissolved in H_2O and passed through an Amberlite IR 120 resin (H^+ form) and eluted with H_2O. The acidic fractions were collected, evaporated to dryness and the residue recrystd from H_2O as the monohydrate (**m** 144-146°). The anhydrous acid is obtained by making a slurry with MeOH, decanting and evaporating to dryness and repeating the process twice more to give the anhydrous acid (**m** 151-152°). Recrystn from H_2O gives the monohydrate. [Nakamura *Chem Pharm Bull Japan* **19** 46 *1971*]. The *ethyl ester* forms needles when crystd from a small volume of Et_2O and has **m** 78-79° and IR ($CHCl_3$) with ν 3500–2300 (OH), 1742 (ester CO), 1628, 1528cm^{-1}, and UV with λ_{max} (EtOH) at 206nm (ε 7080). The *hydrazide* has **m** 174-175° (from MeOH) with IR (KBr) 1656 (C=O)cm^{-1}.

2-Iminothiolane hydrochloride (2-iminotetrahydrothiophene) *[4781-83-3]* **M 137.6, m 187-192°, 190-195°, 193-194°, 202-203°.** Recryst from MeOH-Et_2O (**m** 187-192°) but after sublimation at ~180°/0.2mm the melting point rose to 202-203°. It has NMR with δ 2.27 (2H, t), 3.25 (2H, t) and 3.52 (2H, t)ppm in $(CD_3)_2SO$. [King et al. *Biochemistry* **17** 1499 *1978*]. The *free base* is purifed by vacuum distn (**b** 71-72°/6mm) with a pKa <2 and IR (film) with ν 1700 (C=N)cm^{-1} and NMR ($CDCl_3$) with δ at 3.58 (2H, t) and 2.10-2.8 (4H, m). The *free base* is stable on storage but slowly hydrolyses in aqueous solns with half lives at 25° of 390h at pH 9.1, 210h at pH 10 and 18 h at pH 11. [Alagon and King *Biochemistry* **19** 4343 *1980*].

***trans*-Indol-3-ylacrylic acid** *[1204-06-4]* **M 187.2, m 190-195°(dec), 195°(dec), 196°(dec), 195-196°(dec).** Recrystd from AcOH, H_2O or EtOAc-cyclohexane. UV in MeOH has λ_{max} at 225, 274 and 325nm. [Shaw et al. *JOC* **23** 1171 *1958*; constitution: Rappe *Acta Chem Scand* **18** 818 *1964*; Moffatt *JCS* 1442 *1957*; Kimming et al. *Z physiol Chem* **371** 234 *1958*].

3-Indolylbutyric acid *[133-32-4]* **M 203.2, m 120-123°, 123-125°, 124°.** Recrystd from H_2O. It is soluble in EtOH, Et_2O and Me_2CO but insoluble in $CHCl_3$. [Bowman and Islip *Chemistry and Industry London* 154 *1971*; Jackson and Manske *JACS* **52** 5029 *1930*]. It has pKa in H_2O values of 4.84 and 4.80 [Albaum and Kaiser *Amer J, Botany* **24** 420 *1937*]. UV has λ_{max} 278 and 320nm in isoPrOH [Elvidge *Quarterly J Pharm Pharmacology* **13** 219 *1940*]. The *methyl ester* has **m** 73-74° (from C_6H_6-pet ether) and **b** 230°/6mm [Bullock and Hand *JACS* **78** 5854 *1951*].

3-Indolylpyruvic acid *[392-12-1]* **M 203.2, m~210°(dec), 208-210°(dec), 219°(dec).** Recrystd from Me_2CO-C_6H_6, EtOAc-$CHCl_3$, Me_2CO-AcOH (crystals with 1 molecule of AcOH) and dioxane-C_6H_6 (with 0.5 molecule of dioxane) [Shaw et al. *JOC* **23** 1171 *1958*; Kaper and Veldstra *Biochim Biophys Acta* **30** 401 *1958*]. The *ethyl ester* has **m** 133° (from Et_2O) and its *2,4-dinitrophenylhydrazone* has **m** 255° (from Me_2CO). [Baker *JCS* 461 *1946*].

***myo*-Inositol (cylohexane[1*r*,2*c*,3*c*,4*t*,5*c*,6*t*-hexol)** *[87-89-9]* **M 180.2, m 218° (dihydrate), 225-227°, 226-230°.** Recrystd from H_2O forming a dihydrate, or anhydrous crystals from AcOH. The dihydrate is efflorescent and becomes anhydrous when heated at 100°. The anhydrous crystals are not

hygroscopic. Solubility in H_2O at 25° is 14%, at 60° it is 28%, slightly soluble in EtOH but insoluble in Et_2O. [Ballou and Anderson *JACS* **75** 748 *1953*; Anderson and Wallis *JACS* **70** 2931 *1948*].

Interleukin (from human source). Purified using lyophilisation and desalting on a Bio-Rad P-6DC desalting gel, then two steps of HPLC, first with hydroxylapatite, followed by a TSK-125 size exclusion column. [Kock and Luger *J C* **296** 293 *1984*].

Interleukin-2 (recombinant human) *[94218-72-1]* **M_r ~15,000.** Purified by reverse phase HPLC. [Weir and Sparks *BJ* **245** 85 *1987*; Robb et al. *Proc Natl Acad Sci USA* **81** 6486 *1984*].

Iodonitrotetrazolium chloride (2[4-iodophenyl]-3-[4-nitrophenyl]-5-phenyl-2*H*-tetrazolium chloride) *[146-68-9]* **M 505.7, m 229°(dec), ~245°(dec).** Recrystd from H_2O, aqueous EtOH or EtOH-Et_2O. Alternatively dissolve in the minimum volume of EtOH and add Et_2O; or dissolve in hot H_2O (charcoal), filter and ppte by adding conc HCl. Filter solid off and dry at 100°. Solubility in H_2O at 25° is 0.5%, and in hot MeOH-H_2O (1:1) it is 5%. [Fox and Atkinson *JACS* **72** 3629 *1950*].

Iodonitrotetrazolium violet-Formazan *[7781-49-9]* **M 471.3, m 185-186°.** Dissolve in boiling dioxane (20g in 300ml), add H_2O (100ml) slowly, cool, filter and dry *in vacuo* at 100°. Its solubility in $CHCl_3$ is ~1%. [UV: Fox and Atkinson *JACS* **72** 3629 *1950*].

5-Iodouridine (5-iodo-1-[β-D-ribofuranosyl]-pyrimidine-2,4(1*H*)-dione) *[1024-99-3]* **M 370.1, m 205-208°(dec), 210-215°(dec), $[\alpha]_D^{20}$ -23.5° (c 1, H_2O).** Recrystd from H_2O and dried *in vacuo* at 100°. UV has λ_{max} 289nm (0.01N HCl) and 278nm (0.01N NaOH). [Prusoff et al. *Cancer Research* **13** 221 *1953*].

3-Isobutyl-1-methylxanthine (3-isobutylpurine-2,6(1*H*,3*H*)-dione) *[28822-58-4]* **M 22.3, m 199-210°, 202-203°.** Recrystd from aqueous EtOH.

Isopentenyl pyrophosphate *[358-71-4]* **M 366.2.** Purified by chromatography on Whatman No 1 paper using *tert*-butyl alcohol/formic acid/water (20:5:8, R_F 0.60) or 1-propanol/ammonia/water (6:3:1. R_F 0.48). Also purified by chromatography on a DEAE-cellulose column or a Dowex-1 (formate form) ion-exchanger using formic acid and ammonium formate as eluents. A further purification step is to convert it to the monocyclohexylammonium salt by passage through a column of Dowex-50 (cyclohexylammonium form) ion-exchange resin. Can also be converted into its lithium salt.

DL-Isoserine (±-3-amino-2-hydroxypropionic acid) *[632-12-2]* **M 105.1, m 250-252°(dec), 235°(dec), 237°(dec), 245°(dec).** Recrystd from H_2O or 50% aqueous EtOH. It has pKa^{25} values in H_2O of 2.78 (acid) and 9.27 (base) and an isoelectric pH of 6.02. [Rinderknocht and Niemann *JACS* **75** 6322 *1953*; Gundermann and Holtmann *B* **91** 160 *1958*; Emerson et al. *JBC* **92** 451 *1931*]. The *hydrobromide* has **m** 128-130° (from aqueous HBr) [Schöberl and Braun *A* **542** 288 *1939*].

Kanamycin B

(4-*O*-[2,6-diamino-2,6-dideoxy-α-D-glucopyranosyl]-6-*O*-[3-amino-3-deoxy-α-D-glucopyranosyl]-2-deoxystreptamine) *[4696-79-8]* **M 483.5, m 170-179°(dec), 178-182°(dec), $[\alpha]_D^{18}$ +130° (c 0.5, H_2O).** A small quantity (24mg) can be purified on a small Dowex 1 x 2 column (6 x 50mm), the correct fraction is evapd to dryness and the residue crystd from EtOH containing a small amount of H_2O. [Umezawa et al. *Bull Chem Soc Japan* **42** 537 *1969*]. It has been crystd from H_2O by dissolving ~1g in H_2O (3ml), adding Me_2NCHO (3ml) setting aside at 4° overnight, The needles are collected and dried to constant weight at 130°. It has also been recrystd from aq EtOH. It is slightly sol in $CHCl_3$ and isoPrOH. [IR: Wakazawa et al. *J Antibiotics* **14A** 180, 187 *1961*; Ito et al. *J Antibiotics* **17 A** 189 *1964*].

Lactate dehydrogenase (from dogfish, Beef muscle) *[9001-60-9]* **M_r 140,000 [EC 1.1.1.27].** 40-Fold purification by affinity chromatography using Sepharose 4B coupled to 8-(6-aminohexyl)amino-5'-AMP or -NAD^+. [Lees et al. *Arch Biochem Biophys* **163** 561 *1974*; Pesce et al. *JBC* **239** 1753 *1964*].

Lactoferrin (from human whey). Purified by direct adsorption on cellulose phosphate by batch extraction, then eluted by a stepped salt and pH gradient. [Foley and Bates *AB* **162** 296 *1987*].

Lecithin. For purification of commercial egg lecithin see Pangborn [*JBC* **188** 471 *1951*].

Lecithin. From hen egg white. Purified by solvent extraction and chromatography on alumina. Suspended in distilled water and kept frozen until used [Lee and Hunt *JACS* **106** 7411 *1984*, Singleton et al. *J Amer Oil Chemists Soc* **42** 53 *1965*].

Lectins (from seeds of *Robinia pseudoacacia*). Purified by pptn with ammonium sulphate and dialysis; then chromatographed on DE-52 DEAE-cellulose anion-exchanger, hydroxylapatite and Sephacryl S-200. [Wantyghem et al. *BJ* **237** 483 *1986*].

Leucopterin (2-amino-5,8-dihydropteridine-4,6,7(1*H*)-trione) *[492-11-5]* **M 195.1, m >300°(dec).** Purified by dissolving in aqueous NaOH, stirring with charcoal, filtering and precipitating by adding aqueous HCl, then drying at 100° in a vacuum. It separates with 0.5 moles of H_2O. Its solubility in H_2O is 1g/750 litres [Albert et al. *JCS* 4219 *1952*]. It has pKa^{25} values in H_2O of 7.4, 9.5 and 13.0. [Albert and Wood *J Applied Chem (London)* **2** 591 *1952*; Pfleiderer *B* **90** 2631 *1957*].

DL-α-Lipoamide (±-6,8-thioctic acid amide, 5-[1,2]-dithiolan-3-ylvaleric acid amide) *[3206-73-3]* **M 205.3, m 124-126°, 126-129°, 130-131°.** Recrystd from EtOH and has UV with λ_{max} 331nm in MeOH. [Reed et al. *JBC* **232** 143 *1958*; IR: Wagner et al. *JACS* **78** 5079 *1956*].

DL-α-Lipoic acid (±-6,8-thioctic acid, 5-[1,2]-dithiolan-3-ylvaleric acid) *[1077-28-7]* **M 206.3, m 59-61°, 60.5-61.5° and 62-63°, b 90°/10^{-4}mm, 150°/0.1mm.** It forms yellow needles from cyclohexane or hexane and has been distd at high vacuum, and sublimes at ~90° and very high vacuum. Insoluble in H_2O but dissolves in alkaline soln. [Lewis and Raphael *JCS* 4263 *1962*; Soper et al. *JACS* **76** 4109; Reed and Niu *JACS* **77** 416 *1955*; Tsuji et al. *JOC* **43** 3606 *1978*; Calvin *Fed Proc USA* **13** 703 *1954*]. The *S-benzylthiouronium salt* has m 153-154° (evacuated capillary; from MeOH), 132-134°, 135-137° (from EtOH). The *d-* and *l-* forms have **m** 45-47.5° and $[\alpha]_D^{23}$ ±113° (c 1.88, C_6H_6) and have UV in MeOH with λ_{max} at 330nm (ε 140).

Lipoprotein lipase (from bovine skimmed milk). Purified by affinity chromatography on heparin-Sepharose [Shirai et al. *Biochim Biophys Acta* **665** 504 *1981*].

Lipoproteins (from human plasma). Individual human plasma lipid peaks were removed from plasma by ultracentrifugation, then separated and purified by agarose-column chromatography. Fractions were characterised immunologically, chemically, electrophoretically and by electron microscopy. [Rudel et al. *BJ* **13** 89 *1974*].

Lipoteichoic acids (from gram-positive bacteria). Extracted by hot phenol/water from disrupted cells. Nucleic acids that were also extracted were removed by treatment with nucleases. Nucleic resistant acids, proteins, polysaccharides and teichoic acids were separated from lipoteichoic acids by anion-exchange chromatography on DEAE-Sephacel or by hydrophobic interaction on octyl-Sepharose [Fischer et al. *Eur J Biochem* **133** 523 *1983*].

D-Luciferin (firefly luciferin, *S*-2[6-hydroxybenzothiazol-2-yl]-4,5-dihydrothiazol-4-carboxylic acid), *[2591-17-5]* **M 28-.3, m 189.5-190°(dec), 196°(dec), 201-204°, 205-210°(dec, browning at 170°), $[\alpha]_D^{22}$ -36° (c 1.2, Me_2NHCO).** Recrystallises as pale yellow needles from H_2O, or MeOH (83mg from 7ml). It has UV λ_{max} at 263 and 327nm (log ε 3.88 and 4.27) in 95%

EtOH. The Na salt has a solubility of 4mg in 1 ml of 0.05M glycine. [White et al. *JACS* **83** 2402 11961, **85** 337 *1963*; UV and IR: Bitler and McElroy *Arch Biochem* **72** 358 *1957*; Review: Cormier et al. *Fortschr Chem Org Naturstöffe* **30** 1 *1973*].

Lumiflavin (7,8,10-trimethylbenzo[*g*]pteridine-2,4(3*H*,10*H*)-dione) *[1088-56-8]* **M 256.3, m 330°(dec), 340°(dec).** Forms orange crystals upon recrytn from 12% aqueous AcOH, or from formic acid. It sublimes at high vacuum. It is freely soluble in $CHCl_3$, but not very soluble in H_2O and most organic solvents. In H_2O and $CHCl_3$ soln it has a green fluorescence. UV has λ_{max} at 269, 355 and 445nm (ε 38,800, 11,700 and 11,800 respectively) in 0.1N NaOH and 264, 373 and 440nm (ε 34,700, 11,400 and 10,400 respectively) in 0.1N HCl while UV in $CHCl_3$ has λ_{max} at 270, 312, 341, 360, 420, 445 and 470nm. [Hemmerich et al. *HCA* **39** 1242 *1956*; Holiday and Stern *B* **67** 1352 *1834*; Yoneda et al. *Chem Pharm Bull Japan* **20** 1832 *1972*; Birch and Moye *JCS* 2622 *1958*]. The pKa in H_2O is 10.2. [Fluorescence: Kuhn and Moruzzi *B* **67** 888 *1934*].

Magnesium protoporphyrin dimethyl ester. Crude product dissolved in as little hot dry C_6H_6 as possible and left overnight at room temperature to cryst. [Fuhrhop and Graniek *Biochemical Preparations* **13** 55 *1971*].

Maleimide (pyrrol-2,5-dione) *[541-59-3]* **M 97.1, m 91-93°, 92.6-93°, $d_D^{105.5}$ 1.2493, $n_D^{110.7}$ 1.49256.** Purified by sublimation in a vacuum. The UV has λ_{max} at 216 and 280nm in EtOH. [de Wolf and van de Straete *Bull Soc Chim Belges* **44** 288 *1935*; UV: Rondestvedt et al. *JACS* **78** 6115 *1956*; IR: Chiorboli and Mirone *Ann Chimica* **42** 681 *1952*].

α-Melanotropin, ß-Melanotropin. Extract separated by ion-exchange on carboxyymethyl cellulose, desalted, evapd and lyophilised, then chromatographed on Sephadex G-25. [Lande et al. *Biochemical Preparations* **13** 45 *1971*].

6-Mercaptopurine monohydrate *[6112-76-1]* **M 170.2, m 314-315°(dec), ~315°(dec), 313-315°(dec).** Recrystallises from H_2O as yellow crystals of the monohydrate which become anhydrous on drying at 140°. It has pKa^{20} values of 7.77 and 10.84 in H_2O, and UV λ_{max} at 230 and 312nm (ε 14,000 and 19,600) in 0.1N NaOH; 222 and 327nm (ε 9,2400 and 21,300), and 216 and 329nm (ε 8,740 and 19,300) in MeOH. [Albert and Brown *JCS* 2060 *1954*; IR: Brown and Mason *JCS* 682 *1957*; UV: Fox et al. *JACS* **80** 1669 *1958*; UV: Mason *JCS* 2071 *1954*].

6-Mercaptopurine-9-β-D-ribofuranoside *[574-25-4]* **M 284.3, m 208-210°(dec), 210-211°(dec), 220-223°(dec), 222-224°(dec), $[\alpha]_D^{25}$ -73° (c 1, 0.1N NaOH).** Recrystd from H_2O or EtOH. It has a pKa value of 7.56 in H_2O and UV λ_{max} in H_2O at 322nm (pH 1), 320 nm (pH 6.7) and 310nm (pH 13). [IR: Johnson et al. *JACS* **80** 699 *1958*; UV: Fox et al. *JACS* **80** 1669 *1958*].

Metallothionein (from rabbit liver) *[73767-16-5]*. Purified by precipitation to give Zn- and Cd-containing protein fractions and running on a Sephadex G-75 column, then isoelectric focussing to give two protein peaks [Nordberg et al. *BJ* **126** 491 *1972*].

Methoxantin coenzyme (PQQ, pyrrolo quinoline quinone, 2,7,9-tricarboxy-1*H*-pyrrolo-[2,3-*f*]-quinoline-4,5-dione, 4,5-dihydro-4,5-dioxo-1*H*-pyrrolo[2,3-*f*]quinoline-2,7,9-tricarboxylic acid) *[72909-34-3]* **M 330.2, m 220°(dec).** Efflorescent yellow-orange needles on recrystn from H_2O by addition of Me_2CO, or better from a supersaturated aqueous soln, as it forms an acetone adduct. [Forrest et al. *Nature* **280** 843 *1979*]. It has also been purified by passage through a C-18 reverse phase silica cartridge or a silanized silica gel column in aqueous soln whereby methoxantin remains behind as a red-orange band at the origin. This band is collected and washed thoroughly with dilute aqueous HCl (pH 2) and is then eluted with MeOH-H_2O (7:3) and evapd *in vacuo* to give the coenzyme as a red solid. It has also been purified by dissolving in aqueous 0.5M K_2CO_3 and acidified to pH 2.5 whereby PQQ pptes as a deep red solid which is

collected and dried *in vacuo*. Methoxantin elutes at 3.55 retention volumes from a C18 μBondapak column using H_2O-MeOH (95:5) + 0.1% AcOH pH 4.5. It has UV λ_{max} at 247 and 330nm (shoulder at 270nm) in H_2O and λ_{max} at 250 and 340nm in H_2O at pH 2.5. With excitation at λ_{ex} 365nm it has a λ_{max} emission at 483nm. The ^{13}C NMR has δ: 113.86, 122.76, 125.97, 127.71, 130.68, 137.60, 144.63, 146.41, 147.62, 161.25, 165.48, 166.45, 173.30 and 180.00ppm.
When a soln in 10% aqueous MeCO is adjudted to pH 9 with aqueous NH_3 and kept at 25° for 30 min, the *acetone adduct* is formed; UV has λ_{max} at 250, 317 and 360nm (H_2O, pH 5.5) and with λ_{ex} at 360nm it has max fluorescence at λ_{max} at 465nm; and the ^{13}C NMR [$(CD_3)_2SO$, TMS) has δ: 29.77, 51.06,74.82, 111.96, 120.75, 121.13, 125.59, 126.88, 135.21, 139.19, 144.92, 161.01, 161.47, 165.17, 168.61, 190.16 and 207.03ppm. It also forms a *methanol adduct.*
When it is reacted with Me_2SO_4-K_2CO_3 in dry Me_2NCHO at 80° for 4h, it forms the *trimethyl ester* which has **m** 265-267°(dec) [260-263°(dec)] after recrystn from hot MeCN (orange crystals) with UV λ_{max} at 252 and 344nm (H_2O) and 251, 321 and 373nm (in MeOH; MeOH adduct ?). [Duine et al. *Eur J Biochem* **108** 187 *1980*; Duine et al. *Adv Enzymology* **59** 169 *1987*; Corey and Tramontano *JACS* **103** 5599 *1981*; Gainor and Weinreb *JOC* **46** 4319 *1981*; Hendrickson and de Vries *JOC* **17** 1148 *1982*; McKenzie, Moody and Reese *JCS Chem Commun* 1372 *1983*].

5-Methylphenazinium methyl sulphate *[299-11-6]* **M 306.3, m 155-157° (198°dec by rapid heating).** It forms yellow prisms from EtOH. Solubility in H_2O at 20° is 10%. In the presence of aqueous KI it forms a *semiquinone* which crystallises as blue leaflets from EtOH. [Wieland and Roseen *B* **48** 1117 *1913*; Voriskova *Coll Czech Chem Commun 12* 607 *1947*; Bülow *B* **57** 1431 *1924*].

1-Methyl-4-phenyl-1,2,3,6-tetrahydropyridine hydrochloride *230007-85-4]* **M 209.7, m 196-198°.** Purified by recrystn from Me_2CO + isoPrOH. The *free base* has **b** 137-142°/0.8 mm, n_D^{25} 1,5347. [Schmidle and Mansfield *JACS* **78** 425 *1956*; Defeudis *Drug Dev Research* **15** 1 *1988*].

6-α-Methylprednisolone (Medrol, 11β,17-21-trihydroxy-6α-methylpregna-1,4-dien-3,20-dione) *[83-43-2]* **M 347.5, m 226-237°, 228-237°, 240-242°, $[\alpha]_D^{24}$ +91° (c 0.5, dioxane).** Recrystd from EtOAc. UV has λ_{max} in 95% EtOH 243nm (ε 14,875). The *21-acetoxy derivative* has **m** 205-208° (from EtOAc), $[\alpha]_D^{24}$ +95° (c 1, $CHCl_3$). [Spero et al. *JACS* **78** 6213 *1956*; Fried et al. *JACS* **81** 1235 *1959*; ^1H NMR: Slomp and McGarvey *JACS* **81** 2200 *1959*].

5-Methyltetrahydrofolic acid disodium salt *[68792-52-9]* **M 503.4.** Check purity by measuring UV at pH 7.0 (use phosphate buffer) and it should have λ_{max} 290nm and λ_{min} 245nm with a ratio of A_{290}/A_{250} of 3.7. This ratio goes down to 1.3 as oxidation to the dihydro derivative occurs. The latter can be reduced back to the tetrahydro compound by reaction with 2-mercaptoethanol at room temp. If oxidation had occurred then the compound should be chromatographed on DEAE-cellulose (~0.9 milliequiv/g, in AcO^- form) in $(NH_4)_2CO_3$ (1.5 M) and washed with 1M NH_4OAc containing 0.01M mercaptoethanol till free from UV absorption and then washed with 0.01M mercaptoethanol. All is done in a nitrogen atmosphere. The reduced folate is then eluted with a gradient between 0.01M mercaptoethanol and 1M NH_4OAc containing 0.01M mercaptoethanol and the fractions with absorption at 290nm are collected. These are evapd under reduced pressure at 25° and traces of NH_4OAc and H_2O are removed at high vacuum/25° (~24-48h). The residue is dissolved in the minimum volume of 0.01M mercaptoethanol and an equivalent of NaOH is added to convert the acid to the diNa salt and evaporated to dryness at high vacuum/25°. The product should have λ_{max} 290nm (ε 32,000) in pH 7.0 buffer. [Sakami *Biochemical Preparations* **10** 103 *1963*].

5-Methyltryptamine hydrochloride (3-[2-aminoethyl]-5-methylindole hydrochloride) *[1010-95-3]* **M 210.7, m 289-291°(dec), 290-292°.** Recrystd from H_2O. The *free base* has **m** 93-95° (from C_6H_6-cyclohexane), and the *picrate* has **m** 243°(dec) (from EtOH). [Young *JCS* 3493 *1958*; Gaddum et al. *Quart J Exp Physiol* **40** 49 *1955*; Röhm *Z physiol Chem* **297** 229 *1954*].

4-Methylumbelliferone(β) hydrate (7-hydroxy-4-methylcoumarin) *[90-33-5]* **M 194.2, m 185-186°, 185-188°, 194-195°.** Purified by recrystn from EtOH. It is insoluble in cold H_2O, slightly soluble in Et_2O and $CHCl_3$, but soluble in MeOH and AcOH. It has blue fluorescence in aqueous EtOH, and

has UV λ_{max} 221, 251 and 322.5nm in MeOH. IR has ν 3077 br, 1667, 1592, 1385, 1267, 1156, 1130 and 1066 cm^{-1}. The *acetate* has **m** 153-154°. [Woods and Sapp *JOC* **27** 3703 *1962*].

4-Methylumbellifer-7-yl-α-D-glucopyranoside *[17833-43-1]* **M 338.3, m 221-222°, $[\alpha]_D^{20}$ 237° (c 3, H_2O).** Recrystd from hot H_2O.

4-Methylumbellifer-7-yl-β-D-glucopyranoside *[18997-57-4]* **M 338.3, m 210-212°, 211°, $[\alpha]_D^{20}$ -61.5° (c 2, pyridine), -89.5° (c 0.5, H_2O for half hydrate).** Recrystallises as the half hydrate from hot H_2O. [Constantzas and Kocourek *Coll Czech Chem Commun* **24** 1099 *1959*; De Re et al. *Ann Chimica* **49** 2089 *1959*].

1-Methyluric acid *[708-79-2]* **M 182.1, m >350°.** Recrystd from H_2O. It has pKa values of 5.75 and 10.6 [Bergmann and Dikstein *JACS* **77** 691 *1955*]. It has UV λ_{max} at 231 and 283. nm (pH 3) and 217.5 and 292.5nm (pH >12) [Johnson *BJ* **5** 133 *1952*].

Mevalonic acid lactone *[674-26-0]* **M 130.2, m 28°, b 145-150°/5mm.** Purified *via* the *dibenzylethylenediammonium salt* (**m** 124-125°) [Hofmann et al. *JACS* **79** 2316 *1957*], or by chromatography on paper or on Dowex-1 (formate) column. [Bloch et al. *JBC* **234** 2595 *1959*]. Stored as DBED salt, or as the lactone in a sealed container at 0°.

Mevalonic acid 5-phosphate *[1189-94-2]* **M 228.1.** Purified by conversion to the *tricyclohexylammonium salt* (**m** 154-156°) by treatment with cyclohexylamine. Crystd from water/acetone at -15°. Alternatively, the phosphate was chromatographed by ion-exchange or paper (Whatman No 1) in a system isobutyric acid/ammonia/water (66:3:30; R_F 0.42). Stored as the cyclohexylammonium salt.

Mevalonic acid 5-pyrophosphate *[1492-08-6]* **M 258.1.** Purified by ion-exchange chromatography on Dowex-1 formate [Bloch et al. *JBC* **234** 2595 *1959*], DEAE-cellulose [Skilletar and Kekwick, *AB* **20** 171 *1967*], on by paper chromatography [Rogers et al. *BJ* **99** 381 *1966*]. Likely impurities are ATP and mevalonic acid phosphate. Stored as a dry powder or as a slightly alkaline (pH 7-9) soln at -20°.

Mithramycin A (Aureolic acid, Plicamycin) *[18378-89-7]* **M 1085.2, m 180-183°, $[\alpha]_D^{20}$ -51° (c 0.3, EtOH).** Purified from $CHCl_3$, and is soluble in MeOH, EtOH, Me_2CO, EtOAc, Me_2SO and H_2O, and moderately soluble in $CHCl_3$, but is slightly soluble in C_6H_6 and Et_2O. Fluorescent antitumour agent used in flowcytometry. [Thiem and Meyer *TET* **37** 551 *1981*; NMR: Yu et al. *Nature* **218** 193 *1968*].

Mitomycin C *[50-07-7]* **M 334.4, m >360°.** Blue-violet crystals form C_6H_6-pet ether. It is soluble in Me_2CO, MeOH and H_2O, moderately soluble in C_6H_6, CCl_4 and Et_2O but insoluble in pet ether. It has UV λ_{max} at 216, 360 and a weak peak at 560nm in MeOH. [Stevens et al. *J Medicinal Chem* **8** 1 *1965*; Shirahata and Hirayama *JACS* **105** 7199 *1983*].

Muramic acid [*R*-2(2-amino-2-deoxy-D-glucose-3-yloxy)-propionic acid] *[114-41-6]* **M 251.2, m 145-150°(dec), 152-154°(dec), 155°(dec), $[\alpha]_D^{25}$ +109° (c 2, H_2O), +165.0° (extrapolated to 0 time) → +123° (after 3h (c 3, H_2O).** It has been recrystd from H_2O or aqueous EtOH as monohydrate which loses H_2O at 80° *in vacuo* over P_2O_5. Sometimes contains some NaCl. It has been purified by dissolving 3.2g in MeOH (75ml), filtered from some insoluble material, concentrated to ~10ml and refrigerated. The colourless crystals are washed with absolute MeOH. This process does not remove NaCl; to do so the product is recrystd from a equal weight of H_2O to give a low yield of very pure acid (0.12g). On paper chromatography 0.26μg give one ninhydrin positive spot after development with 75% phenol (R_f 0.51) or with *sec*-BuOH-HCO_2O-H_2O (7:1:2) (R_F 0.30). [Matsushima and Park *Biochemical Preparations* **10** 109 *1963*; *JOC* **27** 3581 *1962*]. The acid has been also purified by dissolving 990mg in 50% aqueous EtOH (2ml), cooling, collecting the colourless needles on a sintered glass funnel and dried over P_2O_5 at 80°/0.1mm to give the anhydrous acid. [Lambert and Zilliken *B* **93** 2915 *1960*]. Alternatively the acid is dissolved in a small volume of H_2O, neutralised to pH 7 with ion exchange resin beads (IR.4B in OH^- form), filtered, evaporated and dried. The residue is recrystd from 90% EtOH (v/v) and dried as above for 24h. [Strange and Kent *BJ* **71** 333

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1959]. The *N-acetyl* derivative has **m** ~125° (dec) and $[\alpha]_D^{20}$ +41.2° after 24h (c 1.5, H_2O). [Watanabe and Saito *J Bacteriology* **144** 428 *1980*].

Muscimol (pantherine, 5-aminoethyl-3[2*h*]-isoxazolone) *[2763-96-4]* **M 114.1, m 170-172°(dec), 172-174°(dec), 172-175°, 175°, 176-178°(dec).** Recrystd from MeOH-tetrahydrofuran or EtOH and sublimed at 110-140° (bath) at 10^{-4} mm and gives a yellow spot with ninhydrin which slowly turns purple [NMR: Bowden et al. *JCS (C)* 172 *1968*]. Also purified by dissolving in the minimum volume of hot H_2O and adding EtOH dropwise until cloudy, cool, and colourless crystals separate; IR: ν 3445w, 3000-2560w br, 2156w, 1635s and 1475s cm^{-1}. [NMR: Jager and Frey *A* 817, 1982]. Alternatively it has been purified by two successive chromatographic treatments on Dowex 1 x 8 with the first elution with 2M AcOH and a second with a linear gradient between 0—2M AcOH and evaporating the desired fractions and recrystallising the residue from MeOH. [McCarry and Savard *TET LETT* **22** 5153 *1981*; Nakamura *Chem Pharm Bull Japan* **19** 46 *1971*].

Mycophenolic acid (6-[1,3-dihydro-7-hydroxy-5-methoxy-4-methyl-1-oxoisobenzofuran-6-yl]-4-methylhex-4-enoic acid) *[24280-93-1]* **M 320.3, m 141°, 141-143°.** Purified by dissolving in the minimum volume of EtOAc, applying to a silica gel column (0.05-0.2 mesh) and eluting with a mixture of EtOAc + $CHCl_3$ + AcOH (45:55:1) followed by recrystn from heptane-EtOAc, from aqueous EtOH or from hot H_2O and drying *in vacuo*. It is a weak dibasic acid moderately soluble in Et_2O, $CHCl_3$ and hot H_2O but weakly soluble in C_6H_6 and toluene. [Birch and Wright *Australian J Chem* **22** 2635 *1969*; Canonica et al. *JCS Perkin Trans I* 2639 *1972*; Birkinshaw, Raistrick and Ross *BJ* **50** 630 *1952*].

Myoglobin (from sperm whale muscle). *[9047-17-0]]* **M_r ~17,000.** Purified by CM-cellulose chromatography and Sephadex G-50 followed by chromatography on Amberlite IRC-50 Type III or BioRex 70 (<400mesh). The crystalline product as a paste in saturated $(NH_4)_2SO_4$ at pH 6.5-7.0 may be stored at 4° for at least 4 years unchanged, but must not be kept in a freezer. [Anres and Atassi *Biochemistry* **12** 942 *1980*; Edmundson *Biochemical Preparations* **12** 41 *1968*].

Myricetin (Cannabiscetin, 3,3',4',5,5',7-hexahydroxyflavone) *[529-44-2]* **M 318.2, m >300°, 357°(dec).** Recrystd from aq EtOH (**m** 357° dec, as monohydrate) or Me_2CO (**m** 350° dec, with one mol of Me_2CO) as yellow crystals. Almost insol in $CHCl_3$ and AcOH. The *hexaacetate* has **m** 213°. [Hergert *JOC* **21** 534 *1956*; Spada and Cameroni *Gazzetta* **86** 965, 975 *1956*; Kalff and Robinson *JCS* **127** 181 *1925*].

Nalidixic acid

(1-ethyl-7-methyl-1,8-naphthyridin-4-one-3-carboxylic acid) *[389-08-2]* **M 232.3, m 226.8-230.2°, 228-230°, 229-230°.** Crystd from H_2O or EtOH as a pale buff powder. It is soluble at 23° in $CHCl_3$ (3.5%), toluene (0.16%), MeOH (0.13%), EtOH (0.09%), H_2O (0.01% and Et_2O (0.01%). It inhibits nucleic acid and protein synthesis in yeast. [Lesher et al. *J Medicinal and Pharm Chem* **5** 1063 *1962*].

Naloxone hydrochloride hydrate (Narcan, 1-*N*-allyl-7,8-dihydro-14-hydroxynormorphinone hydrochloride) *[51481-60-8]* **M 399.9, m 200-205°, $[\alpha]_D^{20}$ -164° (c 2.5, H_2O).** This opiate antagonist has been recrystd from EtOH + Et_2O. or H_2O. It is soluble in H_2O (5%) and EtOH but insoluble in Et_2O. The *free base* has **m** 184° (177-178°) after recrystn from EtOAc, $[\alpha]_D^{20}$ -194.5° (c 0.93, $CHCl_3$). [Olofson et al. *TET LETT* 1567 *1977*; Gold et al. *Medicinal Research Reviews* **2** 211 *1982*].

Naltrexone hydrochloride dihydrate (17-[cyclopropylmethyl]-4,5-epoxy-3,14-dihydroxy-morphinan-6-one hydrochloride) *[16676-29-2]* **M 413.9, m 274-276°, $[\alpha]_D^{20}$ -173° (c 1, H_2O).** This narcotic antagonist has been purified by recrystn from MeOH and dried air. The *free base* has **m** 168-170° after recrystn from Me_2CO. [Cone et al. *J Pharm Sci* **64** 618 *1975*; Gold et al. *Medicinal Research Reviews* **2** 211 *1982*].

α-Naphthoflavone (7,8-benzoflavone) *[504-59-1]* **M 272.3, m 153-155°, 155°, 153-155°.** Recrystd from EtOH or aqueous EtOH. [IR: Cramer and Windel *B* 89 354 *1956;* UV Pillon and Massicot *Bull Soc Chim France* 26 *1954*; Smith *JCS* 542 *1946*; Mahal and Venkataraman *JCS* 1767 *1934*]. It is a competitive inhibitor of human estrogen synthase. [Kellis and Vickery *Science* **225** 1032 *1984*].

Naphthol AS-acetate (3-acetoxynaphthoic acid anilide] *[1163-67-3]* **M 305.3, m 152°, 160°.** Recrystd from hot MeOH and dried *in vacuo* over P_2O_5. It is slightly soluble in AcOH, EtOH, $CHCl_3$ or C_6H_6. It is a fluorogenic substrate for albumin esterase activity. [Chen and Scott *Analyt Letters* **17** 857 *1984*]. At λ_{ex} 320nm it had fluorescence at λ_{em} 500nm. [Brass and Sommer *B* **61** 1000 *1928*].

1-Naphthyl phosphate disodium salt *[2183-17-7]* **M 268.1.** Purified through an acid ion-exchange column (in H^+ form) to give the *free acid* which is obtained by freeze drying and recrystn from Me_2CO + C_6H_6, or by adding 2.5 vols of hot $CHCl_3$ to a hot soln of 1 part acid and 1.2 parts Me_2CO and cooling (**m** 155-157°, 157-158°). The acid is dissolved in the minimum volume of H_2O to which 2 equivalents of NaOH are added and then freeze dried, or by adding the equivalent amount of MeONa in MeOH to a soln of the acid in MeOH and collecting the Na salt, washing with cold MeOH then Et_2O and drying in a vacuum. It has pKa^{26} values of 0.97 and 5.85 in H_2O. [Friedman and Seligman *JACS* **72** 624 *1950*; Chanley and Feageson *JACS* **77** 4002 *1955*]. It is a substrate for alkaline phosphatase [Gomori *Methods in Enzymology* **4** 381 *1957*, **128** 212 *1968*], and prostatic phospatase [Babson *Clinical Chem* **30** 1418 *1984*].

2-Naphthyl phosphate monosodium salt *[14463-68-4]* **M 246.2, m 296° (sintering at 228°).** The *free acid* is purified as for the preceding 1-isomer and has **m** 176-177°, 177-178° after recrystn from $CHCl_3$ + Me_2CO as the 1-isomer above. It is neutralised with one equivalent of NaOH and freeze dried or prepared as the 1-isomer above. Its solubility in H_2O is 5% and it has pKa^{26} values of 1.28 and 5.53 in H_2O. It also forms a 0.5 Na.1 H_2O salt which has **m** 203-205° (244° ?). [Friedman and Seligman *JACS* **72** 624 *1950*; Chanley and Fegeason *JACS* **77** 4002 *1955*].

D(+)-Neopterin *[2009-64-5]* **M 253.2, m >300°(dec), $[\alpha]_{546}^{20}$ +64.5° (c 0.14, 0.1M HCl), $[\alpha]_D^{25}$ +50.1° (c 0.3, 0.1N HCl).** Purified as biopterin. Also purified on a Dowex 1 x 8 (formate form) column and eluted with 0.03M ammonium formate buffer pH 8.0 then pH 7.2. The fluorescent neopterin fraction is evapd under reduced pressure leaving neopterin and ammonium formate (the latter can be sublimed out at high vacuum). The residue is stirred for 24h with EtOH and the solid is collected and recrystd from H_2O [Viscontini et al. *HCA* **53** 1202 *1970*; see Wachter et al. eds *Neopterin* W de Guyter, Berlin *1992*].

β-Nicotinamide adenine dinucleotide (diphosphopyridine nucleotide, NAD, DPN) *[53-84-9]* **M 663.4, $[\alpha]_D^{23}$ -34.8° (c 1, H_2O).** Purified by paper chromatography or better on a Dowex-1 ion-exchange resin. The column was prepared by washing with 3M HCl until free of material absorbing at 260nm, then with water, 2M sodium formate until free of chloride ions and, finally, with water. NAD, as a 0.2% soln in water, adjusted with NaOH to pH 8, was adsorbed on the column, washed with water, and eluted with 0.1M formic acid. Fractions with strong absorption at 360nm were combined, acidified to pH 2.0 with 2M HCl, and cold acetone (*ca* 5L/g of NAD) was added slowly and with constant agitation. It was left overnight in the cold, then the ppte was collected in a centrifuge, washed with pure acetone and dried under vacuum over $CaCl_2$ and paraffin wax shavings [Kornberg *Methods in Enzymology* **3** 876 *1957*]. Purified by anion-exchange chromatography [Dalziel and Dickinson *Biochemical Preparations* **11** 84 *1966*]. The purity is checked by reduction to NADH (with EtOH and yeast alcohol dehydrogenase) which has ε_{340mn} 6220 $M^{-1}cm^{-1}$. [Todd et al. *JCS* 3727,3733 *1957*]. It has pKa values of 2.2, 3.9 and 11.3 [Lamborg et al. *JBC* **231** 685 *1958*]. The *free acid* crystallises from aq Me_2CO with $3H_2O$ and has **m** 140-142°. It is stable in cold neutral aqueous solns in a desiccator ($CaCl_2$) at 25°, but decomposes at strong acid and alkaline pH. Its purity is checked by reduction with yeast alcohol dehydrogenase and EtOH to NADH and noting the OD at 340nm. Pure NADH has ε_{340} 6.2 x $10^4 M^{-1}cm^{-1}$, i.e. 0.1μmole of NADH in 3ml and in a 1cm path length cell has an OD at 340nm of 0.207.

β-Nicotinamide adenine dinucleotide reduced disodium salt trihydrate (reduced diphosphopyridine nucleotide sodium salt, NADH) *[606-68-8]* **M 763.5.** This coenzyme is available in high purity and it is advised to buy a fresh preparation rather than to purify an old sample as purification will invariably lead to a more impure sample contaminated with the oxidised form (NAD). It has

UV λ_{max} at 340nm (ε 6,200 $M^{-1}cm^{-1}$) at which wavelength the oxidised form NAD has no absorption. At 340 nm a 0.161mM solution in a 1cm (pathlength) cell has an absorbance of 1.0 unit. The purity is best checked by the ratio OD_{280nm}/OD_{340nm} ~2.1, a value which increases as oxidation proceeds. The dry powder is stable indefinitely at -20°. Solutions in aqueous buffers at pH ~7 are stable for extended periods at -20° and for at least 8h at 0°, but are oxidised more rapidly at 4° in a cold room (e.g. almost completely oxidised overnight at 4°). [UV: Drabkin *JBC* **175** 563 *1945*; Fluorescence: Boyer and Thorell *Acta Chem Scand* **10** 447 *1956*; Redox: Rodkey *JBC* **234** 188 *1959*; Schlenk in *The Enzymes* **2** 250, 268 *1951*; Kaplan in *The Enzymes* **3** 105, 112 *1960*]. Deuterated NADH, i.e. NADD, has been purified through the anion exchange resin AG-1 x 8 (100-200 mesh, formate form) and through a Bio-Gel P-2 column. [Viola, Cook and Cleland *AB* **96** 334 *1979*].

β-Nicotinamide adenine dinucleotide phosphate (NADP) *[53-59-8]* **M 743.4.** Purified by anion-exchange chromatography in much the same way as for NAD [Dalziel and Dickinson *BJ* **95** 311 *1965*]; *Biochemical Preparations* **11** 87 *1966*]. Finally it is purified by dissolving in H_2O and precipitating with 4 volumes of Me_2CO and dried *in vacuo* over P_2O_5. It is unchanged by storing *in vacuo* at 2°. [Hughes et al. *JCS* 3733 *1957*, Schuster and Kaplan *JBC* **215** 183 *1955*]. Deuterated NADPH, i.e. NADPD, has been purified through the anion exchange resin AG-1 x 8 (100-200 mesh, formate form) and through a Bio-Gel P-2 column. [Viola, Cook and Cleland *AB* **96** 334 *1979*].

β-Nicotinamide adenine dinucleotide phosphate reduced tetrasodium salt (reduced diphosphopyridine nucleotide phosphate sodium salt, NADPH) *[2646-71-1]* **M 833.4.** Mostly similar to NADH above.

β-Nicotinamide mononucleotide (NMN) *[1094-61-7]* **M 334.2, $[\alpha]_D^{23}$ -38.3° (c 1, H_2O).** Purified by passage through a Dowex 1 (Cl^- form), washed with H_2O until no absorbance at 260 nm. The tubes containing NMN are pooled, adjusted to pH 5.5-6 and evapd *in vacuo* to a small volume. This is adjusted to pH 3 with dilute HNO_3 in an ice bath and treated with 20 volumes of Me_2CO at 0-5°. The heavy white ppte is collected by centrifugation at 0°. It is best stored wet and frozen or can be dried to give a gummy residue. It has λ_{max} 266nm (ε 4600) and λ_{min} 249nm (ε 3600) at pH 7.0 (i.e. no absorption at 340nm). It can be estimated by reaction with CN^- or hydrosulphite which form the 4-adducts equivalent to NADH) which has UV λ_{max} 340nm (ε 6200). Thus after reaction an OD_{340} of one is obtained from a 0.1612mMolar soln in a 1cm path cuvette. [Plaut and Plaut *Biochemical Preparations* **5** 56 *1957*; Maplan and Stolzenbach *Methods in Enzymology* **3** 899 *1957*; Kaplan et al. *JACS* **77** 815 *1955*].

(-)-Nicotine (1-methyl-2[3-pyidyl]-pyrrolidine) *[54-11-5]* **M 162.2, b 123-125°/17mm, 246.1°/730.5mm, 243-248°/atm (partial dec), d_4^{20} 1.097, n_D^{20} 1.5280, $[\alpha]_D^{20}$ -169° (c 1, Me_2CO).** Very pale yellow *hygroscopic* oil with a characteristic odour (tobacco extract) with browns in air on exposure to light. Purifed by fractional distn under reduced pressure in an inert atmosphere. A freshly distd sample should be stored in dark sealed containers under N_2. It is a strong base with pKa^{15} values of 6.16 and 10.96 and a 0.05 M soln has a pH of 10.2. Very soluble in organic solvents. It is soluble in H_2O and readily forms salts. [UV: Parvis *JCS* **97** 1035 *1910*; Dobbie and Fox *JCS* **103** 1194 *1913*]. The *hydrochlorides* (mono- and di-) form deliquescent crystals soluble in H_2O and EtOH but insoluble in Et_2O. It has also been purified *via* the $ZnCl_2$ double salt. [Ratz *M* **26** 1241 *1905*; Biosynthesis: Nakan and Hitchinson *JOC* **43** 3922 *1978*]. The *picrate* has **m** 218° (from EtOH).

(±)-Nicotine (tetrahydronicotyrine) *[22083-74-5]* **M 162.2, b 242.3°/atm, d_4^{20} 1.082.** Purified by distn. Its solubility in EtOH is 5%. The *picrate* forms yellow needles from hot H_2O and has **m** 218°. The *methiodide* has **m** 219° (from MeOH).

Nisin *[1414-45-5]* **M 3354.2.** Crystd from EtOH. [Berridge et al. *BJ* **52** 529 *1952*].

2-Nitrophenyl-β-D-galactopyranoside *[369-07-3]* **M 301.3, m 185-190°, 193°, 193-194°, $[\alpha]_D^{18}$ -51.9° (c 1, H_2O).** Purified by recrystn from EtOH. [Seidman and Link *JACS* **72** 4324 *1950*; Snyder and Link *JACS* **75** 1758 *1953*]. It is a chromogenic substrate for β-galactosidases [Jagota et al. *J Food Science* **46** 161 *1981*].

4-Nitrophenyl-α-D-galactopyranoside *[7493-95-0]* **M 301.3, m 166-169°, 173°, $[\alpha]_D^{25}$ +248 (c 1, H_2O).** Purified by recrystn from H_2O or aqueous EtOH. The *monohydrate* has **m** 85° which resolidifies and melts at 151-152° (the hemihydrate) which resolidifies and melts again at 173° as the anhydrous form. Drying the monohydrate at 60° yields the hemihydrate and drying at 100° gives the anhydrous compound. The *tetraacetate* has **m** 147° after drying at 100°. [Jermyn *Australian J Chem* **15** 569 *1962*; Helfreich and Jung *A* **589** 77 *1954*]. It is a substrate for α-galactosidase [Dangelmaier and Holmsen *AB* **104** 182 *1980*].

4-Nitrophenyl-β-D-galactopyranoside *[3150-24-1]* **M 301.3, m 178°, 178-181°,181-182°, $[\alpha]_D^{20}$ -83° (c 1, H_2O).** Purified by recrystn from EtOH. [Horikoshi *J Biochem Tokyo* **35** 39 *1042*; Goebel and Avery *J Exptl Medicine* **50** 521 *1929*; Snyder and Link *JACS* **75** 1758]. It is a chromogenic substrate for β-galactosidases [Buoncore et al. *J Applied Biochem* **2** 390 *1980*].

4-Nitrophenyl-α-D-glucopyranoside *[3767-28-0]* **M 301.3, m 206-212°, 216-217° (sinters at 210°), $[\alpha]_D^{20}$ +215° (c 1, H_2O).** Purified by recrystn from H_2O, MeOH or EtOH. [Jermyn *Australian J Chem* **7** 202 *1954*; Montgomery et al. *JACS* **64** 690 *1942*]. It is a chromogenic substrate from α-glucosidases [Oliviera et al. *AB* **113** 188*1981*], and is a substrate for glucansucrases [Binder and Robyt *Carbohydrate Research* **124** 287*1983*]. It is a chromogenic substrate for β-glucosidases [Weber and Fink *JBC* **255** 9030 *1980*].

4-Nitrophenyl-β-D-glucopyranoside *[2492-87-7]* **M 301.2, m 164°, 164-165°, 165°, $[\alpha]_D^{20}$ -107° (c 1, H_2O).** Purified by recrystn from EtOH or H_2O. [Montgomery et al. *JACS* **64** 690 *1942*; Snyder and Link *JACS* **75** 1758 *1953*].

***N*-Nonanoyl-*n*-methylglucamine (Mega-9)** *[85261-19-4]* **M 335.4, m 87-89°.** A non-ionic detergent purified as *n*-decanoyl-*N*-methylglucamine above. [Hildreth *BJ* **207** 363 *1982*].

Nonyl-β-D-glucopyranoside *[69984-73-2]* **M 306.4, m 67.5-70°, $[\alpha]_D^{20}$ -34.4° (c 5, H_2O), $[\alpha]_D^{25}$ -28.8° (c 1, MeOH).** Purified by recrystn from Me_2CO and stored in well stoppered containers as it is *hygroscopic*. [Pigman and Richtmyer *JACS* **64** 369 *1942*]. It is a UV transparent non-ionic detergent for solubilising membrane proteins [Schwendener et al. *BBRC* **100** 1055 *1981*].

L-Noradrenaline (Adrenor, *R*-2-amino-1-[3,4-dihydroxyphenyl]ethan-1-ol, L-norepinephrine) *[51-41-2]* **M 169.2, m 216.5-218°(dec), ~220-230°(dec), $[\alpha]_D^{20}$ -45° (c 5, N HCl), $[\alpha]_D^{25}$ 37.3° (c 5, 1 equiv aqueous HCl).** Recrystd from EtOH and stored in the dark under N_2. It has pKa values in H_2O of 5.58, 8.90 and 9.78 [Lewis *Brit J Pharmacol Chemotherapy* **9** 488 *1954*; UV: Bergström et al. *Acta Physiol Scand* **20** 101 *1950*; Fluorescence: Bowman et al. *Science NY* **122** 32 *1955*; Tullar *JACS* **70** 2067 *1948*]. The *L-tartrate salt monohydrate* has **m** 102-104.5°, $[\alpha]_D^{25}$ -11° (c 1.6, H_2O), after recrystn from H_2O or EtOH.

L-Noradrenaline hydrochloride (Arterenol) *[329-56-6]* **M 205.6, m 145.2-146.4°, ~150°(dec), $[\alpha]_D^{25}$ -40° (c 6, H_2O).** Recrystd from isoPrOH and stored in the dark as it is oxidised in the presence of light (see preceding entry). [Tullar *JACS* **70** 2067 *1948*].

Novobiocin (7-[*O*^{3}-carbamoyl-5-*O*^{4}-dimethyl-β-L-*lyso*-6-desoxyhexahydropyranosyloxy]-4-hydroxy-3[4-hydroxy-3-{3-methylbut-2-enyl}-benzyl-amino]-8-methylcoumarin *[303-81-1]* **M 612.6, two forms m 152-156° and m 172-174°, 174-178°, λ_{max} at 330nm (acid EtOH), 305nm (alk EtOH), $[\alpha]_D^{25}$ -63° (c 1, EtOH).** Crystd from EtOH and stored in the dark. It has also been recrystd from Me_2CO-H_2O. It has pKa values of 4.03 and 9.16 in H_2O. [Hoeksema et al. *JACS* **77** 6710 *1955*; Kaczka et al. *JACS* **77** 9404 *1955*].
The **sodium salt** *[1476-53-5]* **M 634.6, m 210-215°, 215-220°(dec), 222-229°, $[\alpha]_D^{25}$ -38° (c 1, H_2O)** has been recrystd from MeOH, then dried at 60°/0.5mm. [Sensi, Gallo and Chiesa, *AC* **29** 1611 *1957*; Kaczka et al. *JACS* **78** 4126 *1956*].

5'-Nucleotidase (from Electric ray, *Torpedo sp*) *[9027-73-0].* Purified by dissolving in Triton X-100 and deoxycholate, and by affinity chromatography on concanavalin A-Sepharose and AMP-Sepharose [Grondal and Zimmerman *BJ* **245** 805 *1987*].

Nucleotide thiophosphate analogues. The preparation and purification of [^{3}H]ATPγS, [^{3}H]GTPγS, s^{6}ITPγS (6-thioinosine), cl^{6}ITPγS (6-chloroinosine) and [^{3}H]ATPγS are described and the general purification was achieved by chromatography of the nucleotide thiophosphates in the minimum volume of H_2O placed onto a DEAE-Sephadex A25 column and eluting with a linear gradient of triethylammonium bicarbonate (0.1 to 0.6M for G and I nucleotides and 0.2 to 0.5M for A nucleotides). [*Biochim Biophys Acta* **276** 155 *1972*].

Nystatin dihydrate (Mycostatin, Fungicidin) *[1400-61-9]* **M 962.1, m dec>160° (without melting by 250°), $[\alpha]_D^{25}$ -7° (0.1N HCl in MeOH), -10° (AcOH), +12° (Me_2NCHO), +21° (pyridine).** Light yellow powder with the following solubilities at ~28°: MeOH (1.1%), ethylene glycol (0.9%), H_2O (0.4%), CCl_4 (0.12%), EtOH (0.12%), $CHCl_3$ (0.05%) and C_6H_6 (0.03%). Could be ppted from MeOH soln by addition of H_2O. Aqueous suspensions of this macrolide antifungal antibiotic are stable at 100°/10min at pH 7.0 but decomposes rapidly at pH <2 and >9, and in the presence of light and O_2. [Birch et al. *TET LETT* 1491, 1485 *1964*; Weiss et al. *Antibiotics and Chemotherapy* **7** 374 *1957*]. It contains a mixture of components A_1, A_2 and A_3.

Octyl-β-D-glucopyranoside *[29836-26-8]* M 292.4, m 62-65°, 63.8-65°, $[\alpha]_D^{20}$ -34° (c 4, H_2O).

Purified by recrystn from Me_2CO. It is *hygroscopic* and should be stored in a well stoppered container. [Noller and Rockwell *JACS* **60** 2076 *1938*; Pigman and Richtmyer *JACS* **64** 369 *1942*]. It is a UV transparent non-ionic dialysable detergent for solubilising membrane proteins. The *α–D-isomer* with $[\alpha]_D^{20}$ +118° (c 1, MeOH) has similar solubilising properties. [Lazo and Quinn *AB* **102** 68 *1980*; Stubbs et al. *Biochim Biophys Acta* **426** 46 *1976*].

Orcine monohydrate (3,5-dihydroxytoluene) *[6153-39-5]* **M 142.2, m 56°, 56-58°, 58°, b 147°/5 mm.** Purified by recrystn from H_2O as the monohydrate. It sublimes *in vacuo* and the *anhydrous* compound has **m** 106.5-108° (110°, 108°). Also can be recrystd from $CHCl_3$ (plates) or C_6H_6 (needles or prisms). [UV: Kiss et al. *Bull Soc Chim France* 275 *1949*; Adams et al. *JACS* **62** 732 *1940*].

Orosomucoid (glycoprotein α_1 acid, from human plasma). Purified by passage through a carboxymethyl cellulose column and through a Sephadex G-25 column. [Aronson et al. *JBC* **243** 4564 *1968*].

Orotic acid Li salt monohydrate *[5266-20-6]* **M 180.0, m >300°.** It is soluble in H_2O at 17° and 100°. Best to acidify an aqueous soln, isolating the free acid which is recrytd from H_2O (as monohydrate) **m** 345-347° (345-346°), then dissolving in EtOH, adding an equivalent amount of LiOH in EtOH and evaporating. Its solubility in H_2O is 1.28% (17°) and 2.34% (100°). It has pKa values at 2.8, 9.45 and >13. [Bachstez *B* **63** 1000 *1930*; Johnson and Shroeder *JACS* **54** 2941 *1932*; UV: Shugar and Fox *Biochim Biophys Acta* **9** 199 *1952*].

Oxacillin sodium salt (5-methyl-3-phenyl-4-isoxazolylpenicillin sodium salt) *[1173-88-2]* **M 423.4, m 188°(dec), $[\alpha]_D^{20}$ +29° (c 1, H_2O).** This antibiotic which is stable to penicillinase is purified by recrystn from isoPrOH and dried *in vacuo*. Its solubility in H_2O at 25° is 5%. [Doyle et al. *Nature* **192** 1183 *1961*].

Oxolinic acid (5-ethyl-5,8-dihydro-8-oxo-1,3-dioxolo[4,5-*g*]quinoline-7-carboxylic acid) *[14698-29-4]* **M 261.2, m 313-314°(dec), 314-316°(dec).** Purified by recrystn from aqueous Me_2CO or 95% EtOH. It has UV λ_{max} 220, (255.5sh), 259.5, 268, (298sh, 311sh), 321 and 326nm [ε 14.8, (36.8sh), 38.4, 38.4, (6.4sh, 9.2sh), 10.8 and 11.2 x 10^3]. [Kaminsky and Mettzer *J Medicinal Chem* **11** 160 *1968*].

Oxytocin *[50-56-6]* **M 1007.2, m dec on heating, $[\alpha]_D^{22}$ -26.2° (c 0.53, N AcOH).** A cyclic nonapeptide which was purified by countercurrent distribution between solvent and buffer. It is soluble in H_2O, *n*-BuOH and isoBuOH. [Bodanszky and du Vigneaud *JACS* **81** 2504 *1959*; Cash et al. *J Med Pharm Chem* **5** 413 *1962*; Sakakibara et al. *Bull Chem Soc Japan* **38** 120 *1965*; solid phase synthesis: Bayer and Hagenmyer *TET LETT* 2037 *1968*]. It was also synthesised on a solid phase matrix and finally purified as follows: A Sephadex G-25 column was equilibrated with the aqueous phase of a mixture of 3.5% AcOH (containing 1.5% of pyridine) + *n*-BuOH + C_6H_6 (2:1:1) and then the organic phase of this mixture was run through. A soln of oxytocin (100mg) in H_2O (2ml) was applied to the column which was then eluted with the organic layer of the above mixture. The fractions containing the major peak [as determined by the Folin-Lowry protein assay (Fryer et al. *AB* **153** 262 *1986*)] were pooled, diluted with twice their vol of H_2O, evaporated to a small vol and lyophilised to give oxytocin as a pure white powder (20mg, 508 U/mg). [Ives *Canad J Chem* **46** 2318 *1968*].

Palmitoyl coenzyme A *[1763-10-6]* M 1005.9.

Possible impurities are palmitic acid, S-palmitoyl thioglycolic acid and S-palmitoyl glutathione. These are removed by placing *ca* 200mg in a centrifuge tube and extracting with Me_2CO (20ml), followed by two successive extractions with Et_2O (15ml) to remove S-palmitoyl thioglycolic acid and palmitic acid. The residue is dissolved in H_2O (4 x 4 ml), adjusted to pH 5 and centrifuged to remove insoluble S-palmitoyl glutathione and other insoluble impurities. To the clear supernatant is added 5% $HClO_4$ (6ml) whereby S-palmitoyl CoA pptes. The ppte is washed with 0.8% $HClO_4$ (10ml) and finally with Me_2CO (3 x 5ml) and dried *in vacuo*. It is stable for at least one year in dry form at 0° in a desiccator (dark). Solns are stable for several months at -15°. Its solubility in H_2O is 4%. The adenine content is used as the basis of purity with λ_{max} at 260 and 232nm (ε 6.4 x 10^6 and 9.4 x 10^6 cm^2/mol respectively). Higher absorption at 232nm would indicate other thio ester impurities, e.g. S-palmitoyl glutathione, which absorb highly at this wavelength. Also PO_4 content should be determined and acid phosphate can be titrated potentiometrically. [Seubert *Biochemical Preparations* **7** 80 *1960*; Srer et al. *Biochim Biophys Acta* **33** 31 *1959*; Kornberg and Pricer *JBC* **204** 329 , 345 *1953*].

3-Palmitoyl-sn-glycerol (*R*-glycerol-1-palmitate, L-β-palmitin) *[32899-41-5]* **M 330.5, $d^{27.3}$ 0.9014, m 66.5° (α-form), 74° (β'-form) and 77° (β-form).** The stable β-form is obtained by crystn from EtOH or Skellysolve B and recrystn from Et_2O provides the β'-form. The α-form is obtained on cooling the melt. [Malkin and el Sharbagy *JCS* 1631 *1936*; Chapman *JCS* 58 *1956*; Luton and Jackson *JACS* **70** 2446 *1948*].

Pancuronium bromide (2β,16β-dipiperidino-5α-androstan-3α,17β-diol diacetate dimethobromide) *[1500-66-0]* **M 732.7, m 212-215°, 215°.** Odourless crystals with a bitter taste which are purified through acid-washed Al_2O_3 and eluted with isoPrOH-EtOAc (3:1) to remove impurities (e.g. the monomethobromide) and eluted with isoPrOH to give the pure bromide which can be recrystd from CH_2Cl_2-Me_2CO or isoPrOH-Me_2CO. It is soluble in H_2O (50%) and $CHCl_3$ (3.3%) at 20°. It is a non-depolarising muscle relaxant. [Buckett et al. *J Medicinal Chem* **16** 1116 *1973*].

D-Panthenol (Provitamin B, *R*-2,4-dihydroxy-3,3-dimethylbutyric acid 3-hydroxypropylamide) *[81-13-0]* **M 205.3, b 118-120°/0.02mm, d_{20}^{20} 1.2, n_D^{20} 1.4935, $[\alpha]_D^{20}$ (c 5, H_2O).** Purified by distn *in vacuo*. It is a slightly *hygroscopic* viscous oil. Soluble in H_2O and organic solvent. It is hydrolysed by alkali and strong acid. [Rabin *J Amer Parm Assoc (Sci Ed)* **37** 502 *1948*; Bonati and Pitré *Farmaco Ed Scient* **14** 43 *1959*].

***R*-Pantothenic acid** *[867-81-2]* **M 241.2, m 122-124°, $[\alpha]_D^{25}$ +27° (c 5, H_2O).** Crystd from EtOH.

D-(+)-Pantothenic acid calcium salt (*N*-[2,4-dihydroxy-3,3-dimethylbutyryl] β-alanine calcium salt) *[137-08-6]* **M 476.5, m 195-196°, 200-201°, $[\alpha]_D^{20}$ +28.2° (c 5, H_2O).** It forms needles on recrystn from MeOH, EtOH or isoPrOH (with 0.5mol of isoPrOH). Moderately *hygroscopic*. The

S-benzylisothiuronium salt has **m** 151-152° (149° when crystd from Me_2CO). [Kagan et al. *JACS* **79** 3545 *1957*; Wilson et al. *JACS* **76** 5177 *1954*; Stiller and Wiley *JACS* **63** 1239 *1941*].

Papain *[9001-73-4]* **(EC 3.4.22.2).** A suspension of 50g of papain (freshly ground in a mortar) in 200ml of cold water was stirred at 4° for 4h, then filtered through a Whatman No 1 filter paper. The clear yellow filtrate was cooled in an ice-bath while a rapid stream of H_2S was passed through it for 3h, and the suspension was centrifuged at 2000rpm for 20min. Sufficient cold MeOH was added slowly and with stirring to the supernatant to give a final MeOH concn of 70 vol%. The ppte, collected by centrifugation for 20min at 2000rpm, was dissolved in 200ml of cold water, the soln was saturated with H_2S, centrifuged, and the enzyme again ppted with MeOH. The process was repeated four times. [Bennett and Niemann *JACS* **72** 1798 *1950*]. Papain has also been purified by affinity chromatography on a column of Gly-Gly-Tyr-Arg-agarose [Stewart et al. *JACS* **109** 3480 *1986*].

Papaverine hydrochloride (6,7-dimethoxy-1-veratrylisoquinoline hydrochloride) *[61-25-6]* **M 375.9, m 215-220°, 222.5-223.5°(dec), 231°.** Recrystd from H_2O and sublimed at 140°/0.1mm. Solubility in H_2O is 5%. [Saunders and Srivastava *J Pharm Pharmacol* **3** 78 *1951*]. It has pKa^{20} values of 5.98 (NH^+) and 7.6 [Biggs *TFS* **50** 800 *1954*]. The *free base* has **m** 148-150° [Bobbitt *JOC* **22** 1729 *1957*].

Pargyline hydrochloride (Eutonyl, *N*-methyl-*n*-propargylbenzylamine hydrochloride) *[306-07-0]* **M 195.7, m 154-155°, 155°.** Recrystd from EtOH-Et_2O and dried *in vacuo*. It is very soluble in H_2O, in which it is unstable. The *free base* has **b** 101-103°/11mm. It is a glucuronyl transferase inducer and a monoamine oxidase inhibitor. [von Braun et al. *A* **445** 205 *1928*; Yeh and Mitchell *Experientia* **28** 298 *1972*; Langstrom et al. *Science* **225** 1480 *1984*].

Pectic acid M $(176.1)_n$, $[\alpha]_D$ +250° (c 1, 0.1M NaOH). Citrus pectic acid (500g) was refluxed for 18h with 1.5L of 70% EtOH and the suspension was filtered hot. The residue was washed with hot 70% EtOH and finally with ether. It was dried in a current of air, ground and dried for 18h at 80° under vacuum. [Morell and Link *JBC* **100** 385 *1933*]. It can be further purified by dispersing in water and adding just enough dilute NaOH to dissolve the pectic acid, then passing the soln through columns of cation- and anion-exchange resins [Williams and Johnson *IECAE* **16** 23 *1944*], and precipitating with two volumes of 95% EtOH containing 0.01% HCl. The ppte is worked with 95% EtOH, then Et_2O, dried and ground.

Pectin *[9000-69-5]* **M 25000-50000.** Dissolved in hot water to give a 1% soln, then cooled, and made about 0.05M in HCl by addition of conc HCl, and ppted by pouring slowly, with vigorous stirring into two volumes of 95% EtOH. After standing for several hours, the pectin is filtered onto nylon cloth, then redispersed in 95% EtOH and stood overnight. The ppte is filtered off, washed with EtOH/Et_2O, then Et_2O and air dried.

D-(-)-Penicillamine (*R*-3-mercapto-D-valine, 3,3-dimethyl-D-cysteine, from natural penicillin) *[52-67-5]* **M 149.2, m 202-206°, 214-217°, $[\alpha]_D^{21}$ -63° (c 1, N NaOH or pyridine).** The melting point depends on the rate of heating (**m** 202-206° is obtained by starting at 195° and heating at 2°/min). It is soluble in H_2O and alcohols but insoluble in Et_2O, $CHCl_3$, CCl_4 and hydrocarbon solvents. Purified by dissolving in MeOH and adding Et_2O slowly. Dried *in vacuo* and stored under N_2. [Weight et al. *Angew Chem Int Ed* (English) **14** 330 *1975*; Cornforth in *The Chemistry of Penicillin* (Clarke, Johnson and Robinson eds) Princeton Univ Press, 455 *1949*; Polymorphism: Vidler *J Pharm Pharmacol* **28** 663 *1976*]. The D-S-*benzyl derivative* has **m** 197-198° (from H_2O), $[\alpha]_D^{17}$ -20° (c 1, NaOH), -70° (N HCl).

L-(-)-Penicillamine (*S*-3-mercapto-L-valine, 3,3-dimethyl-L-cysteine) *[1113-41-3]* **M 149.2, m 190-194°, (202-206°, 214-217°), $[\alpha]_D^{21}$ +63° (c 1, N NaOH or pyridine).** Same as preceding entry as it is its enantiomer.

D-Penicillamine disulphide hydrate (*S,S'*-di-[D-penicillamine] hydrate) *[20902-45-8]* **M 296.4 + aq, m 203-204°(dec), 204-205°(dec), $[\alpha]_D^{23}$ +27° (c 1.5, N HCl), -82° (c 0.8, N NaOH).** Purified by recrytn from EtOH or aqueous EtOH. [Crooks in *The Chemistry of Penicillin* (Clarke, Johnson and Robinson eds) Princeton Univ Press, 469 *1949*; Use as a thiol reagent for proteins: Garel *Eur J Biochem* **123** 513 *1982*; Süs *A* **561** 31 *1948*].

Pepsin *[9001-75-6]* **M_r 31,500(human), 6000(hog) [EC 3.4.23.1).** Rechromatographed on a column of Amberlite CG-50 using a pH gradient prior to use. Crystd from EtOH. [Richmond et al. *Biochim Biophys Acta* **29** 453 *1958*; Huang and Tang, *JBC* **244** 1085 *1969*, **245** 2189 *1970*].

Pertussis toxin (from *Bordetella pertussis*) *[70323-44-3].* Purified by stepwise elution from 3 columns comprising Blue Sepharose, Phenyl Sepharose and hydroxylapatite, and SDS-polyacrylamide gel electrophoresis [Svoboda et al. *AB* **159** 402 *1986*].

2-Phenylethyl-β-D-thiogalactoside *[63407-54-5]* **M 300.4, m 108°, $[\alpha]_D^{23}$ -32.2° (c 5, MeOH).** Recryst from H_2O and dried in air to give the $1.5.H_2O$ and has **m** 80°. Anhydrous surfactant is obtained by drying at 78° over P_2O_5. [Heilfrich and Türk *B* **89** 2215 *1856*].

Phenyl-β-D-galactopyranoside *[2818-58-8]* **M 256.3, m 153-54°, 146-148°, 155-156°(dried at 105°), $[\alpha]_D^{20}$ -42° (c 1, H_2O).** Recrystd from H_2O as $0.5H_2O$. [Conchie and Hay *BJ* **73** 327 *1959*; IR: Whistler and House *Analyt Chem* 25 1463 *1953*]. It is an acceptor substrate for fucosyltrasferase [Chester et al. *Eur J Biochem* **69** 583 *1976*].

Phenyl-β-D-glucopyranoside *[1464-44-4]* **M 256.3, m 174-175° 174-176°, 176°, $[\alpha]_D^{20}$ -72.2° (c 1 for dihydrate, H_2O).** Recrystd from H_2O as $2H_2O$ and can be dried *in vacuo* at 100°/P_2O_5. Dry preparation has $[\alpha]_D^{25}$ -70.7° (c 2, H_2O). [Robertson and Waters *JCS* 2729 *1930*; IR: Bunton et al. *JCS* 4419 *1955*; Takahashi *J Pharm Soc Japan* **74** 7436 *1954*; Whixtler and House *AC* **25** 1463; UV: Lewis *JACS* **57** 898 *1935*]. It is a substrate for β–D-glucosidase [deBryne *Eur J Biochem* **102** 257 *1979*].

Phenylmercuric acetate *[62-38-4]* **M 336.7, m148-151°, 149°, 151.8-152.8°.** Small colourless lustrous prisms from EtOH. Its solubility in H_2O is 0.17% but it is more soluble in EtOH, Me_2CO and C_6H_6. [Maynard *JACS* **46** 1510 *1925*; Coleman et al. *JACS* **59** 2703 *1937*; Grave et al. *J Amer Pharm Assocn* **25** 752 *1936*].

Phenylmethane sulphonyl fluoride (PMSF) *[329-98-6]* **M 174.2, m 90-91°, 92-93°.** Purified by recrystn from C_6H_6, pet ether or $CHCl_3$-pet ether. [Davies and Dick *JCS* 483 *1932*; cf Tullock and Coffman *JOC* **23** 2016 *1960*]. It is a general protease inhibitor (specific for trypsin and chymotrypsin) and is a good substitute for diisopropylphosphoro floridate [Fahrney and Gould *JACS* **85** 997 *1963*].

Phosphatase alkaline (alkaline phosphatase) *[9001-78-9]* **M_r ~40,000 (bovine liver), ~140,000 (bovine intestinal mucosa), 80,000 (*E.coli*) [EC 3.1.3.1].** The *E.coli* supernatant in sucrose (20%, 33mM) in Tris-HCl pH 8.0 was purified through a DEAE-cellulose column and recrystallised. To the column eluates in 0.125M NaCl is added $MgCl_2$ (to 0.01M) and brought to 50% saturation in $(NH_4)_2SO_4$ by adding the solid (0.20g/ml). The mixture is centrifuged to remove bubbles and is adjusted to pH 8.0 (with 2N NaOH). Saturated $(NH_4)_2SO_4$ at pH 8.0 is added dropwise until the soln becomes faintly turbid (~61% saturation). It is set aside at room temp for 1h (turbidity will increase). The mixture is placed in an ice bath for several minutes when turbidity disappears and a clear soln is obtained. It is then placed in a large ice bath at 0° (~5L) and allowed to warm slowly to room temperature in a dark room whereby crystals are formed appearing as a silky sheen. The crystals are collected by centrifugation at 25° if necessary. The crystalline solns are stable at room temperature for many months. They can be stored at 0°, but are not stable when frozen. Cystein at 10^{-3}M and thioglycolic acid at 10^{-4}M are inhibitory. Inhibition is reversed on addition of Zn^{2+} ions. Many organic phosphates are good substrates for this phosphatase. [Molamy and Horecker *Methods in Enzymology* **9** 639 *1966*; Torriani et al. *Methods in Enzymology* **12b** 212 *1968*; Engstrom *Biochim Biophys Acta* **92** 71 *1964*].
Alkaline phosphatase from rat *osteosarcoma* has been purified by acetone pptn, followed by chromatography on DEAE-cellulose, Sephacryl S-200, and hydroxylapatite. [Nair et al. *ABB* **254** 18 *1987*].

3-sn-Phosphatidylethanolamine (l-α-cephalin, from Soya bean) *[39382-08-6]* . Purified by dissolving in EtOH, adding $Pb(OAc)_2.3H_3O$ (30g in 100ml H_2O) until excess Pb^{++} is present. Filter off the solid. Pass CO_2 gas through the soln until pptn of $PbCO_3$ ceases. Filter the solid off and evaporate (while bubbling CO_2) under vacuum. An equal volume of H_2O is added to the residual oil extracted with hexane. The

hexane extract is washed with H_2O until the aqueous phase is free from Pb [test with dithizone (2 mg in 100 ml CCl_4 ;Feigel *Spot Tests Vol I,* Elsevier p 10 *1954*]. The hexane is dried (Na_2SO_4), filtered and evaporated to give a yellow waxy solid which should be dried to constant weight *in vacuo*. It is practically insoluble in H_2O and Me_2CO, but freely soluble in $CHCl_3$ (5%) and Et_2O, and slightly soluble in EtOH. [Schofield and Dutton *Biochemical Preparations* **5** 5 *1957*].

***O*-Phosphocolamine 2-aminoethyl dihydrogen phosphate)** *[1071-23-4]* **M 141.1, m 237-240°, 242.3°, 234.5-244.5°, 244-245°(capillary).** Purified by recrystn from aqueous EtOH as a hydrate (**m** 140-141°). Its solubility in H_2O is 17% and 0.003% in MeOH or EtOH at 22°. It has pKa^{20} values in H_2O of <1.5 (OH), 5.57 (H) and 10.89 (NH^+) [Fölisch and Österberg *JBC* **234** 2298 *1959*; Baer aand Staucer *Canad J Chem* **34** 434 *1956*; Christensen *JBC* **135** 399 *1940*]. It is a potent inhibitor of ornithine decarboxylase [Gilad and Gilad *BBRC* 122 277 *1984*].

Phosphoenolpyruvic acid monopotassium salt (KPEP) *[4265-07-0]* **M 206.1.** It is purified *via* the monocyclohexylamine salt (see next entry). The salt (534mg) in H_2O (10ml) is added to Dowex 50 H^+ form (x 4; 200-400 mesh, 2ml, H_2O washed) and stirred gently for 30min and filtered. The resin is washed with H_2O (6ml) and the combined solns are adjusted to pH 7.4 with 3N KOH (~1.4ml) and the volume adjusted to 18.4ml with H_2O to give a soln of 0.1M KPEP which can be lyophilised to a pure powder and is very good for enzyme work. It has been recrystd from MeOH-Et_2O. It has pKa^{25} values of 3.4 and 6.35 in H_2O. [Clark and Kirby *Biochemical Preparations* **11** 103 *1966*; Wold and Ballou *JBC* **227** 301 *1957*; Cherbuliez and Rabinowitz *HCA* **39** 1461 *1956*].

Phosphoenolpyruvic acid tris(cyclohexylamine) salt *[35556-70-8]* **M 465.6, m 155-180°(dec).** Recrystd from aqueous Me_2CO and dried in a vacuum. At 4° it is stable for >2 years and has IR at 1721cm^{-1} (C=O). [Wold and Ballou *JBC* **227** 301 *1957*; Clark and Kirby *Biochemical Preparations* **11** 103 *1966* for the monocyclohexylamine salt].

D-3-Phosphoglyceric acid disodium salt (D-glycerate 3-phosphate diNa salt) *[80731-10-8]* **M 230.0, $[\alpha]_D^{25}$ +7.7° (c 5, H_2O), -735° (in aq NH_4^+ molybdate).** Best purified by conversion to the Ba salt by pptn with $BaCl_2$ which is recrystd three times before conversion to the sodium salt. The Ba salt (9.5g) is shaken with 200ml of a 1:1 slurry of Dowex 50 (Na^+ form) for 2h. The mixture is filtered and the resin washed with H_2O (2 x 25ml). The combined filtrates (150ml) are adjusted to pH 7.0 and concentrated *in vacuo* to 30-40ml and filtered if not clear. Absolute EtOH is added to make 100ml and then *n*-hexane is added whereby a white solid and/or a second phase separates. When set aside at room temperature complete pptn of the Na salt as a solid occurs. The salt is removed by centrifugation, washed with Me_2CO, dried in air then in an oven at 55° to give a stable powder (4.5g). It did not lose weight when dried further over P_2O_5 at 78°/8h. The high rotation in the presence of $(NH_4)_6Mo_7O_{24}$ is not very sensitive to the concentration of molybdate or pH as it did not alter appreciably in 1/3 volume between 2.5 to 25% (w/v) of molybdate or at pH values ranging between 4 and 7. [Cowgill *Biochim Biophys Acta* **16** 613 *1955*; Embdan, Deuticke and Kraft *Z physiol Chem* **230** 20 *1934*].

Phospholipids. For the removal of ionic contaminants from raw zwitterionic phospholipids, most lipids were purified twice by mixed-bed ionic exchange (Amberlite AB-2) of methanolic solutions. (About 1g of lipid in 10ml of MeOH). With both runs the first 1ml of the eluate was discarded. The main fraction of the solution was evaporated at 40°C under dry N_2 and recryst three times from *n*-pentane. The resulting white powder was dried for about 4h at 50° under reduced pressure and stored at 3°. Some samples were purified by mixed-bed ion exchange of aqueous suspensions of the crystal/liquid crystal phase. [Kaatze et al. *JPC* **89** 2565 *1985*].

Phosphoproteins (various). Purified by adsorbing onto an iminodiacetic acid substituted agarose column to which was bound ferric ions. This chelate complex acted as a selective immobilised metal affinity adsorbent for phosphoproteins. [Muszyfiska et al. *Biochemistry* **25** 6850 *1986*].

Phosphopyruvic acid triNa salt *[5541-93-5]* **M 360.0.** It is recrystd from MeOH-Et_2O: the salt (1g) is dissolved in MeOH (40ml) and dry Et_2O is added in excess. The white crystals are collected and dried over P_2O_5 at 20°. [*B* **92** 952 *1959*].

5'-Phosphoribosyl pyrophosphate synthetase (from human erythrocytes, or pigeon or chicken liver) *[9015-83-2]* **[EC 2.7.6.1].** Purified 5100-fold by elution from DEAE-cellulose, fractionation with ammonium sulphate, filtration on Sepharose 4B and ultrafiltration. [Fox and Kelley *JBC* **246** 5739 *1971*; Flaks *Methods in Enzymology* **6** 158 *1963*; Kornberg et al. *JBC* **15** 389 *1955*].

***O*-Phospho-L-serine** *[407-41-0]* **M 185.1, m 175-176°, $[\alpha]_D^{20}$ +4.3° (c 3.2, H_2O), +16.2° (c 3.2, 2N HCl).** Recrystd by dissolving 10g in H_2O (150ml) at 25°, stirring for up to 20min. Undissolved material is filtered off (Büchner) and 95% EtOH (85ml) is added dropwise during 4min, and set aside at 25° for 3h then at 3° overnight. The crystals are washed with 95% EtOH (100ml) then dry Et_2O (50ml) and dried in a vacuum (yield 6.5g). A further quantity (1.5mg) can be obtained by keeping the mother liquors and washings at -10° for 1 week. It has pKa values of <1.0 (PO_4H_2), 2.65 (CO_2H), 5.91 (PO_4H^-) and 9.99 (NH_4^+) in H_2O. The *DL-isomer* has **m** 167-170°(dec) after recrystn from H_2O + EtOH or MeOH. [Neuhaus and Korkes *Biochemical Preparations* **6** 75 *1958*; Neuhaus and Byrne *JBC* **234** 113 *1959*; IR: Fölsch and Mellander *Acta Chem Scand* **11** 1232 *1957*].

***O*-Phospho-L-threonine (L-threonine-*O*-phosphate)** *[1114-81-4]* **M 199.1, m 194°(dec), $[\alpha]_D^{24}$ -7.37° (c 2.8, H_2O).** Dissolve in the minimum volume of H_2O, add charcoal, stir for a few min, filter and apply onto a Dowex 50W (H^+ form) then elute with 2N HCl. Evaporate the eluates under reduced pressure whereby the desired fraction produced crystals of the phosphate which can be recrystd from H_2O-MeOH mixtures and the crystals are then dried *in vacuo* over P_2O_5 at ~80°. [de Verdier *Acta Chem Scand* **7** 196 *1953*].

***O*-Phospho-L-tyrosine (L-tyrosine-*O*-phosphate]** *[21820-51-9]* **M 261.2, m 225°, 227°, 253°, $[\alpha]_D^{20}$ -5.5° (c 1, H_2O), -9.2° (c 1, 2N HCl).** Purified by recrystn from H_2O or H_2O + EtOH. [Levene and Schormüller *JBC* **100** 583 *1933*; Posternak and Graff *HCA* **28** 1258 *1945*].

Phytol (*d*-3,7*R*,11*R*,15-tetramethylhexadec-2-en-1-ol) *[150-86-7]* **M 296.5, b 145°/0.03mm, 150-151°/0.06mm, 202-204°/10mm, d_4^{25} 0.8497, n_D^{25} 1.437, $[\alpha]_D^{22}$+0.06° (neat).** Purified by distn under high vacuum. It is almost insoluble in H_2O but soluble in most organic solvents. It has UV λ_{max} at 212nm (log ε 3.04) in EtOH and IR ν at 3300 and 1670cm^{-1}. [Demole and Lederer *Bull Soc Chim France* 1128 *1958*; Burrell *JCS (C)* 2144 *1966*; Bader *HCA* **34** 1632 *1951*].

D-Pipecolinic acid (*R*-piperidine-2-carboxylic acid) *[1723-00-8]* **M 129.2, m 264°(dec), 267°(dec), ~280°(dec), $[\alpha]_D^{19}$+26.2° (c 2, H_2O), $[\alpha]_D^{25}$+35.7° (H_2O).** Recrystallises as platelets from EtOH and is soluble in H_2O. The *hydrochloride* has **m** 256-257°(dec) from H_2O and $[\alpha]_D^{25}$ +10.8° (c 2, H_2O). [Lukés et al. *Coll Czech Chem Commun* **22** 286 *1957*; Bayerman *Rec Trav Chim Pays-Bas* **78** 134 *1959*; Asher et al. *TET LETT* **22** 141 *1981*].

L-Pipecolinic acid (*S*-piperidine-2-carboxylic acid) *[3105-95-1]* **M 129.2, m 268°(dec), 271°(dec), ~280°(dec), $[\alpha]_D^{20}$ -26° (c 4, H_2O), $[\alpha]_D^{25}$ -34.9° (H_2O).** Recrystd from aqueous EtOH and sublimes as needles in a vacuum. It is sparingly soluble in absolute EtOH, Me_2CO and $CHCl_3$ but insoluble in Et_2O. The *hydrochloride* has **m** 258-259°(dec, from MeOH) and $[\alpha]_D^{25}$ -10.8° (c 10, H_2O). [Fujii and Myoshi *Bull Chem Soc Japan* **48** 1241 *1975*].

Piperidine-4-carboxylic acid (isonipecotic acid) *[498-94-2]* **M 129.2, m 336°(dec, darkens at ~300°).** Recrystallises from H_2O or EtOH as needles. The *hydrochloride* recrystallises from H_2O or aqueous HCl and has **m** 293°dec (298°dec, 300°dec). [Wibaut *Rec Trav Chim Pays Bas* **63** *141* 1944; IR: Zacharius et al. *JACS* **76** 2908 *1954*].

Pituitary Growth Factor (from human pituitary gland). Purified by heparin and copper affinity chromatography, followed by carboxymethyl cellulose (Whatman 52). [Rowe et al. *Biochemistry* **25** 6421 *1986*].

Podophylotoxin *[518-28-5]* **M 414,4, m 181-181°, 183-184°, 188-189°, $[\alpha]_D^{20}$ -132° (c 1, $CHCl_3$).** Recrystallises form C_6H_6 (with $0.5C_6H_6$), EtOH-C_6H_6, aqueous EtOH (with $1\text{-}1.5H_2O$, **m** 114-115°) and CH_2Cl_2-pentane. When dried at 100°/10 mm it has **m** 183-184°. [UV: Stoll et al. *HCA* **37** 1747

1954; IR: Schecler et al. *JOC* **21** 288 *1956*]. Inhibitor of microtubule assembly [Prasad et al. *Biochemistry* **25** 739 *1986*].

Polyethylene glycol. May be contaminated with aldehydes and peroxides. Methods are available for removing interfering species. [Ray and Purathingal *AB* **146** 307 *1985*].

Porphobilinogen (5-amino-4-carboxymethyl-1*H*-pyrrole-3-propionic acid) *[487-90-1]* **M 226.2, m 172-175°(dec), 175-180°(dec, darkening at 120-130°).** Recrystallises as the monohydrate (pink crystals) from dil NH_4 OAc solns of pH 4, and is dried *in vacuo*. It has pKa values of 3.70, 4.95 and 10.1. The *hydrochloride monohydrate* has **m** 165-170°(dec) (from dilute HCl). [Jackson and MacDonald *Canad J Chem* **35** 715 *1957*, Westall *Nature* **170** 614 *1952*; Bogarad *JACS* **75** 3610 *1953*].

Porphyrin a (from ox heart). Purified on a cellulose powder column followed by extraction with 17% HCl and fractionation with HCl. [Morell et al. *BJ* **78** 793 *1961*].

Prazosin hydrochloride (2[4-{(2-furoyl)piperazin-1-yl}4-amino-6,7-dimethoxyquinazoline hydrochloride) *[19237-84-4]* **M 419.9, m 278-280°, 280-282°.** It is recrystd by dissolving in hot MeOH adding a small volume of MeOH-HCl (dry MeOH saturated with dry HCl gas) followed by dry Et_2O until crystn is complete. Dry *in vacuo* over solid KOH till odour of HCl is absent. It has been recrystd from hot H_2O, the crystals were washed with H_2O, and the H_2O was removed azeotropically with CH_2Cl_2, and dried in a vacuum. [NMR and IR: Honkanen et al. *JHC* **17** 797 *1980*; *cf* Armarego and Reece *Australian J Chem* **34** 1561 *1981*]. It is an antihypertensive drug and is an α_1-adrenergic antagonist [Brosman et al. *Proc Natl Acad Sci USA* **82** 5915 *1985*].

Prednisolone acetate (21-acetoxypregna-1,4-diene-11β-17α-diol-3,20-dione) *[52-21-1]* **M 402.5, m 237-239°, 240-242°, 240-243°, 244°, $[\alpha]_D^{20}$ +116° (c 1, dioxane).** Recrystd from EtOH, Me_2CO, Me_2CO-hexane, and has UV λ_{max} at 243nm in EtOH. [Joly et al. *Bull Soc Chim France* 366 *1958*; Herzog et al. *JACS* **77** 4781 *1955*].

Primaquine diphosphate (*RS*- 8-[4-amino-1-methylbutylamino]-6-methoxyquinoline diphosphate) *[63-45-6]* **M 455.4, m 197-198°, 204-206°.** It forms yellow crystals from 90% aq EtOH and is moderately soluble in H_2O. The *oxalate salt* has **m** 182.5-185° (from 80% aq EtOH) and the *free base* is a viscous liquid **b** 165-170°/0.002mm, 175-177°/2mm. [Elderfield et al. *JACS* **68** 1526 *1964*; **77** 4817 *1955*].

Procaine hydrochloride (Novocain, 2-diethylaminoethyl-4-aminobenzoate) *[51-05-8]* **M 272.8, m 153-156°, 154-156°, 156°.** Recrystd from aqueous EtOH. It has solubility at 25° in H_2O (86.3%), EtOH (2.6%) and Me_2CO (1%), it is slightly soluble in $CHCl_3$ but is almost insoluble in Et_2O. The anhydrous *free base* is recrystd from ligroin or Et_2O and has **m** 61°. [Einhorn *A* **371** 125 *1909*; IR: Szymanski and Panzica *J Amer Pharm Assoc* 47 443 *1958*].

L-C-Propargylglycine (*S*-2-aminopent-4-ynoic acid) *[23235-01-0]* **M 113.1, m 230°(dec starting at 210°), $[\alpha]_D^{20}$ -35° (c 1,H_2O), -4° (c 5, 5N HCl).** Recrystd from aqueous Me_2CO, R_F on SiO_2 TLC plates with *n*-BuOH-H_2O-AcOH (4:1;1) is 0.26. The *racemate* has **m** 238-240°. [Leukart et al. *HCA* **59** 2181 *1976*; Eberle and Zeller *HCA* **68** 1880 *1985*; Jansen et al. *Rec Trav Chim Pays Bas* **88** 819 *1969*]. It is a suicide inhibitor of γ-cystathionase and other enzymes [Washtier and Abeles *Biochemistry* **16** 2485 *1977*; Shinozuka et al. *Eur J Biochem* **124** 377*1982*].

Propidium iodide (3,8-diamino-5-(3-diethylaminopropyl)-6-phenylphenantridinium iodide methiodide) *[25535-16-4]* **M 668.4, m 210-230°(dec).** Recrystd as red crystals from H_2O containing a little KI. It fluoresces strongly with nucleic acids. [Eatkins *JCS* 3059 *1952*].

***R*-Propranalol hydrochloride (*R*-1-isopropylamino-3-(1-naphthyloxy)-2-propanol HCl)** *[13071-11-9]* **M 295.8, m 192°, 193-195°, $[\alpha]_D^{20}$ -25° (c 1, EtOH).** Recryst from *n*-PrOH or Me_2CO. It is soluble in H_2O and EtOH but is insoluble in Et_2O, C_6H_6 or EtOAc. The *racemate* has **m** 163-

164°, and the *free base* recryst from cyclohexane has **m** 96°. [Howe and Shanks *Nature* **210** 1336 *1966*]. The *S*-isomer (below) is the physiologically active isomer.

***S*-Propranalol hydrochloride** (*S*-1-isopropylamino-3-(1-naphthyloxy)-2-propanol HCl) *[4199-10-4]* **M 295.8, m 192°, 193-195°, $[\alpha]_D^{20}$ +25° (c 1, EtOH).** See preceding entry for physical properties. The is the active isomer which blocks isoprenaline tachycardia and is a β-adrenergic blocker. [Leclerc et al. *Trends in Pharmaceutical Sci* **2** 18 *1981*; Howe and Shanks *Nature* **210** 1336 *1966*].

Protamine kinase (from rainbow trout testes). Partial purification by hydoxylapatite charomatography followed by biospecific chromatography on nucleotide coupled Sepharose 4B (the nucleotide was 8-(6-aminohexyl)amine coupled cyclic-AMP). [Jergil et al. *BJ* **139** 441 *1974*].

Protamine sulphate (from herring sperm) *[9007-31-2]* **$[\alpha]_D^{22}$-85.5° (satd H_2O).** A strongly basic protein (white powder) with pKa values of 7.4-8.0 used to ppte nucleic acids from crude protein extracts. It dissolved to the extent of 1.25% in H_2O. It is freely soluble in hot H_2O but separates as an oil on cooling. It has been purified by chromatography on an IRA-400 ion-exchange resin in the SO_4^{2-} form and washed with dilute H_2SO_4. Eluates are freeze-dried under high vacuum below 20°. This method is used to convert proteamine and protamine hydrochloride to the sulphate. [UV: Rasmussen *Z physiol Chem* **224** 97 *1934*; Ando and Sawada *J Biochem Tokyo* **49** 252 *1961*; Felix and Hashimoto *Z physiol Chem* **330** 205 *1963*]

Protease nexin. (From cultured human fibroblasts). Purified by affinity binding of protease nexin to dextran sulphate-Sepharose. [Farrell et al. *BJ* **237** 707 *1986*].

Proteoglycans (from cultured human muscle cells). Separated by ion-exchange HPLC using a Bio-gel TSKDEAE 5-PW analytical column. [Harper et al. *AB* **159** 150 *1986*].

Prothrombin (from equine blood plasma). Purified by two absorptions on a barium citrate adsorbent, followed by decomposition of the adsorbents with a weak carboxylic cation-exchanger (Amberlite IRF-97), isoelectric pptn (pH 4.7-4.9) and further purification by chromatography on Sephadex G-200 or IRC-50. Finally recrystd from a 1% soln adjusted to pH 6.0-7.0 and partial lyophilisation to *ca* 1/5 to 1/10th vol and set aside at 2-5° to crystallise. Occasionally seeding is required.. [Miller *Biochemical Preparations* **13** 49 *1971*].

Protoporphyrin IX (3,18-divinyl-2,7,13,17-tetramethylporphine-8,12-dipropionic acid, ooporphyrin) *[553-12-8]* **M 562.7.** Purified by dissolving (4g) in 98-100% HCOOH (85ml), diluting with dry Et_2O (700ml) and keeping at 0° overnight. The ppte is collected and washed with Et_2O then H_2O and dried in a vacuum at 50° over P_2O_5. It has been recrystd from aqueous pyridine and from Et_2O as monoclinic, brownish-yellow prisms. UV λ_{max} values in 25% HCl are 557.2, 582.2 and 602.4nm. It is freely soluble in ethanolic HCl, AcOH, $CHCl_3$, and Et_2O containing AcOH. It forms sparingly soluble diNa and diK salts. [Ramsey *Biochemical Preparations* **3** 39 *1953*; UV: Holden *Australian J. Exptl Biol and Med Sci* **15** 412 *1937*; Garnick *JBC* **175** 333 *1948*; IR: Falk and Willis *Australian J Scientific Research* [A] **4** 579 *1951*].
The **Dimethyl ester** *[5522-66-7]* **M 590.7, m 228-230°**, is prepared by dissolving (0.4g) in $CHCl_3$ (33ml) by boiling for a few min, then diluting with boiling MeOH (100ml) and refrigerating for 2 days. The crystals are collected, washed with $CHCl_3$-MeOH (1:9) and dried at 50° in a vacuum (yield 0.3g). UV has λ_{max} 631, 576, 541, 506 and 407nm in $CHCl_3$ and 601, 556 and 406nm in 25% HCl. [Ramsey *Biochemical Preparations* **3** 39 *1953*].

Pterin-6-carboxylic acid (2-amino-4-oxo-3,4-dihydropteridine-6-carboxylic acid) *[948-60-7]* **M 207.2, m >360°.** Yellow crystals by repeated dissolution in aqueous NaOH and adding aqueous HCl. It has pKa^{20} values of 1.43, 2.88 and 7.72 in H_2O. UV has λ_{max} at 235, 260 and 265nm (ε 11000, 10500 and 9000) in 0.1N HCl and 263 and 365nm (ε 20500 and 9000) in 0.1N NaOH. [UV: Pfleiderer et al. *A* **741** 64 *1970*; Stockstad et al. *JACS* **70** 5 *1948*; Fluorescence: Kavanagh and Goodwin *Arch Biochem* **20** 315 *1949*].

Purine-9-β-ribifuranoside (Nebularin) *[550-33-4]* **M 252.2, m 178-180°, 181-182°, $[\alpha]_D^{25}$ -48.6° (c 1, H_2O), -22° (c 0.8, 0.1N HCl) and -61° (c 0.8, 0.1N NaOH).** Recrystd from butanone + MeOH or EtOH and forms a MeOH photo-adduct. It is a strong inhibitor of adenosine deaminase

[EC 3.5.4.4]. [Nair and Weichert *Bioorganic Chem* **9** 423 *1980*; Löfgren et al. *Acta Chem Scand* **7** 225 *1953*; UV: Brown and Weliky *JBC* **204** 1019 *1953*].

Puromycin dihydrochloride (***O*-methyl-l-tyrosine[N^6,N^6-dimethylaminoadenosin-3'-yl-amide]**) *[58-58-2]* **M 616.5, m 174°, $[\alpha]_D^{25}$ -11° (free base in EtOH).** Purified by recrystn from H_2O. It has pKa values of 6.8 and 7.2 in H_2O. The *free base* has **m** 175.5-177° (172-173°) (from H_2O). The *sulphate* has **m** 180-187° dec (from H_2O), and the *picrate monohydrate* has **m** 146-149° (from H_2O). [Baker et al. *JACS* **77** 1 *1955*; Fryth et al. *JACS* **80** 3736 *1958*]. It is an inhibitor of aminopeptidase and terminates protein synthesis [Reboud et al. *Biochemistry* **20** 5281 *1981*].

Pyridine-2-carboxaldoxime *[873-69-8]* **M 122.1, m 111-113°, 114°.** Purified by recrystn from Et_2O-pet ether. It has pKa^{25} values of 3.2 and 10.2 in H_2O. The *picrate* has **m** 169-171° (from aqueous EtOH). It is used in peptide synthesis. [UV: Grammaticakis *Bull Chem Soc France* 109, 116 *1956*; Ginsberg and Wilson *JACS* **79** 481 *1957*; Hanania and Irvine *Nature* **183** 40 *1959*; Green and Saville *JCS* 3887 *1956*].

Pyridoxal hydrochloride *[65-12-5]* **M 203.6, m 176-180°(dec).** Dissolve in water and adjust the pH to 6 with NaOH. Set aside overnight to crystallise. The crystals are washed with cold water, dried in a vacuum desiccator over P_2O_5 and stored in a brown bottle at room temperature. [Fleck and Alberty *JPC* **66** 1678 *1962*].

Pyridoxal-5'-phosphate monohydrate (**PLP, codecarboxylase**) *[54-47-7]* **M 265.2.** It has been purified by dissolving 2g in H_2O (10-15ml, in a dialysis bag a third full) and dialysing with gentle stirring against 1L of H_2O (+ two drops of toluene) for 15h in a cold room. The dialysate is evaporated to 80-100 ml then lyophilised. Lemon yellow microscopic needles of the monohydrate remain when all the ice crystals have been removed. The purity is checked by paper chromatography (in EtOH or *n*-PrOH-NH_3) and the spot(s) visualised under UV light after reaction with *p*-phenylene diamine, NH_3 and molybdate. Solutions stored in a freezer are 2-3% hydrolysed in 3-weeks. At 25°, only 4-6% hydrolysis occurs even in N NaOH or HCl, and 2% is hydrolysed at 37° in 1 day - but is complete at 100° in 4h. Best stored as dry solid at -20°. In aqueous acid the solution is colourless but is yellow in alkaline solutions. It has UV λ_{max} at 305nm (ε 1100) and 380nm (ε 6550) in 0.1 N NaOH; 330nm (ε 2450) and 388nm (ε 4900) in 0.05M phosphate buffer pH 7.0 and 295nm (ε 6700) in 0.1N HCl. [Peterson et al. *Biochemical Preparations* **3** 34, 119 *1953*]. The *oxime* dec at 229-230° and is practically insoluble in H_2O, EtOH and Et_2O. The *O-methloxime* decomposes at 212-213°. [Heyl et al *JACS* **73** 3430 *1951*]. It has also been purified by column chromatography through Amberlite IRC-50 (H^+) [Peterson and Sober *JACS* **76** 169 *1954*].

Pyridoxamine hydrochloride *[5103-96-8]* **M 241.2, m 226-227°(dec).** Crystd from hot MeOH. The *free base* crystallises from EtOH and has **m** 193-193.5°. [Harris et al. *JBC* **154** 315 *1944*, *JACS* **66** 2088 *1944*].

Pyridoxine hydrochloride (vitamin B_6) *[58-56-0]* **M 205.7, m 209-210°(dec).** Crystd from EtOH/acetone.

Prymnesin (**toxic protein from phytoflagellate *Pyrymnesium parvum*).** Purified by column chromatography, differential soln and pptn in solvent mixtures and differential partition between diphasic mixtures. The product has at least 6 components as observed by TLC. [Ulitzur and Shilo *Biochim Biophys Acta* **301** 350 *1970*].

Pyruvate kinase isoenzymes (**from *Salmonella typhimurium*).** Purified by $(NH_4)_2SO_4$ fractionation and gel filtration, ion-exchange and affinity chromatography. [Garcia-Olalla and Garrido-Pertierra *BJ* **241** 573 *1987*].

Quisqualic acid (3-[3,5-dioxo-1,2,4-oxadiazolin-2-yl]-L-alanine) *[52809-07-1]*

M 189.1, m 190-191°, $[\alpha]_D^{20}$ +17° (c 2, 6M HCl). It has been purified by ion-exchange

chromatography on Dowex 50W (x 8, H^+ form), the desired fractions are lyophilised and recrystd from H_2O-EtOH. It has IR (KBr) ν: 3400-2750br, 1830s, 1775s, 1745s and 1605s cm^{-1}; and ^1H NMR (NaOD, pH 13) d: 3.55-3.57 (1H m, X of ABX, H-2), 3.72-3.85 (2H, AB of ABX, H-3) ppm, ^{13}C NMR (D_2O) δ: 50.1t, 53.4d, 154.8s, 159.7s and 171.3s ppm. [Baldwin et al. *JCSCC* 256 *1985*]. It is a quasiqualate receptor agonist [Joels et al. *Proc Natl Acad Sci USA* **86** 3404 *1989*].

Renal dipeptidase (from porcine kidney cortex) M_r 47,000 [EC 3.4.13.11].

Purified by homogenising the tissue, extracting with Triton X-100, elimination of insoluble material, and ion-exchange, size exclusion and affinity chromatography. [Hitchcock et al. *AB* **163** 219 *1987*].

Retinal see **Vitamin A aldehyde.**

Retinyl acetate,
Retinyl palmitate see entries in Chapter 3.

Reverse transcriptase (from avian or murine RNA tumour viruses) *[9068-38-6].* Purified by solubilising the virus with non-ionic detergent. Lysed virions were adsorbed on DEAE-cellulose or DEAE-Sephadex columns and the enzyme eluted with a salt gradient, then chromatographed on a phosphocellulose column and enzyme activity eluted in a salt gradient. Purified from other viral proteins by affinity chromatography on a pyran-Sepharose column. [Verna *Biochim Biophys Acta* **473** 1 *1977*; Smith *Methods in Enzymology* **65** 560 *1980*].

L-α-Rhamnose (H_2O) see entry in Chapter 3.

Riboflavin *[83-88-5]* **M 376.4, m 295-300°(dec), $[\alpha]_D$ -9.8° (H_2O), -125° (c 5, 0.05N NaOH).** Crystd from 2M acetic acid, then extracted with $CHCl_3$ to remove lumichrome impurity. [Smith and Metzler *JACS* **85** 3285 *1963*]. Has also been crystd from water.

Riboflavin-5'-phosphate (Na salt, $2H_2O$) *[130-40-5]* **M 514.4.** Crystd from acidic aqueous soln.

D-(+)-Ribonic acid-γ-lactone *[5336-08-3]* **M 148.12, m 80°, 84-86°, $[\alpha]_D^{20}$ +18.3° (c 5, H_2O).** Purified by recrystn from EtOAc. The *tribenzoate* has **m** 54-56° (from AcOH), $[\alpha]_D^{25}$ +27° (c 2.37, Me_2NCHO) and the *3,5-O-benzylidene* deivative has **m** 230-231.5° (needles from Me_2CO-pet ether), $[\alpha]_D^{25}$ -177° ($CHCl_3$). [Chen and Joulié *JOC* **49** 2168 *1984*; Zinner and Voigt *J Carbohydrate Research* **7** 38 *1968*].

Ribonuclease (from human plasma). Purified by $(NH_4)_2SO_4$ fractionation, followed by PC cellulose chromatography and affinity chromatography (using Sepharose 4B to which $(G)_n$ was covalently bonded). [Schmukler et al. *JBC* **250** 2206 *1975*].

Ribonucleic acid (RNA). Martin et al. [*BJ* **89** 327 *1963*] dissolved RNA (5g) in 90ml of 0.1mM EDTA, then homogenised with 90ml of 90% (w/v) phenol in water using a Teflon pestle. The suspension was stirred vigorously for 1h at room temperature, then centrifuged for 1h at 0° at 25000rpm. The lower (phenol) layer was extracted four times with 0.1mM EDTA and the aqueous layers were combined, then made 2% (w/v) with respect to AcOK and 70% (v/v) with respect to EtOH. After standing overnight at -20°, the ppte was centrifuged down, dissolved in 50ml of 0.1mM EDTA, made 0.3M in NaCl and left 3 days at 0°. The purified RNA was then centrifuged down at 10000xg for 30min, dissolved in 100ml of 0.1mM EDTA, dialysed at 4° against water, and freeze-dried. It was stored at -20° in a desiccator. Michelson [*JCS* 1371 *1959*] dissolved 10g of RNA in water, added 2M ammonia to adjust the pH to 7, then dialysed in Visking tubing against five volumes of water for 24h. The process was repeated three times, then the material after dialysis was treated with 2M HCl and EtOH to ppte the RNA which was collected, washed with EtOH, ether and dried.

α-D-Ribose see entry in Chapter 3.

Ricin (toxin from Castor bean [*Ricinus communis*]) *[96628-29-8].* Crude ricin, obtained by aqueous extraction and $(NH_4)_2SO_4$ pptn, was chromatographed on a galactosyl-Sepharose column with sequential elution of pure ricin. The second peak was due to ricin agglutinin. [Simmons and Russell *AB* **146** 206 *1985*]. **EXTREMELY DANGEROUS, USE EXTREME CARE [instructions accompany the product].**

Ricinoleic acid see entry in Chapter 3.

Rifampicin (Rifampin) *[13292-46-1]* **M 823.0, m 183-185°.** This macrolide antibiotic crystallises form Me_2CO in red-orange plates. It has UV λ_{max} 237, 255,334, and 475nm (ε 33,200, 32,100, 27,000 and 15,400) at pH 7.38. It has pKa values at 1.7 and 7.9, Stable in Me_2SO and H_2O. Freely soluble in most organic solvents and slightly soluble in H_2O at pH <6. [Binda et al. *Arzneimittel-Forsch* **21** 1907 *1971*]. It inhibits cellular RNA synthesis without affecting DNA [Calvori et al. *Nature* **207** 417 *1965*].

Rifamycin B *[13929-35-6]* **M 755.8, m 300° (darkening at 160-164°, $[\alpha]_D^{20}$ -11° (MeOH).** It forms yellow needles from C_6H_6. It has solubility in H_2O (0,027%), MeOH (2.62%) and EtOH (0.44%). It has pKa values of 2.60 and 7.76 and UV λ_{max} 223, 304 and 245nm ($E_{1cm}^{1\%}$ 555, 275 and 220). [Oppolzer and Prelog *HCA* **56** 2287 *1973*; Oppolzer et al. *Experientia* **20** 336 *1964*; X-ray: Brufani et al. *Experientia* **20** 339 *1964*].

Rifamycin SV sodium salt *[15105-92-7]* **M 719.8, m 300°(darkening >140°), $[\alpha]_D^{20}$ -4° (MeOH).** Yellow orange crystals from Et_2O-pet ether or aq EtOH, very soluble in MeOH, EtOH, Me_2CO and EtOAc, soluble in Et_2O and HCO_3^-, slightly soluble in H_2O and pet ether. Its UV has λ_{max} at 223, 314 and 445nm ($E_{1cm}^{1\%}$ 586, 322 and 204) in phosphate buffer pH 7. [NMR: Bergamini and Fowst *Arzneimittel-Forsch* **15** 951 *1965*].

Saccharides.

Resolved by anion-exchange chromatography. [Walberg and Kando *AB* **37** 320 *1970*].

(-)-Scopolamine hydrobromide $2H_2O$ (6β,7β-epoxy-3α-tropanyl *S*(-)-tropate HBr, hyoscine HBr) *[114-49-8]* **M 438.3, m 193-194°, 195°, 195-199°, $[\alpha]_D^{25}$ -25°(c 5, H_2O).** Recrystd from Me_2CO, H_2O or EtOH-Et_2O and dried. Soluble in H_2O (60%) and EtOH (5%) but insol in Et_2O and slightly in $CHCl_3$. The *hydrochloride* has **m** 300° (from Me_2CO). The *free base* is a viscous liquid which forms a crystalline *hydrate* with **m** 59° and $[\alpha]_D^{20}$ -28° (c 2.7, H_2O). Readily hydrolysed in dilute acid or base. [Meinwald *JCS* 712 *1953*; Fodor *TET* **1** 86 *1957*].

Seleno-DL-methionine (±2-amino-4-methylselanylbutyric acid) *[2578-28-1]* **M 196.1, m 265°(dec), 267-269°(dec), 270°.** Crystallises in hexagonal plates from MeOH and H_2O. [Klosterman and Painter *JACS* **69** 2009 *1949*]. The **L-Isomer** is purified by dissolving in H_2O, adjusting the pH to 5.5 with aqueous NH_3, evaporating to near-dryness, and the residue is washed several times with absolute EtOH till solid is formed and then recrystd from Me_2CO. It has **m** 266-268°(dec), 275°(dec), $[\alpha]_D^{25}$ +18.1°(c 1, N HCl). [Pande et al. *JOC* **35** 1440 *1970*].

Serotonin hydrochloride (5-HT, 3-[2-aminoethyl]-5-hydroxyindole HCl) *[153-98-0]* **M 212.7, m 167-168°, 178-180°.** Purified by recrystn from EtOH-Et_2O or Et_2O to give the *hygroscopic* salt. Store in the dark as it is light sensitive. The *free base* has **m** 84-86° (from Et_2O). The *5-benzyloxy* derivative has **m** 84-86° (from Et_2O). [Ek and Witkop *JACS* **76** 5579 *1954*; Hamlin and Fischer *JACS* **73** 5007 *1951*]. The *picrate* $1H_2O$ has **m** 196-197.5° (dec with sintering at 160-165°) after recrystn from Et_2O. Serotonin is a natural neurotransmitter [Chuang *Life Science* **41** 1051 *1987*].

Singrin monohydrate (Myronate K) *[64550-88-5]* **M 415.5, m 125-127°, 127-129°, $[\alpha]_D^{20}$ -17° (c 0.2, H_2O).** Purified by recryst three times from EtOH and once from MeOH. The *tetraacetate* has

m 193-195°, $[\alpha]_D^{20}$ -16° (c 0.14, H_2O). [Benn et al. *JCSCC* 445 *1965*; Kjaer et al. *Acta Chem Scand* **10** 432 *1956*; Marsh et al. *Acta Cryst (Sect B)* **26** 1030 *1970*]. It is a β-D-thioglucopyranoside substrate for thiogluconidase [MacLeod and Rossiter *Phytochem* **25** 1047 *1986*].

α-Solanin (solan-5-en-3β-yl-[*O*^{3}-β-D-glucopyranosyl-*O*^{2}-α-L-rhamnopyranosyl-β-D-galactopyranoside]) *[20562-02-1]* **M 868.0, m 285°(dec), 286°(dec) (sintering >190°), $[\alpha]_D^{20}$ -58° (c 0.8, pyridine).** Recrystd from EtOH, 85% aqueous EtOH, MeOH or aqueous MeOH as *dihydrate* **m** 276-278°. Solubility in H_2O is 25mg/L and 5% in pyridine, but it is very soluble in Et_2O and $CHCl_3$. It has pKa^{15} value of 6.66. The *hydrochloride* is gummy or amorphous but has been crystd (**m** ~212° dec). It has insecticidal properties. [Kuhn et al. *B* **88** 1492 *1955]*.

Somatostatin *[38916-34-6]* **M 1637.9, $[\alpha]_D^{25}$ -36° (c 0.57, 1% AcOH).** A tetradecapeptide which is purified by gel filtration on Sephadex G-25, eluting with 2N AcOH, and then by liquid partition chromatography on Sepahdex G-25 using *n*-BuOH-AcOH-H_2O (4:1:5) and has $R_F = 0.4$. It is a brain growth hormone releasing-inhibiting factor which has also been synthesised. [Burgus et al. *Proc Natl Acad Sci USA* **70** 684 *1973*; Sorantakis and McKinley *BBRC* **54** 234 *1973;* Hartridt et al. *Pharmazie* **37** 403 *1982*].

Spectinomycin dihydrochloride pentahydrate (Actinospectacin) *[21736-83-4]* **M 495.3, m 205-207°(dec), $[\alpha]_D^{20}$ +14.8° (c 0.4, H_2O).** Purified from aqueous Me_2CO and is soluble in H_2O, MeOH and dilute acid and base but only slightly soluble in Me_2CO, EtOH, $CHCl_3$ and C_6H_6. The *free base* is an amorphous solid, **m** 184-194° with $[\alpha]_D^{20}$ -20° (H_2O), and pKa values of 6.95 (6.78) and 8.70 (8.80). [Wiley et al. *JACS* **93** 2652 *1963*; X-ray: Cochran et al. *JCS Chem Commun* 494 *1972*]. It is an aminoglycoside antibiotic which interacts with 16S ribosomal RNA [Moazet and Noller *Nature* **327** 389 *1987*]; and is used for the treatment of gonorrhea [Rinehart *J Infect Diseases* **119** 345 *1969*].

D-Sphingosine (2*S*,3*S*-D-*erythro*-2-aminooctadec-4*t*-ene-1,3-diol from bovine brain) *[123-78-4]* **M 299.5, m 79-82°, 82° 82.5° (softens at ~70°), $[\alpha]_D^{22}$ -3.4° (c 2, $CHCl_3$).** Purified by recrystn from EtOAc, Et_2O or pet ether (60-80°) It is insoluble in H_2O but is soluble in Me_2CO, EtOH and MeOH. It has IR bands at 1590 and 875 cm^{-1}, and is characterised as the *tribenzoate* **m** 122-123° (from 95% EtOH). [Tipton *Biochemical Preparations* **9** 127 *1962*].

Spirilloxanthin *[34255-08-8]* **M 596.9, m 216-218°.** Crystd from $CHCl_3$/pet ether, acetone/pet ether, C_6H_6/pet ether or C_6H_6. Purified by chromatography on a column of $CaCO_3$/$Ca(OH)_2$ mixture or deactivated alumina. It has UV λ_{max} at 463, 493 and 528nm, $E_{1cm}^{1\%}$ 2680 (493nm), in pet ether (b 40-70°). [Polgar et al. *Arch Biochem Biophys* **5** 243 *1944*]. Stored in the dark in an inert atmosphere, at -20°.

Squalane (Cosbiol, 2,6,10,15,19,23-hexamethyltetracosane, perhydrosqualene) *[111-01-3]* **M 422.8, m -38°, b 176°/0.05mm, 210-215°/1mm, 248°/5mm, 274°/10mm, ~350°/760mm, d_4^{20} 0.80785, n_D^{20} 1.416.** Purified by fractional distn *in vacuo* or evaporative distn. It is very soluble in pet ether, C_6H_6, Et_2O and $CHCl_3$, slightly soluble in alcohols, M_2CO and AcOH but insoluble in H_2O. [Staudinger and Leupold *HCA* **15** 223 *1932*; Sax and Stross *AC* **29** 1700 *1951*; Mandai et al. *TET LETT* **22** 763 *1981*].

Squalene (all-*trans*- 2,6,10,15,19,23-hexamethyltetracosahexa-2,6,10,14,18,22-ene, spinacen) *[111-02-4]* **M 410.7, m ~75°, b 203°/0.15mm, 240°/2mm, 285°/25mm, d_4^{20} 0.8584, n_D^{20} 1.49655.** Viscous liquid which is distd under as high a vacuum as possible. It is oxygen and light sensitive, and is soluble in Me_2CO, CCl_4, pet ether and Et_2O but insoluble in H_2O. Its iodine number is between 360 and 380. It has bactericidal properties. [Heilbron and Thompson *JCS* 883 *1929*; Karrer et al. *HCA* **13** 1084 *1930*; UV: Farmer et al. *JCS* 544 *1943*].

Starch *[9005-84-9]* **M (162.1)n.** Defatted by Soxhlet extraction with Et_2O or 95% EtOH. For fractionation of starch into "amylose" and "amylopectin" fractions, see Lansky, Kooi and Schoch [*JACS* **71** 4066 *1949*].

Sterigmatocystin (3a,12c-dihydro-8-hydroxy-6-methoxy-3*H*-furo[3',2',:4,5]furo[2,3-c]xanthen-7-one) *[10048-13-2]* **M 324.3, m 246°, 247-248°, $[\alpha]_D^{20}$ -398° (c 0.1, $CHCl_3$).** Recrystd from amyl acetate, Me_2CO or EtOH and sublimed *in vacuo*. It has UV λ_{max} at 208, 235, 249 and 329nm (log ε 4.28, 4.39, 4.44 and 4.12). [UV: Bullock et al. *JCA* 4179, *1962*; UV, IR: Holker and Mulheirn *JCS Chem Commun* 1576, 1576 *1968*; Birkinshaw and Hammady *BJ* **65** 162 *1957*]. This mycotoxin induces bone marrow changes in mice [Curry et al. *Mutation Research* **137** 111 *1984*].

Stigmatellin A (2-[4,6-dimethoxy-3,5,11-trimethyltridecatri-7*t*,9*t*,11*t*-enyl]-8-hydroxy-5,7-dimethyoxy-3-methyl-4*H*-1-benzopyran-4-one) *[91682-96-1]* **M 514.6, m 128-130°, $[\alpha]_D^{20}$ +38.5° (c 2.3, MeOH).** It is stable in aqueous soln at neutral pH but decomposes at pH <5. Purified by recrystn from toluene-hexane). It has UV λ_{max}: nm (ε) 248sh (41000), 258 (59500) 267 (65500), 279 (41400) and 335 (5200) in MeOH; 249sh (45600), 258 (60000), 268 (72700), 277 (54100), 320 (2500) and 370 (3000) in MeOH + 1 drop of N KOH; 243sh (29300), 264 (63200), 274 (64100), 283sh (45800), 329 (4800) and 420 (21000) in MeOH + 6N HCl; and IR ($CHCl_3$) ν: 3550m, 1645chs, 1635ss, 1620ss, 1590s, 1510m and 905m cm^{-1}. It gives color reactions at 110° with vanillin/H_2SO_4 (grey), Cer(IV)/$(NH_4)_2SO_4$ (yellow) and phosphomolybdate (blue-grey). [Höfle et al. *A* 1882 *1984*]. It inhibits electron transport [Jagow and Link *Methods in Enzymology* **126** 253 *1986*; Robertson et al. *Biochemistry* **32** 1310 *1933*], and has antibiotic properties [Kunze et al. *J Antibiot* **37** 454 *1984*]. The **7*t*,9*t*,11*c*-isomer** is ***Stigmatellin B*.**

Streptomycin sulphate *[3810-74-0]* **M 1457.4, $[\alpha]_D^{20}$ -84.3° (c 3, H_2O).** Recrystd from H_2O-EtOH, washed with a little EtOH, Et_2O and dried in a vacuum. [UV and IR: Grove and Randall *Antibiotics Monographs NY* **2** 163 *1855*; Heuser et al. *JACS* **75** 4013 *1953*, Kuehl et al. *JACS* **68** 1460 *1946*; Regna et al. *JBC* **165** 631 *1946*]. During protein synthesis it inhibits initiation and causes misreading of mRNA [Zierhut et al. *Eur J Biochem* **98** 577 *1979*; Chandra and Gray *Methods in Enzymology* **184** 70 *1990*].

Streptonegrin (negrin, 5-amino-6-[7-amino-5,8-dihydro-6-methoxy-5,8-dioxo-2-quinolinyl]-4-[2-hydroxy-3,4-dimethoxyphenyl]-3-methyl-2-pyridinecarboxylic acid) *[3930-19-6]* **M 506.5, m 262-263°, 275°(dec).** Purified by TLC on pH 7-buffered silica gel (made from a slurry of Silica Gel 60 and 400ml of 0.05M phosphate buffer pH 7.0) and eluted with 5% MeOH/$CHCl_3$. The extracted band can then be recrystd from Me_2CO or dioxane as almost black plates or needles. It is soluble in pyridine, Me_2NCHO, aqueous $NaHCO_3$ (some dec), and slightly soluble in MeOH, EtOH, EtOAc and H_2O. It has a pKa value in the range 6.2-6.4 (dioxane/H_2O 1:1) and UV λ_{max} 248, 375-380nm (ε 38400 and 17400). [Weinreb et al. *JACS* **104** 536 *1982*; Rao et al. *JACS* **85** 2532 *1963*]. It is an antineoplastic and causes severe bone marrow depression [Wilson et al. *Antibiot Chemother* **11** 147 *1961*].

Streptozotocin (*N*-[methylnitrosocarbamoyl]-α-D-glucosamine, streptozocin) *[18883-66-4]* **M 265.2, m 111-114°(dec), 114-115°(dec), 115°(dec with evolution of gas), $[\alpha]_D^{20}$ ~+39° (H_2O, may vary due to mutarotation).** Recrystd from 95% EtOH and is soluble in H_2O, MeOH and Me_2CO. It has UV λ_{max} 228nm (ε 6360) in EtOH. The *tetraacetate* has **m** 111-114°(dec), $[\alpha]_D^{25}$ +41° (c 0.78, 95% EtOH) after recrystn from EtOAc. [Herr et al. *JACS* **89** 4808 *1967*; NMR: Wiley et al. *JOC* **44** 9 *1979*]. It is a potent methylating agent for DNA [Bennett and Pegg *Cancer Research* **41** 2786 *1981*].

Subtilisin (from *Bacillus subtilis*) *[9014-01-1]* **[EC 3.4.21.62].** Purified by affinity chromatography using 4-(4-aminophenylazo)phenylarsonic acid complex to activated CH-Sepharose 4B. [Chandraskaren and Dhar *AB* **150** 141 *1985*].

Succinyl coenzyme A Trisodium salt *[108347-97-3]* **M 933.5.** If it should be purified further then it should be dissolved in H_2O (0.05g/ml) adjusted to pH 1 with 2M H_2SO_4 and extracted several times with Et_2O. Excess Et_2O is removed from the aqueous layer by bubbling N_2 through it and stored frozen at pH 1. When required the pH should be adjusted to 7 with dilute NaOH and used within 2 weeks (samples should be frozen). Succinyl coenzyme A is estimated by the hydroxamic acid method [*JBC* **242** 3468 *1967*]. It is more stable in acidic than in neutral aqueous solutions. [*Methods in Enzymology* **128** 435 *1986*].

2-Sulphobenzoic cyclic anhydride (2,1-benzoxathiazol-3-one 1,1-dioxide) *[81-08-3]* **M 184.2, m 116-124°, 126-127°, 129.5°, 130°, b 184-186°.** If the sample has hydrolysed extensively

(presence of OH band in the IR) then treat with an equal bulk of $SOCl_2$ reflux for 3h ($CaCl_2$ tube), evaporate and distil residue in a vacuum. The solid distillate is then recrystd from C_6H_6, Et_2O-C_6H_6 or $CHCl_3$ (EtOH free by passing through Al_2O_3, or standing over $CaCl_2$). [Clarke and Breger *Org Synth* Coll Vol I 495 *1948*]. Used for modifying ζ-amino functions of lysyl residues in proteins [Bagree et al. *FEBS LETT* **120** 275 *1980*].

Syrexin (from bovine liver). Purified by $(NH_4)_2SO_4$ pptn, then by pH step elution from chromatofocusing media in the absence of ampholytes. [Scott et al. *AB* **149** 163 *1985*].

Taurodeoxycholic acid sodium salt monohydrate (*n*-[desoxycholyl)taurine Na salt H_2O) *[1180-95-6]* M 539.7, m 171-175°, $[\alpha]_D^{23}$ +37° (c 1, H_2O).

The salt is recrystd from EtOH-Et_2O. Its solubility in H_2O is 10%. The *free acid* has **m** 141-144°. [Norman *Ark Kemi* **8** 331 *1956*]. It forms mixed micelles and solubilises some membrane proteins [Hajjar et al. *JBC* **258** 192 *1983*].

2,2:5',2"-Terthiophene *[1081-34-1]* **M 248.4, m 92-93°, 94-95°, 94-94.5°, 94-96°.** Recrystd from MeOH C_6H_6, pet ether or MeOH. [UV: Zechmeister and Sease *JACS* **69** 273 *1947*; Steinkopf et al. *A* **546** 180 *1941*]. Phototoxic nematocide [Cooper and Nitsche *Bioorganic Chem* **13** 36 *1985*; *Chan* et al. *Phytochemistry* **14** 2295 *1975*]. See **Terthienyl** entry in Chapter 3.

Tetracycline hydrochloride *[64-75-5]* **M 480.9, m 214°(dec), 215-220°, $[\alpha]_D^{25}$ -258° (c 0.5, 0.1N HCl), $[\alpha]_D^{20}$-245° (c 1, MeOH).** Recrystd from MeOH + *n*-BuOH or *n*-BuOH + HCl. It is insoluble in Et_2O and pet ether. It has UV λ_{max} at 270 and 366nm in MeOH. [Gottstein et al. *JACS* **81** 1198 *1959*; Conover et al. *JACS* **84** 3222 *1962*].

6*R*-Tetrahydro-*erythro*-biopterin dihydrochloride (BH_4.2HCl, 6*R*-2-amino-4-hydroxy-6-[{1*R*,2*S*}-1,2-dihydroxypropyl]-5,6,7,8-tetrahydropteridine 2HCl) *[69056-38-8]* **M 316.2, m 245-246°(dec), $[\alpha]_D^{25}$ -6.8° (c 0.67, 0.1N HCl).** Recrystn from HCl enriches BH_4 in the natural 6*R* isomer. Dissolve the salt (~6g) in conc HCl (15ml) under gentle warming then add EtOH (30ml) dropwise, chill and collect the colourless needles (67%, up to 99% if mother liquors are concentrated), and dried *in vacuo* immediately over P_2O_5 and KOH. Stores indefinitely at -20° in a dry atmosphere, Better store in sealed ampoules under dry N_2. It can be recrystd from 6N aqueous HCl. It has UV λ_{max} (2N HCl) 264nm (ε 16770; pH 3.5 phosphate buffer) 265nm (ε 13900); (pH 7.6) 297nm (ε 9500) and 260nm sh (ε4690). It has been separated from the 6*R*-isomer by HPLC on a Partisil-10SCX column using 30mM ammonium phosphate buffer (pH 3.0) containing 3mM $NaHSO_3$ (2ml/min flow rate; 275nm detector) with retention times of 5.87min (6*R*) and 8.45min (6*S*). It is stable in acidic soln and can be stored for extended periods at -20° in 0.04M HCl. Above pH 7 the neutral species are obtained and these are readily oxidised by oxygen in the solvent to quinonoid species and then further oxidation and degradation occurs at room temperatures. These changes are slower at 0°. The *sulphate salt* can be obtained by recrystn from 2M H_2SO_4 and is less soluble than the hydrochloride salt. The *6R-2,5,1',2'-tetraacetylbiopterin* derivative has **m** 292° (dec) after recrystn from MeOH (100 parts) and $[\alpha]_{589}^{20}$ -144° (c 0.5, $CHCl_3$), $[\alpha]_{589}^{20}$ +12.8° (c 0.39, Me_2SO). [NMR, UV: Matsuura et al. *Heterocycles* **23** 3115 *1985*; Viscontini et al. *ICA* **62** 2577 *1979*; Armarego et al. *Australian J Chem* **37** 355 *1984*].

Tetrahydrofolic acid dihydrochloride $2H_2O$ (6*S*- or 6*RS*- 5,6,7,8-tetrahydrofolic acid 2HCl $2H_2O$, 5,6,7,8-tetrahydropteroyl-L-glutanic acid 2HCl $2H_2O$) *[135-16-0]* **M 544.4, m >200°(dec), $[\alpha]_D^{27}$ +16.9° (H_2O pH 7.0 + 2-mercaptoethanol).** Very high quality material is now available commercially and should be a white powder. It can be dried over P_2O_5 in a vacuum desiccator and stored in weighed aliquots in sealed ampoules. It is stable at room temp in sealed ampoules for many months and for much more extended periods at -10°. When moist it is extremely sensitive to moist air whereby it oxidises to the yellow 7,8-dihydro derivative. In soln it turns yellow in colour as it oxidises and then particularly in the presence of acids it turns dark reddish brown in colour. Hence aqueous solutions should be frozen immediately when not in use. It is always advisable to add 2-mercaptoethanol (if it does not interfere with the procedure) which stabilises it by depleting the soln of O_2. The *sulphate salt* is more stable but then it

is much less soluble. The best way to prepare standard solns of this acid is to dissolve it in the desired buffer and estimate the concentration by UV absorption in pH 7 buffer at 297nm (ε 22,000 $M^{-1}cm^{-1}$). If a sample is suspect it is not advisable to purify it because it is likely to deteriorate further as "dry box" conditions are necessary. Either a new sample is purchased or one is freshly prepared from folic acid. It has pKa values of -0.1, 4.3 and 9.0. [Hafeti et al. *Biochemical Preparations* **7** 89 *1960*; UV: Mathews and Huennekens *JBC* **235** 3304 *1960*; Osborn and Huennekens *JBC* **233** 969 *1958*; O'Dell et al. *JACS* **69** 250 *1947*; Blakley *BJ* **65** 331 *1957*; Asahi *J Pharm Soc Japan* **79** 1548 *1959*].

5,6,7,8-Tetrahydropterin sulphate (2-amino-5,6,7,8-tetrahydropteridin-4-one H_2SO_4) *[20350-44-1]* **M 265, m >200°(dec).** If it has become too strongly violet in colour then it may need reducing again. Best to check the UV absorption in N HCl where it has a peak at ~265nm which drops sharply to zero having no absorption at *ca* 340nm. The presence of absorption at 340nm indicated oxidation to quinonoid or 7,8-dihydropterin. If the absorption is weak then dissolve in the minimum volume of anhydrous trifluoroacetic acid (fume hood) add charcoal, filter, then add one or two drops of N H_2SO_4 followed by dry Et_2O at 0°, allow the white tetrahydro salt to settle and collect, and wash with dry Et_2O, by centrifugation. Dry the residue in a vacuum desiccator over P_2O_5 and KOH. Store in aliquots in the dark at <0°. It has pKa^{25} values of 1.3, 5.6 and 10.6 in H_2O and UV λ_{max} at 265nm (ε 16980) at pH -1.0 (dication); 219nm (ε 23440) and 266nm (ε 12880) at pH 3.5 (monocation); 220nm (ε 18620), [260nm (ε 4270)sh] and 299nm (ε 9330) at pH 8.0 (neutral species); 218nm (ε 10000), [240nm (ε 5500)sh] and 287nm (ε 5500) at pH 13 (anion). [Blakley *BJ* **72** 707 *1959*; Asahi *J Pharm Soc Japan* **79** 1557 *1959*; Pfleiderer in *Pterins and Folate* (Benkovic and Blakley eds) J Wiley **vol 2** p97 *1985*].

Thiamine monophosphate chloride $1H_2O$ (Aneurine monophosphate chloride) *[532-40-1]* **M 416.8, m 193°(dec), 200°(dec), 200-203°(dec).** Purified by recrystn from aqueous HCl, EtOH-Me_2CO, H_2O, H_2O-EtOH + Et_2O. Dissolve in a small volume of H_2O and mix with EtOH + Me_2CO (1:1) to give the HCl.H_2O as crystals. Filter, wash with Et_2O and dry in a vacuum. The *chloride hydrochloride* , **m** 215-217°(dec) is obtained when crystd from aqueous HCl. [Wenz et al. *A* **618** 2280 *1958*, Viscontini et al. *HCA* **34** 1388 *1951, Leichssenring and Schmidt B* **95** 767 *1962*; McCormick and Wright *Methods in Enzymology* **18A** 141, 147 *1970*].

Thiamphenicol (1*R*,2*R*-2-[2,2-dichloroacetylamino]-1-[4-methanesulphonylphenyl]-propan-1,3-diol) *[90-91-5]* **M 356.2, m 163-166°, 165.2-165.6°, 165-166°, $[\alpha]_D^{25}$ +15.6° (c 2, EtOH).** Recrystd from H_2O or $CHCl_3$. UV λ_{max} 224, 266 and 274nm (ε 13700, 800 and 700) in 95% EtOH. The *1S,2S-isomer [14786-51-7]* has **m** 164.3-166.3° (from H_2O + EtOAc + pet ether) and $[\alpha]_D^{25}$ -12.6° (c 1, EtOH); and the *racemate 1RS,2RS* **Racefenical** *[15318-45-3]*] has **m** 181-183° (sinter at 180-183°) from $CHCl_3$-EtOAc-pet ether. [Cutler et al. *JACS* **74** 5475, 5482 *1952*; UV: Nachod and Cutler *JACS* **74** 1291 *1952*; Suter et al. *JACS* **75** 4330 *1953*; Cutler et al. *J Amer Pharm Assoc* **43** 687 *1954*].

Thiazolyl blue tetrazolium bromide (3-[4,5-dimethyl-2-thiazolyl]-2,5-diphenyl-2*H*-tetrazolium bromide) *[298-93-1] [2348-71-2]* **M 414.3, m 171°.** It is recrystd by dissolving in MeOH containing a few drops of HBr and then adding dry Et_2O to complete the crystn, wash the needles with Et_2O and dry in a vacuum desiccator over KOH. [Beyer and Pyl *B* **87** 1505 *1954*].

6,8-Thioctic acid *[1077-28-7]* **M 206.3, m 45-47.5° (R-isomer), 60-61° (RS-form).** Crystd from cyclohexane.

2-Thiocytosine (4-amino-2-mercaptopyrimidine) *[333-49-3]* **M 127.2, m 236-237°(dec), 285-290°(dec).** It is recrystd from hot H_2O and dried at 100° to constant weight. It has pKa^{20} values of 3.09 and 11.10. [Brown *J Appl Chem London* **9** 203 *1959*; Russell et al. *JACS* **71** 2279 *1949*]. It is used in transcription and translation studies [Rachwitz and Scheit *Eur J Biochem* **72** 191 *1977*].

6-Thioguanine *[154-42-7]* **M 167.2, m >300°.** Recrystd from H_2O as needles. It has pKa^{23} values of 8.2 and 11.6 and UV λ_{max} at 258 and 347nm (H_2O, pH 1) and 242, 270 and 322nm (H_2O, pH 11). [Elion and Hitchings *JACS* **77** 1676 *1955*; Fox et al. *JACS* **80** 1669 *1958*]. It is an antineoplastic agent [Kataoka et al. *Cancer Research* **44** 519 *1984*].

Thrombin (from bovine blood plasma) *[9002-04-4]* **M_r 32,600 [EC 3.4.4.13].** Purified by chromatography on a DEAE-cellulose column, while eluting with 0.1M NaCl, pH 7.0, followed by chromatography on Sephadex G-200. Final preparation was free from plasminogen and plasmin. [Yin and Wessler *JBC* **243** 112 *1968*].
Thrombin from bovine blood was purified by chromatography using *p*-chlorobenzylamino-ε-aminocaproyl agarose, and gel filtration through Sephadex G-25. [Thompson and Davie *Biochim Biophys Acta* **250** 210 *1971*].
Thrombin from various species was purified by precipitaion of impurities with rivanol. [Miller *Nature* **184** 450 *1959*].

D-Thyroxine (*O*-[3,5-diiodo-4-oxyphenyl]-3,5-diiodo-D-(-)-tyrosine, 3,3',5,5'-tetra-iodo-D-thyrinine} *[51-49-0]* **M 776.9, m 235°(dec), 235-236°(dec), 340°(dec), $[\alpha]_D^{20}$ +4.5° (c 3, aq 0.2N NaOH in 70% EtOH), $[\alpha]_D^{20}$ -17° (c 2, aq N HCl + EtOH 1:4).** Recrystd from H_2O as needles or from an ammonical soln by dilution with H_2O, MeOH or Me_2CO. Also purified by dissolving ~6.5 g in a mixture of MeOH (200ml) and 2N HCl (20ml), add charcoal, filter then add NaOAc soln to pH 6 and on standing the thyroxin separates, is washed with MeOH then Me_2CO and dried *in vacuo*. The *N-formyl-D-thyroxine* derivative has **m** 210° and $[\alpha]_{546}^{21}$ -26.9° (c 5, EtOH). The racemate *±-thyroxine* has **m** 256° and is purified in the same way. [Nahm and Siedel *B* **96** 1 *1963*; Salter *BJ* **24** 471 *1930*].

L-Thyroxine (*O*-[3,5-diiodo-4-oxyphenyl]-3,5-diiodo-L-(+)-tyrosine, 3,3',5,5'-tetraiodo-D-thyrinine] *[51-49-0]* **M 776.9, m 229-230°(dec), 237°(dec), ~235°(dec), $[\alpha]_D^{22}$ -5.1° (c 2, aq N NaOH + EtOH 1:2), $[\alpha]_D^{22}$ +15° (c 5, aq N HCl in 95% EtOH 1:2).** Purification is the same as for the D-isomer above. It has a pKa of 6.6 in H_2O. The *N-formyl-L-thyroxine* has **m** 214°(dec) and $[\alpha]_{546}^{21}$ +27.8° (c 5, EtOH). [Harington et al. *BJ* **39** 164 *1945*; Nahm and Siedel *B* **96** 1 *1963*; Reineke and Turner *JBC* **161** 613 *1945*; Chalmers et al. *JCS* 3424 *1949*].

Tissue inhibitor of metalloproteins (from human blood plasma). Purified by immuno-affinity chromatography and gel filtration. [Cawstin et al. *BJ* **238** 677 *1986*].

***dl*-α-Tocopherol** (see **vitamin E**) *[59-02-9]* **M 430.7, $\varepsilon_{1cm}^{1\%}$ 74.2 at 292 nm in MeOH.** Dissolved in anhydrous MeOH (15ml/g) cooled to -6° for 1h, then chilled in a Dry-ice/acetone bath, crystn being induced by scratching with a glass rod.

γ-Tocopherol (3,4-dihydro-2,7,8-trimethyl-2-(4,8,12-trimethyltridecyl)-2*H*-benzopyran-6-ol) *[54-28-4]* **M 416.7, m -30°, b 200-210°/0.1mm, d_4^{20} 0.951, n_D^{20} 1.505, $[\alpha]_D^{20}$ -2.4° (EtOH).** Purified by distn at high vacuum and stored in dark ampoules under N_2. UV λ_{max} 298nm ($E_{1cm}^{1\%}$ 92.8). It is insoluble in H_2O but soluble in organic solvents. The *allophanate* (used for separating isomers) has **m** 136-138°, $[\alpha]_D^{18}$ +3.4° ($CHCl_3$). [Baxter et al. *JACS* **65** 918*1943*; Emerson et al. *Science* **83** 421 *1936*, *JBC* **113** 319 *1936*].

Toluylene-2,4-diisocyanate (toluene-2,4-diisocyanate). *[584-84-9]* **M 174.2, m 19.5-21.5°, 20-22°, 28°, b 126°/11mm, 124-126°/18mm, 250°/760mm.** It is purified by fractionation in a vacuum and should be stored in a dry atmosphere. It is soluble in organic solvents but reacts with H_2O, alcohols (slowly) and amines all of which could cause explosive polymerisation. It darkens on exposure to light. It has a sharp pungent odour, is **TOXIC** and is **IRRITATING TO THE EYES.** [Siefken *A* **562** 75, 96, 127 *1949*; Bayer *Angew Chemie* **59** 257 *1947*]. It is a reagent for covalent crosslinking of proteins [Wold *Methods in Enzymology* **25** 623 *1972*].

Tomatidine (5α,20β,22α,25β,27-azaspirostan-3β-ol) *[77-59-8]* **M 415.7, m 202-206°, $[\alpha]_D^{20}$ +5.9° (c 1, MeOH), $[\alpha]_D^{20}$ +8° ($CHCl_3$).** Forms plates from EtOAc. Also purified by dissolving 80mg in C_6H_6 and applying to an Al_2O_3 column (3.0g) and eluting with C_6H_6, evaporating and recrystallising three times from EtOAc. The *hydrochloride* has **m** 265-270° from EtOH and $[\alpha]_D^{25}$ -5° (MeOH). [IR: Uhle *JACS* **83** 1460 *1961*; Kessar et al. *TET* **27** 2869 *1971* ; Schreiber and Adams *Experientia* **17** 13 *1961*].

Tomatine (22*S*,25*S*-3β-β-lycotetraosyloxy-5α-spirosolan) *[17406-45-0]* **M 1034.2, m 263-268°(dec), 290-291°(evac capillary), 283.5-287°(dec), 272-277°(dec), 300-305°(dec), $[\alpha]_D^{20}$ -18° to -34° (c 0.55, pyridine).** Recrystd from MeOH, EtOH, aqueous EtOH or dioxane + NH_3. It is almost insoluble in pet ether, Et_2O or H_2O. [Reichstein *Angew Chemie* **74** 887 *1962*].

***N*-Tosyl-L-lysine chloromethyl ketone (3*S*-1-chloro-3-tosylamino-7-amino-2-heptanone HCl)** *[4272-74-6]* **M 369.3, m 150-153°(dec), 156-158°(dec), ~165°(dec), $[\alpha]_D^{20}$ -7.3° (c 2, H_2O).** The hydrochloride slowly crystallises from a conc soln in absolute EtOH, thinned with EtOH-Et_2O for collection and dried *in vacuo*. It is a suicide enzyme inhibitor [Matsuda et al. *Chem Pharm Bull Japan* **30** 2512 *1982*; Shaw et al. *Biochemistry* **4** 2219 *1965*].

Transferrin (from human or bovine serum) *[11096-37-0]* **M_r~80,000.** Purified by affinity chromatography on phenyl-boronate agarose followed by DEAE-Sephacel chromatography. The product is free from haemopexin. [Cook et al. *AB* **149** 349 *1985*; Aisen and Listowsky *Annual Reviews of Biochem* **49** 357 *1980*].

Trehalase (from kidney cortex). Purified by solubilising in Triton X-100 and sodium deoxycholate, and submitting to gel filtration, ion-exchange chromatography, conA-Sepharose chromatography, phenyl-Sepharose CL-4B hydrophobic interaction chromatography, Tris-Sepharose 6B affinity and hydrolyapatite chromatography. Activity was increased 3000-fold. [Yoneyama *Arch Biochem Biophys* **255** 168 *1987*].

1,5,7-Triazabicyclo[4.4.0]dec-5-ene (TBD, 1,3,4,6,7,8-hexahydro-2*h*-pyrimido[1,2-a]-pyrimidine) *[5807-14-7]* **M 139.2, m 125-130°.** Cryst from Et_2O but readily forms white crystals of the carbonate. It is a strong base with a pKa of ~16 (i.e. about 100 times more basic than tetramethylguanidine. The *picrate* has **m** 220.5-222° (from EtOH). Forms the *5-nitro deivative* **m** 14.5-160° that gives a *5-nitro nitrate* salt **m** 100-101° (from EtOH-Et_2O) and a *5-nitro picrate* **m** 144-145° (from H_2O). [McKay and Kreling *Canad J Chem* **35** 1438 *1957*; Schwesinger *Chimia* **39** 369 *1985*; Hilpert et al. *JCSCC* 1401 *1983*; Kamfen and Escenmoser *HCA* **72** 185 *1989*].

Triethyl phosphonoacetate (triethyl carboxymethyl phosphonate) *[867-13-0]* **M 224.2, b 83-84°/0.5mm, 103°/1.2mm, 143-144°/11mm, 260-262°/atm, d_4^{20} 1.1215, n_D^{20} 1,4310.** Purified by fractional distn, preferably *in vacuo*. PNMR has P resonance at 19.5 relative to orthophosphate. [Kosolapoff and Powell *JACS* **68** 1103 *1946*; **72** 4198 *1950*; Speziale and Freeman *JOC* **23** 1586 *1958*].

Trifluoperazine dihydrochloride (10-[3-{4-methyl-1-piperazinyl}propyl]-2-trifluoromethylphenothiazine 2HCl) *[440-17-5]* **M 480.4, m 240-243°, 242-243°.** Recrystd from abs EtOH dried *in vacuo* and stored in tightly stoppered bottles because it is *hygroscopic*. It is soluble in H_2O but insoluble in C_6H_6, Et_2O and alkaline aqueous soln. It has pKa values of 3.9 and 8.1 and has UV λ_{max} at 258 and 307.5nm (log ε 4.50 and 3.50) in EtOH (neutral species). [Craig et al. *JOC* **22** 709 *1957*]. It is a calmodulin inhibitor [Levene and Weiss *J Parmacol Exptl Ther* **208** 454 *1978*], and is a psychotropic agent [Fowler *Arzneimittel-Forsch* **27** 866 *1977*].

T4-RNA ligase (from bacteriophage-infected *E.coli*). Purified by differential centrifugation and separation on a Sephadex A-25 column, then through hydroxylapatite and DEAE-glycerol using Aff-Gel Blue to remove DNAase activity. (Greater than 90% of the protein in the enzyme preparation migrated as a single band on gradient polyacrylamide gels containing SDS during electrophoresis.) [McCoy et al. *Biochim Biophys Acta* **562** 149 *1979*].

Tubercidin (7-deazaadenosine) *[69-33-0]* **M 266.3, m 247-248°, $[\alpha]_D^{17}$ -67° (50% aq AcOH).** Forms needles from hot H_2O. It is soluble in H_2O (0.33%), MeOH (0.5%) and EtOH 0.05%). It has a pKa^{10} of 5.2-5.3 and UV λ_{max} 270nm (ε 12100) in 0.001N NaOH. The *picrate* has **m** 229-231°(dec). [Tolman et al. *JACS* **91** 2102 *1969*; Mizuno et al. *JOC* **28** 3329 *1963*, IR: Anzai et al. *J Antibiotics Japan* **[9] 10** 201 *1957*].

Tunicamycin *[11089-65-9]* **m 234-235°(dec), $[\alpha]_D^{20}$ +52° (c 0.5, pyridine).** The components are purified by recrystallising 3 times from hot glass-distilled MeOH and the white crystals are dissolved in 25% aqueous MeOH and separated on a Partisil ODS-10μ column (9.4 x 25 cm) [Magnum-9 Whatman] using a 260 nm detector. The column was eluted with MeOH:H_2O mixture adjusted to 1:4 (v/v) then to 2:4 (v/v). The individual components are recovered and lyophilised. Ten components were isolated and all were active (to varying extents) depending on the lengths of the aliphatic side-chains. The mixture has UV λ_{max} 205 and 260nm ($E_{1cm}^{1\%}$ 230 and 110). Stable in H_2O at neutral pH but unstable in acidic soln. It inhibits protein glycosylation. [Mahoney and Duskin *JBC* **254** 6572 *1979*; Elnein *Trends in Biochem Science* **6** 219 *1981*; Takatsuki *J Antibiotics* **24** 215 *1971*].

Ubiquinol-cytochrome c reductase (from beef heart mitochondria)

[EC 1.10.2.2]. Purified in Triton X-100 by solubilising the crude enzyme with Triton X-100, followed by hydroxylapatite and gel chromatography. The minimum unit contains nine polypeptide subunits of M_r 6000 - 49000 kD. [Engel et al. *Biochim Biophys Acta* **592** 211 *1980*].

Uracil, uridine and uridine nucleotides. Resolved by ion-exchange chromatography AG1 (Cl^- form). [Lindsay et al. *AB* **24** 506 *1968*].

Uridine 5'-diphosphoglucose pyrophosphorylase (from rabbit skeletal muscle) *[9029-22-6]* **M_r 350,000 [EC 2.7.7.9].** Purified by two hydrophobic chromatographic steps and gel filtration. [Bergamini et al. *AB* **143** 35 *1984*]. Also purified from calf liver by $(NH_4)_2SO_4$ (40-58%) pptn, $Ca_3(PO_4)_2$ gel filtration, DEAE-cellulose chromatography and recrystn by dialysis against increasing concentrations of $(NH_4)_2SO_4$ (from 10%) in 0.02M TEA (at 2.5% increments) until at 20% $(NH_4)_2SO_4$ it crystallises out [Hansen et al. *Methods in Enzymology* **8** 248 *1966*].

Uridine 5'-(1-thio) monophosphate and Uridine 5'-(α-thio) diphosphate The Et_3N salt was purified by dissolving ~4g in 500ml of H_2O (add a drop or two of Et_3N if it does not dissolve) and chromatographed by applying to a column (3 x 30cm) of DEAE-Sephadex A-25 and eluted with a 1.4L linear gradient of $Et_3NH.HCO_3$ from 0.05 to 0.55M, pH 7.8 and 4°. The product eluted between 0.2-0.3M $Et_3N.HCO_3$. Pooled fractions were evaporated and the residue was twice taken up in EtOH and evaporated to dryness to remove the last traces of $Et_3NH.HCO_3$. ^{31}P NMR: P_α is a doublet at -40.81 and -40.33, and P_β at 7.02ppm, $J_{\alpha,\beta}$ 32.96Hz. [*Biochemistry* **18** 5548 *1979*].

Urokinase (from human urine) *[9039-53-6]* **M_r 53,000 [EC 3.4.21.31].** Crystn of this enzyme is induced at pH 5.0 to 5.3 (4°) by careful addition of NaCl with gentle stirring until the soln becomes turbid (silky sheen). The NaCl concentration is increased gradually (over several days) until 98% of saturation is achieved whereby the urokinase crystallises as colourless thin brittle plates. It can be similarly recrystd to maximum specific activity [104K CTA units/mg of protein (Sherry et al. *J Lab Clin Med* **64** 145 *1964*)]. [Lesuk et al. *Science* **147** 880 *1965*; NMR: Bogusky et al. *Biochemistry* **28** 6728 *1989*]. It is a plasminogen activator [Gold et al. *BJ* **262** *1989*].

(+)-Usnic acid (2,6-diacetyl-7,9-dihydroxy-8,9b-dimethyldibenzofuran-1,3(2*H*,9b*H*)-dione) *[6159-66-6]* **M 344.3, m 201-204°, 203-206°, $[\alpha]_D^{16}$ +509.4° (c 0.7, $CHCl_3$).** This is the natural form which is recrystd from Me_2CO. At 25° it is soluble in H_2O (<0.01%), Me_2CO (0.77%), EtOAc (0.88%), $MeOCH_2CH_2OH$ (0.22%) and furfural (7.32%). [Curd and Robertson *JCS* 894 *1937*; Barton and Brunn *JCS* 603 *1953*; resolution: Dean et al. *JCS* 1250 *1953*; synthesis: Barton et al. *JCS* 538 *1956*].

(-)-Usnic acid (2,6-diacetyl-7,9-dihydroxy-8,9b-dimethyldibenzofuran-1,3(2*H*,9b*H*)-dione) *[7562-61-0]* **M 344.3, m 201-204°, 204°, $[\alpha]_D^{20}$ -495° (c 0.9, $CHCl_3$).** Properties almost similar to those of the preceding entry.

Valinomycin (**Potassium ionophore I**) *[2001-95-8]* **M 111.3, m 186-187°, 190°, $[\alpha]_D^{20}$ +31.0° (c 1.6, C_6H_6).** Recryst from dibutyl ether or Et_2O. Dimorphic, modification A crystallises from *n*-octane, and modification B crystallises from EtOH/H_2O. Soluble in pet ether, $CHCl_3$, AcOH, BuOAc and Me_2CO. [*JACS* **97** 7242 *1975*; UV, IR and NMR see *B* **88** 57 *1955*].

(±)-Verapramil hydrochloride (5-[*N*-{3,4-dimethoxyphenylethyl}methylamino]-2-[3,4-dimethoxyphenyl]-2-isopropylvaleronitrile HCl) *[23313-68-0]* **M 491.1, m 138.5-140.5°.** Purified by dissolving in EtOH, filtering (if insoluble particles are present) and adding Et_2O, filtering the salt, washing with Et_2O and drying *in vacuo*. It has the following solubilities: hexane (0.001%), CH_2Cl_2 (~10%), MeOH (~10%) EtOH (20%) and H_2O (8.3%). It has UV λ_{max} 232 and 278nm. The *free base* is a viscous yellow oil **b** 243-246°/0.01mm (n_D^{25} 1,5448) and is almost insol in H_2O but sol in organic solvents. It is a Ca channel antagonist and is a coronary vasodilator. [Ramuz *HCA* **58** 2050 *1975*; Harvey et al. *BJ* **257** 95 *1989*].

Veratridine. An alkaloid neurotoxin purified from veratrine. [McKinney et al. *AB* **153** 33 *1986*].

Vinblastine sulphate (vincaleucoblastine) *[143-67-9]* **M 909.1, m 284-285°, $[\alpha]_D^{25}$ -28° (c 1, MeOH).** Purified by recrystn from H_2O and dried *in vacuo*. [Neuss et al. *JACS* **86** 1440 *1964*]. The *free base* is recrystd from MeOH or EtOH and has **m** 210-212°, 211-216°, $[\alpha]_D^{25}$ +42° ($CHCl_3$); and has pKa values of 5.4 and 7.4 in H_2O, and UV λ_{max} 214 and 259nm (log ε 4.73 and 4.21). The *dihydrochloride dihydrate* has **m** 244-246°. [Bommer et al. *JACS* **86** 1439 *1964*]. It is a monoamine oxidase inhibitor [Keun Son et al. *J Medicinal Chem* **33** 1845 *1990*].

Vincristine sulphate (22-oxovincaleucoblastine sulphate) *[2068-78-2]* **M 925.1, m 218-220°, $[\alpha]_D^{25}$ +26.2° (CH_2Cl_2).** Recryst from MeOH. It has pKa values of 5.0 and 7.4 in 33% Me_2NCHO and UV λ_{max} 220, 255 and 296nm (log ε 4.65, 4.21 and 4.18). It is a monoamine oxidase inhibitor and is used in cancer research [Keun Son et al. *J Medicinal Chem* **33** 1845 *1990*; Horio et al. *Proc Natl Acad Sci USA* **85** 3580 *1988*].

Vinyl chloroformate *[5130-24-5]* **M 106.5, b 46.5°/80mm, 67-69°/atm, 109-110°/760mm, d_4^{20} 1.136, n_D^{23} 1.420.** It has been fractionated through a Todd column (Model A with ~60 plates) under atmospheric pressure and purity can be checked by gas chromatography. It has IR with ν at 3100 + 2870 (CH_2), 1780 (C=O), 1640 (C=C) and 940 (CH_2 out-of-plane) and 910 (CH_2 wagging) cm^{-1}. [IR: Lee *JOC* **30** 3943 *1965*; Levaillant *Annales de Chimie* **[11] 6** 504 *1936*]. Used for protecting NH_2 groups in peptide synthesis [Olofson et al. *TET LETT* 1563 *1977*].

4-Vinylpyridine monomer *[100-43-6]* **M 105.1, b 40-41°/1.4mm, 54°/5mm, 58-61°/12mm, 68°/18mm, 79°/33mm, d_4^{20} 0.9836, n_D^{20} 1.5486.** Purified by fractional distn under a good vacuum and a N_2 atmosphere and stored in sealed ampoules under N_2 and kept in the dark at -20°. The *picrate* has **m** 175-176°. [UV: Coleman and Fuoss *JACS* **77** 5472 *1955*; Overberger et al. *J Polymer Sci* **27** 381 *1958*; Petro and Smyth *JACS* **79** 6142 *1957*]. Used for alkylating SH groups in peptides [Anderson and Friedman *Canad J Biochem* **49** 1042 *1971* ; Cawins and Friedman *AB* **35** 489 *1970*].

Viomycin sulphate (Viocin, Tuberactinomycin B) *[37883-00-4]* **M 685.7, m 266°(dec), $[\alpha]_D^{17}$ -29.5° (c 1, H_2O).** Crystd from H_2O-EtOH and dried in a vacuum. Dry material is *hygroscopic* and should be stored dry. It has pKa values of 7.2 and 10.3, and the UV has λ_{max} at 268 and 285nm (log ε 4.4 and 4.2) in H_2O. [Kitigawa et al. *Chem Pharm Bull Japan* **20** 2176 *1972*]. The *hydrochloride* forms *hygroscopic* plates with **m** 270°(dec), $[\alpha]_D^{18}$ -16.6° (c 1, H_2O) with λ_{max} 268nm (log ε 4.5) in H_2O; 268nm (log ε 4.4) in 0.1N HCl and 285nm (log ε 4.3) in 0.1N NaOH.

Vitamin A acid [Retinoic acid, 3,7-dimethyl-9-(2,6,6-trimethyl-1-cyclohexenyl)-2,4,6,8-nonatetraen-1-oic acid] *[302-79-4]* **M 300.4, m 180-181°, 180-182°.** Purified by chromatography on silicic acid columns, eluting with a small amount of EtOH in hexane. Dissolve in Et_2O, wash with H_2O, dry (Na_2SO_4), evaporate and the solid residue crystd from MeOH (0.53g /3.5ml MeOH to give 0.14g) or EtOH. Also recrystd from isoPrOH, or as the *methyl ester* from MeOH. UV in MeOH has λ_{max} 351nm (ε 45,000). **9-*Cis*-acid** forms yellow needles from EtOH, **m** 189-190°, UV in MeOH has λ_{max} 343nm (ε 36,500) and **13-**

cis-**acid** forms red-orange plates from *iso*-PrOH, **m** 174-175°, UV has λmax 345nm (ε 39,800). Store in the dark, in an inert atmosphere, at 0° [Robeson et al. *JACS* **77** 4111 *1955*].

Vitamin A alcohol (retinol) *[68-26-8]* **M 286.5,** $\varepsilon^{1\%}_{1cm}$ (*all-trans*) **1832 (325 nm),**(*13-cis*) **1686 (328nm),** (*11-cis*) **1230 (319 nm),** (*9-cis*) **1480 (323 nm),** (*9,13-di-cis*) **1379 (324 nm),** (*11-13-di-cis*) **908 (311 nm) in EtOH.** Purified by chromatography on columns of water-deactivated alumina eluting with 3-5% acetone in hexane. Separation of isomers is by TLC plates on silica gel G, developed with pet ether (low boiling)/methyl heptanone (11:2). Stored in the dark, under nitrogen, at 0°, as in ethyl ether, acetone or ethyl acetate. [See Gunghaly et al. *Arch Biochem Biophys* **38** 75 *1952*].

Vitamin A aldehyde [all-*trans*-retinal; 3,7-dimethyl-9-(2,6,6-trimethyl-1-cyclohexenyl)-2,4,6,8-nonatetraen-1-al] *[116-31-4]* **M 284.4, m 61-64°.** Separated from retinol by column chromatography on water-deactivated alumina. Eluted with 1-2% acetone in hexane, or on TLC plates of silica gel G development. It crystallises from pet ether or *n*-hexane as yellow-orange crystals, and the UV in hexane has λ_{max} 373nm ($\varepsilon^{1\%}_{1cm}$ 1,548) [368nm (ε 48000)]. It is an **irritant** and is light sensitive. Store in sealed ampoules under N_2. The **semicarbazone** forms yellow crystals from $CHCl_3$-Et_2O or EtOH, **m** 199-201°(dec). The 9-*cis-isomer [514-85-2]* and the 13-*cis-isomer [472-86-6]* [λ_{nax} 375nm ($\varepsilon^{1\%}_{1cm}$ 1250) in EtOH] are also available commercially.

Vitamin B_1 Hydrochloride [Aneurine hydrochloride, Thiamine hydrochloride, 3{(4-amino-2-methyl-5-pyrimidinyl)methyl}-4-methylthiazolium chloride monohydrochloride] *[67-03-8]* **M 337.3, m 248°(dec), 249-250°, monohydrate m 135°(dec).** Crystallises from 95% EtOH (sol, *ca* 1%). The monohydrate is dehydrated by drying at 100° *in vacuo* over H_2SO_4, but is *hygroscopic* and picks up one mol. of H_2O readily. It can be sterilised at 100° if the pH of the solution is below 5.5. It has a pKa of 4.8. The *nitrate* has m 196-200°(dec) and is more stable than the hydrochloride. The *picrolonate* crystallises from H_2O and is dimorphic, **m** 164-165° and 228-229°(dec). [Todd and Bergel *JCS* 364, 367 *1937*; *JACS* **58** 1063, 1504 *1936*, **59** 526 *1937*].

Vitamin B_2 [Riboflavin, Lactoflavin, 6,7-dimethyl-9-(D-1'-ribityl)isoalloxazine] *[83-88-5]* **M 376.4, m 278-282°(dec with darkening at 240°), 281-282°,** $[\alpha]_D^{25}$ **-112° to -122° (c 2.5, 0.02M NaOH),** $[\alpha]_D^{20}$ **-59° (c 0.23, AcOH).** It crystallises from H_2O as a yellow-orange powder in three different forms with differing amounts of H_2O. It melts if placed in an oil bath at 250°, but decomposes at 280° if heated at a rate of 5°/min. Solubility in H_2O is 1g in 3000-15000ml depending on the crystal structure. Sol in EtOH at 25° is 4.5mg in 100ml. It has pKa values of 1.7 and 10.2. Store in the dark because it is decomposed to lumichrome by UV light.

Vitamin B_6 hydrochloride (adermine, 3-hydroxy-4,5-bis[hydroxymethyl]-2-methyl-pyridine HCl) *[58-56-0]* **M 205.6, m 208-208.5°, 208-209°(dec), 209-210°(dec), 205-212° (sublimes).** Purified by recrystn form EtOH-Me_2CO, *n*-BuOH or MeOH-Et_2O. Its solubility in H_2O is 22% and in EtOH it is 1.1%. It is insoluble in Et_2O and $CHCl_3$. Acidic aqueous solns are stable at 120°/30 min. The *free base* has **m** 159-160° after recrystn from Me_2CO and sublimation at 140-145°/0.0001mm. It has pKa^{20} values in H_2O of 4.74 (4.72) and 9.4 (8.69) and UV λ_{max} at 290nm (ε 84000) in 0.1N aqueous HCl and 253 and 325nm (ε 3700 and 7100). [Khua and Wendt *B* **71** 780 *1938, 72* 311 *1939;* Harris and Folkers *JACS* **61** 1242 *1939*; Harris et al. *JACS* **62** 3198 *1940*]. See also **Pyridoxal-5'-phosphate H_2O** and **pyridoxine HCl** above.

Vitamin B_{12} (cyanocobalamine, α-[5,6-dimethylbenzimidazolyl]cyano cobamide) *[68-19-9]* **M 1355.4, dark at 210-220° and does not melt below 300°,** $[\alpha]^{23}_{656}$ **-59° (H_2O).** Crystd from de-ionized H_2O, solubility in H_2O is 1g/80g and dried under vacuum over $Mg(ClO_4)_2$. The dry red crystals are *hygroscopic* and can absorb ~12% of H_2O. A soln at pH 4.5-5 can be autoclaved for 20min at 120° without dec. Aqueous solns are stabilised by addition of $(NH_4)_2SO_4$. [Golding *Comprehensive Organic Chem* **vol 5** *(ed Haslam; Pergamon Press, NY, 1979)* pp549-584].

Alternatively an aqueous soln of the coenzyme was concentrated, if necessary in a vacuum at 25° or less, until the concentration was 0.005 to 0.01M (as estimated by the OD at 522 nm of an aliquot diluted with 0.01M K-phosphate buffer pH 7.0). If crystals begin to form on the walls of the container they should be re-dissolved

with a little H_2O. The concentrated soln is placed in a glass stoppered flask and diluted with 5vols of Me_2CO. After 2-3h at 3° it is centrifuged (10,000xg/10 min) in Me_2CO-insol plastic tubes to remove some amorphous ppte. The clear supernatant is inoculated with a small crystal of the vitamin and allowed to crystallise overnight at 3°. Crystals are formed on the walls and the bottom of the container. A further 2vols of Me_2CO are added and set aside at 3° to further crystallise. Crystallisation is followed by observing the OD_{522} of the supernatant. When the OD falls to 0.27 then *ca* 94% of the crystals have separated. The supernatant is decanted (saved for obtaining a second crop) and the crystals are washed with a little cold 90% aqueous Me_2CO (2 x), 100% Me_2CO (2 x), Et_2O (2 x) at which time the crystals separated from the glass walls. Allow to settle and remove residual Et_2O with a stream of dry N_2. The process can be repeated if necessary. The crystals can be dried in air or in a vacuum for 2h over silica gel at 100° with an 8-9% weight loss. [Barker et al. *Biochemiccal Preparations* **10** 33 *1963*]. This material gives a single spot of paper chromatography (see Weissbach et al. *JBC* **235** 1462 *1960*]. The vitamin is soluble in H_2O (16.4mM at 24°, 6.4mM at 1°), in EtOH and PhOH but insol in Me_2CO, Et_2O, CH_2Cl_2 and dioxane. UV: λ_{max} 260, 375 and 522nm (ε 34.7 x 10^6, 10.9 x 10^6 and 8.0 x 10^6 / mole) in H_2O. The dry crystals are stable for months in the dark, but aqueous solns decompose on exposure to VIS or UV light or alkaline CN^-, but stable in the dark at pH 6-7. The vitamin is inactivated by strong acids or alkalies. [Barker et al. *JBC* **235** 480 *1960*; see also *Vitamin B_{12}* (Zagalak and Friedrich eds) W de Gruyter, Berlin *1979*].

Vitamin C see **ascorbic acid** entry in Chapter 3.

Vitamin D_2 *[50-14-6]* **M 396.7, m 114-116°, $[\alpha]_{546}^{20}$ +122° (c 4, EtOH),**
Vitamin D_3 *[67-97-0]* **384.6, m 83-85°, $[\alpha]_{546}^{20}$ +126° (c 2, EtOH).** Converted into their 3,5-dinitrobenzoyl esters, and crystd repeatedly from acetone. The esters were then saponified and the free vitamins were isolated. [Laughland and Phillips *AC* **28** 817 *1956*].

Vitamin E (2*R*,4'*R*,8'*R*-α-tocopherol, natural active isomer) *[59-02-9]* **M 430.7, m 2.5-3.5°, b 200-220°/0.1mm, 200°/0.005mm, d_4^{25} 0.950, n_D^{25} 1.5045, $[\alpha]_D^{25}$ +3.58° (c 1.1, C_6H_6).** Viscous yellow oil which is distd at high vacuum. It has λ_{max} 294nm ($E_{1cm}^{1\%}$ 71). It is oxygen and light sensitive and is best stored as its stable acetate which is purified by evaporative distn at **b** 180-200°(bath temp)/0.7mm, $[\alpha]_D^{25}$ +3.3° (c 5.1, EtOH). [NMR: Cohen et al. *HCA* **64** 1158 *1981*; Burton and Ingold *Accounts Chem Research* **19** 194 *1986*; Karrer et al. *HCA 21* 520 *1938*].

Vitamin E acetate (DL-α-tocopheryl acetate) *[7695-91-2]* **M 472.8, m -27.5°, b 194-196°/0.01mm, 222-224°/0.3mm, d_4^{20} 0.958, n_D^{20} 1.4958.** It is a viscous liquid which is purified by distn under high vacuum in an inert atm and stored in sealed ampoules in the dark. It is considerably more stable to light and air than the parent unacetylated vitamin. It is insoluble in H_2O but freely soluble in organic solvents. All eight stereoisomers have been synthesised. The commercially pure *d-α–tocopheryl acetate* (2R,4'R,8'R) has **b** 180-200°/0.7mm and $[\alpha]_D^{20}$ +3.9° (c 5, EtOH). [Cohen et al. *HCA* **64** 1158 *1981*].

Vitamin K_1 (2-methyl-3-phytyl-1,4-naphthoquinone) *[84-80-0]* **M 450.7, m -20°, b 141-140/0.001mm, b 140-145°/10^{-3} mm, d_{25}^{25} 0.967, n_D^{25} 1.527, $[\alpha]_D^{20}$ -0.4° (c 57.5, C_6H_6).** Yellow viscous oil, which can be distd at high vacuum practically unchanged. Insoluble in H_2O, but soluble in common organic solvents. Store in the dark under N_2, oxygen sensitive. $\varepsilon_{1cm}^{1\%}$ 328 at 248nm. [*JACS* **61** 2557 *1939*, **76** 4592 *1954*; *HCA* **27** 225 *1954*].

Vitamin K_3 (2-methyl-1,4-naphthoquinone, Menadione, Menaphthone) *[58-27-5]* **M 172.2, m 105-106°, 105-107°.** Recrystd from 95% EtOH, or MeOH after filtration. Bright yellow crystals which are decomposed by light. Solubility in EtOH is 1.7% and in C_6H_6 it is 10%. It **IRRITATES** the mucous membranes and skin. [Fieser *JBC* **133** 391 *1940*].

Xanthotoxin (Methoxalen, 9-methoxyfuro[3,2-g][1]benzopyran-7-one) *[298-81-7]*

M 216.2, m 146-148°, 148°, 148-149°. Purified by recrystn from C_6H_6-pet ether (b 60-80°) as silky

needles, EtOH-Et_2O as rhombic prisms or hot H_2O as needles. It is soluble in aqueous alkalies due to ring opening of a lactone but recyclises upon acidification. It has UV λ_{max} in EtOH at 219, 249 and 300nm (log ε 4.32, 4.35 and 4.06) and ^1H NMR in $CDCl_3$ with δ at 7.76 (d, 1H, *J* 10 Hz), 7.71 (d, 1H, *J* 2.5 Hz), 7.38 (s, 1H), 6.84 (d, 1H, *J* 2.5 Hz), 6.39 (d, 1H, *J* 10 Hz) and 4.28 (s, 3H) ppm. [Nore and Honkanen *JHC* **17** 985 *1980*]. It is a DNA intercalator and is used in the treatment of dermal diseases [Tessman et al. *Biochemistry* **24** 1669 *1985*].

Xylanase (from *Streptomyces lividans*) *[37278-89-0]* **M_r 43,000 [EC 3.2.1.8].** Purified by anion-exchange chromatography on an Accell QMA column and finally by HPLC using a ProteinPak DEAE 5PW anion-exchange column. Solutions were stored frozen at -70°. [Morosoli et al. *BJ* **239** 587 *1986*; Wong et al. *Microbiological Reviews* **52** 305 *1988*].

Zeatin (*trans-N^6*-[4-hydroxy-3-methylbut-2-en-1-yl]adenine) *[1637-39-4]* M 219.3, m 207-208, 209-209.5°.

Purified by recrystn from EtOH or H_2O. It has pKa values of 4.4 and 9.8 in H_2O and the UV has λ_{max} at 207 and 275nm (ε 1400 and 14650) in 0.1N aqueous HCl; 212 and 270nm (ε 17050 and 16150) in aqueous buffer pH 7.2; 220 and 276nm (ε 15900 and 14650) in 0.1N aq NaOH. The *picrate* has **m** 192-194° (from H_2O) from which zeatin can be recovered by treatment with Dowex 1 x 8 (200-400 mesh, OH^- form). [Letham et al. *Australian J Chem* **22** 205 *1969*; *Proc Chem Soc London* 230 *1964*; Shaw and Wilson *Proc Chem Soc London* 231 *1964*]. It is a cell division factor (plant growth regulator) [Letham and Palni *Annual Reviews of Plant Physiology* **34** 163 *1983*] and inhibits mitochondrial function [Miller *Plant Physiology* **69** 1274 *1982*]. Its *9-riboside* is a cytokine [McDonald and Morris *Methods in Enzymology* **100** 347 *1985*].

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