Modern Chemical Nomenclature.

A LECTURE DELIVERED BEFORE THE CHEMICAL SOCIETY ON MAY 14th, 1936.

By CLARENCE SMITH.

" DEAR SIR,

Your paper entitled 'The preparation and properties of *cyclo*hexane-1-carboxylic-2-acetic acid' has not been recommended for publication, because the same acid has already been prepared by A. N. Other and described under the name hexahydrohomophthalic acid."

I wonder how many such letters were written before the days of formula indexes, how much unnecessary research work was done, how many exasperated authors exclaimed " Why cannot we have a systematic international nomenclature." For nearly 20 years, chemists of many countries have been trying to devise such a nomenclature, and to-night I will give an account of the agreement that has been reached. Could we but wipe out all the existing names and start afresh, it would not be a very difficult task to create a logical system of nomenclature. Half an hour after first seeing the rules of the international language Espéranto I wrote in that language to Dr. Zamenhof in Warsaw, asking to be enrolled as a member. We want something of the same kind in chemistry—a nomenclature based on principles so simple that a few hours' study would enable a chemist to write the name or the formula of any chemical compound of known constitution. We have, however, to suffer for the sins of our forefathers in chemistry : it would be impossible to expunge from the literature all their inconsistencies; in fact, one of the first things agreed upon by the International Union of Chemistry was that interference with the existing nomenclature should be as little as possible.

Fifty years ago, the need for the revision of organic nomenclature had become so pressing that in 1892 a conference of 34 chemists, representing 9 European countries, was summoned at Geneva; it produced what is known as the Geneva nomenclature. To-day the problem is vastly more complicated, not only in organic but also in inorganic chemistry, and to deal with it there is the International Union of Chemistry representing 27 countries of the world. This body, formerly known as the International Union of Pure and Applied Chemistry, is an outcome of the Great War. During the war French and British chemists pooled their knowledge of the manufacture of explosives and munitions and the advantages accruing were so great that it was felt desirable, after the armistice, to continue the collaboration in the peaceful pursuits of science. Meetings were held in 1919 in Paris, London, and Brussels between representatives of Belgium, France, Great Britain, Italy, and the United States of America, and the International Union of Pure and Applied Chemistry was formed. Germany joined the Union in 1930. To-day its members are : The Argentine, Austria, Belgium, Brazil, Bulgaria, Canada, Czechoslovakia, Denmark, France, Germany, Great Britain, Greece, Holland, Italy, Japan, Norway, Peru, Poland, Portugal, Roumania, Russia, Spain, Sweden, Switzerland, the United States of America, Uruguay, and Yugoslavia. The reports of such a representative body of chemists are surely worthy of adoption.

The tasks imposed upon itself by the Union included the reform of the nomenclature of organic and inorganic chemistry and of biochemistry. With regard to biochemistry I can say very little : after 10 years' work the committee for the reform of the nomenclature produced a report which was submitted to the constituent countries of the Union for consideration. Only a few replies have been received and the proposals made in the report must be regarded as not yet having met with general acceptance.

The Nomenclature of Inorganic Chemistry.

The report of the committee for the reform of inorganic nomenclature was published by Marcel Delépine (*Bull. Soc. chim.*, 1928, **43**, 289) and by W. P. Jorissen (*Rec. trav. chim.*, 1929, **48**, 652). Although Germany entered the Union only in 1930, she had been working independently on problems in nomenclature. A committee was appointed by the German Chemical Society in 1924 and its proposals were published by R. J. Meyer (*Z. angew. Chem.*, 1925, **38**, 713; *Naturwiss.*, 1926, **14**, 269). Those proposals are included and enlarged in a draft report by Dr. Meyer which is now before the International Union and of which I have made extensive use in this lecture. There are, therefore, two reports—the German report and that of the International Union. They agree on many points.

Elements.—The symbols N for nitrogen and W for tungsten are now universally adopted. The French use of Az and Tu is abandoned. This leaves the symbol Tu available for thulium, at present denoted by Tm in the table of the International Atomic Weights Commission. Dr. Meyer considers the symbol Tm wrong, because the m belongs to the ending, not to the radical syllable, of the word. Agreement has not yet been reached on the names of elements 4, 41, and 86. It seems probable that the name beryllium will displace glucinum and radon will supersede emanation, but element 41 is still named niobium in this country and columbium in America.

Compounds.—The principle adopted here is to establish names for classes of compounds and to discuss the names of individual substances only in special cases.

Simple salts. These are named as salts of metals, not as salts of bases. The use of names such as bicarbonate of soda and sulphate of potash as scientific names is abolished. In France, chlorure de soude and chlorure de sodium were used indiscriminately, and in Germany schwefelsaures ammoniak and ammoniumsulfat. The names of simple salts will in future be based on the pattern sodium chloride, potassium sulphate. In the Teutonic and the Anglo-Saxon languages the parts of the name are given in this order, the positive component before the negative, and the formula is written correspondingly, NaCl. The name of the anion ends, as is usual, in ate, ite, ide, etc. In the Romance languages the name takes the form chloride of sodium : the logical French mind therefore writes the formula ClNa; the Italians write it NaCl. These, however, are minor differences; the important point is that in all tongues the salt is named as the chloride of sodium, not of soda.

Compounds of non-metallic elements. Here again, as in the case of salts, the elements are named in the order of decreasing positive character. The order differs slightly in the two reports :

German: As, B, Si, C, P, Te, Se, S, I, Br, Cl, N, O, F
French: Si, C, Sb, As, P, N, Te, Se, S, I, Br, Cl, F, O

So one gets the names boron silicide, not silicon boride; selenium sulphide; iodine chloride; etc. Fluorine is definitely more negative than oxygen; the fluorine–oxygen compounds discovered by Lebeau, Damiens, and Ruff are therefore oxyfluorides, not fluoroxides.

Naming of inorganic compounds by means of valency or by the stoicheiometric proportion of the elements. There are two ways of denoting the quantitative relations of the components of a molecule : (1) by the valency of one element, ferrous chloride, ferric chloride; (2) by the stoicheiometric proportion of the elements, manganese dioxide. The first method fails where an element occurs in more than two states of valency. A. Werner proposed to denote the valencies from 1 to 8 by the letters a, o, i, e, an, on, in, en, intercalated between the names of the metal and the acid component : cuprous chloride, cupra chloride; cupric chloride, cupro chloride. The proposal fails owing to language difficulties; it answers admirably in the German tongue for which it was designed, but in English the distinction between en and in is not very marked (compare benzene, pyridine) and in French and Italian with their chloride of copper the intercalation is impossible. It is proposed, therefore, to denote the valency of a metal by a Roman numeral written or spoken after the name of the metal : ferrous chloride, iron II chloride; ferric chloride, iron III chloride; magnetite Fe_3O_4, iron II,III oxide. The proposal would be useful in indexing and in discourses. All compounds of ferrous iron would be indexed under iron II, those of ferric iron under iron III. In discourses, if one were comparing a number of tervalent metals, instead of saying, as at present, aluminium, ferric iron, tervalent manganese, cerous cerium, one would say aluminium, iron III, manganese III, cerium III. The valency of a metal in a formula is denoted, as usual, by a small Roman numeral written above the line.

The method of denoting the stoicheiometric proportion of the elements in a compound by means of Greek prefixes is retained, but it has been systematised and enlarged. The name manganese dioxide correctly designates the proportion of the elements, one atom of manganese and two atoms of oxygen, but manganese heptoxide does not indicate two atoms of manganese and seven atoms of oxygen : the correct name is dimanganese heptoxide. With the discovery of the oxide NO_3 last year by Schwarz and Achenbach revision of the names of the oxides of nitrogen became necessary. The new oxide could not be named nitrogen trioxide, which was already used, incorrectly, to denote N_2O_3. It is proposed to replace the old names by a rational nomenclature :

	Old Name.	*New Name.*
N_2O	Nitrous oxide	Dinitrogen oxide
N_2O_3........................	Nitrogen trioxide (Nitrous anhydride)	Dinitrogen trioxide
NO	Nitric oxide	Nitrogen oxide
NO_2	Nitrogen dioxide	Nitrogen dioxide
N_2O_4........................	Nitrogen peroxide	Dinitrogen tetroxide
N_2O_5........................	Nitrogen pentoxide	Dinitrogen pentoxide
NO_3	—	Nitrogen trioxide

For numbers exceeding 12, Greek prefixes become cumbrous and are replaced by Arabic numerals; for example, a salt containing $13H_2O$ is a 13-hydrate, not a triscaidecahydrate.

Acid salts. The German report proposes to designate the ionisable hydrogen in salts by the term " hydro " : $KHSO_4$, potassium hydrosulphate ; Na_2HPO_4, sodium hydrophosphate; NaH_2PO_4, sodium dihydrophosphate. The French propose the term acide : SO_4HK, sulfate acide de potassium.

Basic salts. If hydroxyl is certainly present, it is named hydroxo as it is in Werner's notation for the co-ordination compounds of metals. There is no detectable difference in constitution between " basic " complex compounds and simple basic salts containing hydroxyl. It is illogical to name the radical OH hydroxo in the former compounds and hydroxy in the latter. $Cr(OH)SO_4$, therefore, is chromium hydroxosulphate. The usual name oxy-salts is retained for basic salts not containing hydroxyl : bismuth oxychloride. In many cases basic salts can only be indicated by their formulæ.

Acids. The names of all the important simple acids are retained. Some difficulties have arisen in connection with the prefixes ortho, pyro, and meta. The ortho-acid is the most highly hydrated acid known either as the free acid or as a salt or as an organic derivative; *e.g.*, orthophosphoric acid, H_3PO_4. Therefore, when Anschütz and Broeker prepared esters of the hitherto hypothetical acid H_5PO_5, this acid logically should have become orthophosphoric acid. It was felt, however, that the name orthophosphoric acid for H_3PO_4 had been established so firmly that it could not be changed without causing great confusion. The German report suggests the name holophosphoric acid for $P(OH)_5$.

A pyro-acid is produced from 2 mols. of the ortho-acid by loss of 1 mol. of water; $H_4B_2O_5$ is therefore pyroboric acid. Yet the polyboric acid $H_2B_4O_7$, of which borax is the sodium salt, is often called pyroboric acid. We name it diboric acid, and the German report proposes to do the same for the reason I will mention later.

Of the oxy-acids of sulphur, only two call for mention here, $H_2S_2O_3$ and $H_2S_2O_4$. The acid $H_2S_2O_3$, formerly hyposulphurous acid, is now almost universally named thiosulphuric acid and its salts are the thiosulphates. Photographers, please note that hyposulphite of soda is now wrong in both parts of the name. The acid $H_2S_2O_4$ was originally named hydrosulphurous acid by Schützenberger under the erroneous assumption that its salts had the formula $MHSO_2$. Bernthsen showed that the salts are $M_2S_2O_4$ and pointed out that the correct name for the acid is hyposulphurous acid. The common reducing agent $Na_2S_2O_4$ is therefore sodium hyposulphite, not sodium hydrosulphite; the latter name, on the German proposals, denotes the acid salt $NaHSO_3$.

Compounds of complex constitution. (a) *Salts of iso- and hetero-polyacids.* The expression isopolyacid is used to denote the union that takes place between several molecules of one acid only by elimination of water. Heteropolyacids are similarly derived from several molecules of two acids. As the constitutions of the salts of both classes of acid are largely unknown, it is impossible to devise a scientific nomenclature. The salts of isopolyacids are denoted by names indicating by means of arabic numerals the molecular proportion of acid oxide and basic oxide.

The Borates.

Atomic formula.	Molecular formula.	Name.	Various customary names.
M_3BO_3	$3M_2O,B_2O_3$	1/3-Borate	Orthoborate
$M_4B_2O_5$	$2M_2O,B_2O_3$	1/2-Borate	Pyroborate
MBO_2	M_2O,B_2O_3	1-Borate or Monoborate	Metaborate, Monoborate
$M_2B_4O_7$	$M_2O,2B_2O_3$	2-Borate or Diborate	Tetraborate, Pyroborate
MB_3O_5	$M_2O,3B_2O_3$	3-Borate or Triborate	Hexaborate, Triborate
$M_2B_8O_{13}$	$M_2O,4B_2O_3$	4-Borate or Tetraborate	Octaborate, Tetraborate
MB_5O_8	$M_2O,5B_2O_3$	5-Borate or Pentaborate	Decaborate, Pentaborate
$M_2B_{12}O_{19}$	$M_2O,6B_2O_3$	6-Borate or Hexaborate	Dodecaborate, Hexaborate

The Silicates.

M_4SiO_4	$2M_2O,SiO_2$	1/2-Silicate	Orthosilicate
$M_6Si_2O_7$	$3M_2O,2SiO_2$	2/3-Silicate	Pyrosilicate
$M_8Si_3O_{10}$	$4M_2O,3SiO_2$	3/4-Silicate	
M_2SiO_3	M_2O,SiO_2	1-Silicate	Metasilicate
$M_6Si_4O_{11}$	$3M_2O,4SiO_2$	4/3-Silicate	
$M_4Si_3O_8$	$2M_2O,3SiO_2$	3/2-Silicate	
$M_2Si_3O_7$	$M_2O,3SiO_2$	3-Silicate	

Similarly also for tungstates, molybdates, vanadates, and vanadites.

For naming the salts of heteropolyacids, including aluminosilicates, the German report proposes the adoption of Rosenheim's system, in which numerals are used to indicate the proportion of the characteristic elements of the two acid oxides :

$3M_2O,P_2O_5,24MoO_4$	Phospho-12-molybdate
$5M_2O,P_2O_5,17WO_3$	2-Phospho-17-tungstate
$4M_2O,SiO_2,12WO_3$.	Silico-12-tungstate

An analogous nomenclature is already used in English and French textbooks (J. W. Mellor, " A Comprehensive Treatise on Inorganic and Theoretical Chemistry "; P. Pascall, " Traité de Chimie inorganique ").

(b) *Co-ordination compounds of metals.* Werner's system is universally adopted in one form or another. The name to be given to NH_3 co-ordinated to the central atom is under consideration. At present it is ammine or ammino; this when spoken is almost indistinguishable from amine or amino, NH_2. The French report recommends the name ammonio for NH_3; the German report suggests ammoniak or ammane, analogous to methane, borane, and silane.

The German report proposes that the components of a complex salt which are inside the co-ordination sphere shall be named in a definite order; first, the " valency " radicals chloro(Cl), cyano(CN), cyanato(CNO), thiocyanato(CNS), sulphato(SO_4), nitro(NO_2), nitrito(O·NO), oxalato(C_2O_4), and hydroxo(HO), then the " neutral " radicals, aquo(H_2O), substituted amines, and lastly ammino(NH_3). The French scheme names the radicals in the order of increasing weight.

Cationic complexes. The nomenclature is based on the preceding rules.

$$[Cr(NH_3)_5Cl]Cl_2$$

English : Chloropentamminochromic chloride
French : Dichlorure-chrome-III-chloro-pentammonique
German : Chloropentamminchrom(III)-chlorid
del Campo : Dichlorure de chloro-pentammine-chrome-III

The French retain their practice of naming the anion of a salt first, and by means of the suffix ique they turn the name of the cation into an adjective. M. del Campo proposes to name the metal of the complex last, whereby the names of the cation become identical in French and German.

Anionic complexes. One of Werner's achievements was to show that there is no difference in constitution between the simple salts such as potassium sulphate and the anionic complex salts. The names of the complex anions therefore end in ate. Now a difficulty arises—how is the valency of the co-ordination metal to be indicated? The English nomenclature is deficient in precision : potassium chloroplatinate or platinichloride, potassium ferrocyanide—one cannot deduce the formulæ from these names, one has to learn them. The German is in a happier case. Kalium-hexachloroplateat : the suffix " at " denotes an anionic complex, the intercalated "e" denotes quadrivalent platinum, there are six chlorine atoms—therefore the formula is K_2PtCl_6. Similarly, Kalium-hexacyanoferroat: "at," anionic complex; "o," bivalent iron; six cyano-groups; therefore $K_4Fe(CN)_6$. As I have already said, Werner's scheme of denoting valency by intercalated letters cannot be used in France and Italy owing to the language difficulty. If one adopts the system used for the cationic complex salts, namely, Roman numerals to denote valency, one gets unpronounceable names such as potassium hexacyanoferr(II)ate. Dr. Meyer suggests placing the Roman numeral after the "ate," potassium hexacyanoferrate II: thus one gets names which are pronounceable in all languages.

Non-electrolytes. The preceding rules apply here also : $[Co(C_2O_4)(OH)(NH_3)_3]$, oxalatohydroxotriamminocobalt. Of course, the suffix "ate," which denotes an anionic complex, must never be used in naming a non-electrolyte. Moreover, non-electrolytes must not be named as though they were complex cationic salts; it is regrettable that such erroneous names have got into the literature.

The Nomenclature of Organic Chemistry.

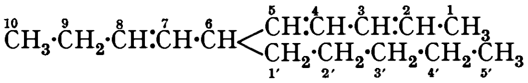
A definitive report on reforms in organic nomenclature was issued by the International Union in 1930 and was published in our Journal (1931, 1610). Of the three reports on reforms in nomenclature, it is the only one upon which agreement is unanimous. Its object is to preserve as much as possible of the nomenclature in common use, to simplify it in some respects, to remove incorrect names, and to provide systematic names which will be comprehended by the chemists of all countries. A considerable part of the report is matter already familiar to you and I can deal with this very briefly.

Hydrocarbons.—(1) Saturated hydrocarbons are indicated by the suffix ane : open-chain, alkanes; cyclic, *cyclo*alkanes.

(2) Unsaturated hydrocarbons : (*a*) With one, two, three, etc., double bonds : alkenes, alkadienes, alkatrienes, etc., and similarly for cyclic compounds, the suffix ene indicating the double bond. (*b*) Hydrocarbons containing triple bonds are indicated by the suffix yne : alkynes, alkadiynes, alkatriynes, etc. The suffix ine is reserved exclusively for amines and other basic substances. (*c*) Hydrocarbons containing both double and triple bonds are alkenynes, alkadienynes, alkenediynes, etc. (*d*) Aromatic hydrocarbons retain their customary names : phene may be used for benzene.

These rules necessitate changes in the customary names of some substances : *e.g.*, pyrane becomes pyran, and tolane becomes tolan; neither is a saturated hydrocarbon. They also enable one to decide which of two spellings is the correct one : $CH_2{:}CO$, is it ketene or keten? According to the rules ene denotes an unsaturated hydrocarbon; the name must therefore be keten.

(3) Branched-chain hydrocarbons : The name is determined by the longest chain of carbon atoms for saturated hydrocarbons and by the longest chain containing the greatest number of double or triple bonds for unsaturated hydrocarbons :

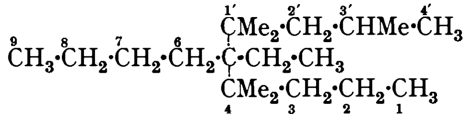


$$\overset{10}{C}H_3\cdot\overset{9}{C}H_2\cdot\overset{8}{C}H{:}\overset{7}{C}H\cdot\overset{6}{C}H{<}\begin{matrix}\overset{5}{C}H{:}\overset{4}{C}H\cdot\overset{3}{C}H{:}\overset{2}{C}H\cdot\overset{1}{C}H_3\\ \underset{1'}{C}H_2\cdot\underset{2'}{C}H_2\cdot\underset{3'}{C}H_2\cdot\underset{4'}{C}H_2\cdot\underset{5'}{C}H_3\end{matrix}$$

6-Pentyldeca-2 : 4 : 7-triene.

Because of the double bonds the substance is named as a derivative of decane even though there is a chain of eleven carbon atoms. The numbering is determined by the rule of lowest numbers, which requires that substituents and unsaturated bonds shall receive the lowest possible numbers.

Where several chains are of equal length, the name is determined by the one allowing of greatest substitution :



$$\begin{array}{ll} & \overset{1'}{C}Me_2\cdot\overset{2'}{C}H_2\cdot\overset{3'}{C}HMe\cdot\overset{4'}{C}H_3\\ \overset{9}{C}H_3\cdot\overset{8}{C}H_2\cdot\overset{7}{C}H_2\cdot\overset{6}{C}H_2\cdot & C\cdot CH_2\cdot CH_3\\ & \underset{4}{C}Me_2\cdot\underset{3}{C}H_2\cdot\underset{2}{C}H_2\cdot\underset{1}{C}H_3\end{array}$$

1′ : 1′ : 3′ : 4 : 4-Pentamethyl-5-ethyl-5-butylnonane, There are three chains each containing nine carbon atoms. The chain C_1—C_9 contains only four substituents and determines the name. The chain $C_{4'}$—C_9 contains five, and C_1—$C_{4'}$, seven, substituents.

Alcohols.—These are denoted by the suffix ol : pentanol, pentanediol, pentanetriol, etc.

Mercaptans.—Denoted by the suffix thiol : ethanethiol. The use of the name mercaptan as a suffix is abandoned.

Ether Oxides.—These are regarded as alkoxyhydrocarbons : $CH_3\cdot O\cdot C_2H_5$, methoxyethane.

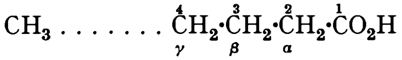
Oxygen linked to two of the atoms in a chain of carbon atoms is denoted by the prefix epoxy in all cases other than those in which a substance is named as a cyclic compound : ethylene oxide = epoxyethane, epichlorohydrin = 3-chloro-1 : 2-epoxypropane, tetramethylene oxide = 1 : 4-epoxybutane.

Sulphur Compounds.—The nomenclature of organic compounds containing sulphur is in a chaotic state. Consider, for example, the names thiophenol, $C_6H_5\cdot SH$, thiodiphenylamine, $C_6H_4{<}\genfrac{}{}{0pt}{}{S}{NH}{>}C_6H_4$, thiourea, $NH_2\cdot CS\cdot NH_2$; the same word thio denotes sulphur exercising three different functions. In the revised nomenclature ·SH is thiol, ·S· thio, ·CS· thione, ·SO· sulphinyl, $\cdot SO_2\cdot$ sulphonyl, $\cdot S_2\cdot$ dithio : $CH_3\cdot SO_2\cdot C_2H_5$ methylsulphonylethane, $CH_3\cdot S\cdot C_3H_7$ methylthiopropane, $CH_3\cdot CH_2\cdot CH_2\cdot SO\cdot CH_2\cdot CH_2\cdot CH_2\cdot CH_3$ propylsulphinylbutane, $C_6H_5\cdot CS\cdot C_6H_5$ diphenylthione.

Aldehydes and thioaldehydes are denoted by the suffixes al and thial respectively, added to the names of the parent hydrocarbons. Acetals are 1 : 1-dialkoxyalkanes. The use of the name carbamide for urea is abolished.

Acids.—The rules of the Geneva nomenclature are retained. Where its use, however, leads to cumbrous names, the carboxyl group is regarded as a substituent and is denoted by the suffix carboxylic acid added to the name of the hydrocarbon. *n*-Butyric acid, for example, is butan-1-oic acid or propane-1-carboxylic acid.

To denote the positions of substituents, the use of either Arabic numerals or Greek letters is permissible. This duality sometimes leads to error :



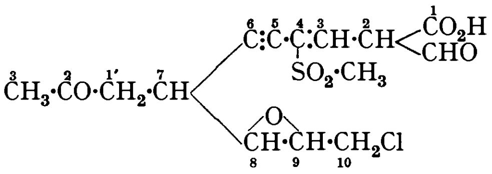
$$CH_3\ .\ .\ .\ .\ .\ .\ .\ \underset{\gamma}{\overset{4}{C}}H_2\cdot\underset{\beta}{\overset{3}{C}}H_2\cdot\underset{\alpha}{\overset{2}{C}}H_2\cdot\overset{1}{C}O_2H$$

The carbon atom 1 is sometimes wrongly lettered α.

Acids in which S replaces O in the carboxyl group are named according to the Geneva nomenclature; alternatively the substituted carboxyl group may be regarded as a substituent :

$C_2H_5\cdot COSH$	$C_2H_5\cdot CO\cdot SH$	$C_2H_5\cdot CS\cdot OH$	$C_2H_5\cdot CS_2H$
Propane-thioic	-thiolic	-thionic	-thionthiolic acid
Ethane-carbothioic	-carbothiolic	-carbothionic	-carbodithioic acid

To illustrate the way in which the preceding rules are combined to produce official names, I have taken the somewhat fantastic formula



10-Chloro-8 : 9-epoxy-4-methylsulphonyl-7-propyldec-3-en-5-yn-2′-on-2-al-1-oic acid.

Each syllable in the name has a characteristic meaning.

(*a*) To get the name from the formula. First, one of the substituents is selected as the principal function. Carboxyl if present is almost invariably taken as the principal function and is given the lowest possible number, in this case 1. Next, the longest chain containing the principal function and the greatest number of the substituents gives the root name of the substance—decanoic acid. Finally, in a definite order (see p. 1076), the numbers and names of the substituents and unsaturated linkings are inserted, as many as possible as suffixes.

(*b*) To deduce the formula from the name. Look along the name and find the syllable that is not preceded by a number—dec (sulphonyl is not preceded by a number, but it is obviously a part of a substituent). The termination of the name, oic acid, determines the principal function. Therefore, write a chain of ten carbon atoms, the first one as CO_2H. 7-Propyl : attach a chain of three carbon atoms at C_7. Now insert the symbols of the remaining substituents and of the unsaturated linkings, add H's where necessary, and the formula is complete.

Nitrogenous Bases.—As I have already mentioned, the suffix ine is reserved exclusively for these compounds; even the historical name olefine now becomes olefin. Monoamines retain their customary names. Polyamines are denoted by the name of the hydrocarbon followed by the suffix diamine, triamine, etc. Ethylenediamine thus becomes officially ethanediamine.

Pyrrol is a misnomer : the substance is a heterocyclic base, not an alcohol. This can be partly remedied by the addition of a terminal e, but the name is too well established to be altered much; it cannot be "pyrroline" because this has long been given to the dihydro-derivative.

For aliphatic compounds containing quinquevalent nitrogen or its electronic equivalent the suffix ine becomes onium. For cyclic compounds containing quinquevalent nitrogen in the ring the suffixes ine and ole become inium and olium respectively.

Organo-metallic Compounds.—These are designated by the name of the alkyl group linked to that of the metal: dimethylzinc, methylmagnesium iodide. If the metal is linked in a complex fashion, it may be regarded as a substituent; $HgCl{\cdot}C_6H_4{\cdot}CO_2H$, chloromercuribenzoic acid.

Table of Prefixes and Suffixes.

Function.	*Prefix.*	*Suffix.*
Acid	Carboxy	carboxylic or oic
Alcohol	Hydroxy	ol
Aldehyde	Oxo, aldo (for O : aldehydic), or formyl (CHO)	al
Amine	Amino	amine
Quinquevalent nitrogen		onium, inium
Carbonitrile (nitrile)	Cyano	carbonitrile or nitrile
Ketone	Oxo or Keto	one
Azo-derivative	Azo	
Azoxy-derivative	Azoxy	
Nitro-derivative	Nitro	
Nitroso-derivative	Nitroso	
Sulphinated derivative	Sulphino	sulphinic
Sulphonated derivative	Sulpho	sulphonic
Ether oxide	Alkoxy	
Halogenide	Halogeno	
Hydrazine	Hydrazino	hydrazine
Double linking		ene
Triple linking		yne
Mercaptan	Mercapto	thiol
Ethylene oxide, etc.	Epoxy	
Sulphones	Sulphonyl	
Sulphoxides	Sulphinyl	
Sulphides	Alkylthio	
Urea	Ureido	urea

Radicals.—*Aliphatic hydrocarbons.* (1) Loss of one hydrogen atom : alkane → alkyl, alkene → alkenyl, alkyne → alkynyl, alkadiene → alkadienyl.

(2) Loss of 2H or 3H from the same carbon atom : alkane → alkylidene or alkylidyne, alkene → alkenylidene or alkenylidyne.

(3) Loss of 1H from each of the terminal carbon atoms of an alkane : ethylene, trimethylene, tetramethylene, etc.

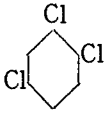
Aromatic hydrocarbons. The names of univalent radicals produced by the loss of one atom of hydrogen from the ring will in principle be formed by changing the terminal ene into yl; xylene, xylyl. However, the names phenyl and naphthyl are retained, and I expect that we shall all continue to say tolyl instead of toluyl.

Heterocyclic compounds. For univalent radicals produced by the loss of one hydrogen atom from the ring, the names are derived by changing the termination or, where ambiguity would arise, the final e into yl: pyridine, pyridyl; pyrrole, pyrryl: pyrroline, pyrrolinyl; triazole, triazolyl; triazine, triazinyl.

Numbering.—In denoting the positions of substituents, authors sometimes do not observe the rule that the lowest possible numbers shall be used. The compound (I) is 1 : 2 : 4-trichlorobenzene, not 1 : 3 : 4-, because the sum of 1, 2, and 4 is smaller than the sum of 1, 3, and 4.

According to the rule of lowest numbers, (II) would be 1 : 2-dihydroxybutan-4-oic or butane-1 : 2-diol-4-oic acid. Here, however, another rule takes precedence, namely, that the lowest possible number is given (1) to the principal function of a compound, (2) to the double bond, and (3) to the triple bond. By naming (II) as a butanoic acid, the carboxyl group is made the principal function; it must therefore receive the lowest possible number, and (II) is accordingly 3 : 4-dihydroxybutan-1-oic or butane-3 : 4-diol-1-oic acid. The compound (III) is pent-1-en-4-yne, not pent-4-en-1-yne, the double bond taking the lowest possible number.

(I.)



$OH\cdot CH_2\cdot CH(OH)\cdot CH_2\cdot CO_2H$ (II.)

$CH_2{:}CH\cdot CH_2\cdot C{\vdots}CH$ (III.)

The prefixes bis, tris, tetrakis, etc., are used in place of di, tri, tetra, etc., in complex expressions: dimethylamino $\cdot NMe_2$, bis(methylamino) $(NHMe)_2$, bis(dimethylamino) $(NMe_2)_2$.

Leaving now international nomenclature and turning to that used in this country, I will deal with various points that in my experience need comment.

(1) No one nowadays would use the name sodium hydrate for sodium hydroxide, yet many authors write sodium ethylate for sodium ethoxide.

(2) Petroleum ether does not contain oxygen; it is a mixture of hydrocarbons. Name it light petroleum and if necessary give the boiling point range.

(3) *Writing Formulæ in Line.*—This space-saving device is based on rules which are apparently not understood by some authors. The dots, other than those in parentheses, denote the links of the chain, and atoms or radicals placed between one link atom and the next are directly attached to the former atom:

$$OH\cdot CH_2\cdot CO\cdot CH(NH\cdot C_6H_5)\cdot C({:}NH)\cdot CCl_3$$

(4) *Denoting the Names of New Compounds.*—The indexer cannot be expected to know which of the compounds described in a paper are new ones and which are not. He must be told in some way. The convention used is to italicise (*i.e.*, underline once) the name of a new compound the first time it is mentioned, both in the introductory and in the experimental portion of the paper; further, the theoretical percentages of the elements are given in the form: such and such a formula requires C,—; H,—%. For known compounds, the theoretical percentages, if given, are put in the form: Calc. for such and such a formula: C,—; H,—%. Incidentally I may mention that the name of a new compound is not indexed unless the substance has been analysed: if a new compound is worth making, it is worth analysing.

The first time one consults a formula index one realises the necessity of writing the symbols of a formula in a definite order: C,H,O,N,Cl,Br,I,F,S,P, and the remainder alphabetically. It is astonishing how often this convention is ignored: the authors surely cannot be in the habit of consulting formula indexes, and yet this is the best way of ascertaining whether or no a compound has already been prepared.

(5) *Isotopes.*—The Society recently decided that the figures denoting the nuclear mass and the nuclear charge of an element shall be written both on the left side of the symbol: ${}^{9}_{4}Be$, ${}^{75}_{33}As$, ${}^{207}_{82}Pb$, in agreement with continental practice.

The only isotope at present requiring consideration from the point of view of nomenclature is heavy hydrogen, ^2H. On this question our Society and the American Chemical Society have been in correspondence. A committee appointed by the Council in 1934, on which our present President rendered valuable service, made the following recommendations:

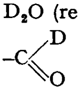
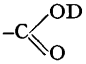
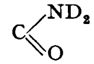
(*a*) That ^2H be named deuterium and denoted by the symbol D (^2H is a permissible alternative symbol).

(*b*) Used as a prefix, deuterium becomes deutero, or deuter before a following vowel.

(*c*) For purposes of nomenclature, deuterium be regarded as an entirely distinct element, like chlorine or sodium. The naming of deuterium compounds will then follow well-recognised rules.

NaOD............	Sodium deuteroxide	1 : 2 : 3-$C_6H_3D_2Cl$	1-Chloro-2 : 3-dideuterobenzene
DCl...............	Deuterium chloride	$C_2H_5{\cdot}OD$............	Deuterium ethoxide Ethyl deuteroxide
ND_3	Trideuterammonia	$CHD_2{\cdot}CO{\cdot}OD$......	Deuterium dideuteracetate
CH_3D	Deuteromethane		
NHD·OD	αβ-Dideuterohydroxylamine		

(*d*) The deuterium analogues of frequently occurring groups might receive contracted names :

Group.	*Name.*	*Example.*	
D_2O (replacing H_2O in hydrates)	Deuterate	$Na_2SO_4,10D_2O$	Sodium sulphate decadeuterate
 $-C{\diagup D \atop \diagdown O}$	Deuteraldehyde	$CH_3{\cdot}CDO$	Acetdeuteraldehyde
 $-C{\diagup OD \atop \diagdown O}$	Deuteracid	$CH_3{\cdot}CO{\cdot}OD$	Acetic deuteracid
 $C{\diagup ND_2 \atop \diagdown O}$	Deuteramide	$CH_3{\cdot}CO{\cdot}ND_2$	Acetdeuteramide
Alk. OD	Deuteralcohol	$C_2H_5{\cdot}OD$	Ethyl deuteralcohol

(6) *The Notation of Optically Active Compounds.*—In modern usage the letters *d* and *l* indicate the configuration of an optically active compound relative to that of *d*-glucose as the standard; they do not denote that the substance is dextrorotatory or lævorotatory. A substance displaying dextro- or lævo-rotation is indicated by the symbol + or — placed in parentheses before the name. As of old, *r* denotes the racemic mixture of two antimerides, *dl* either the optically inactive conglomerate or mixed crystals of two antimerides, and *i* the internally compensated, non-resolvable form. The symbol *d*(—) is used in the Freudenberg notation to indicate a compound that has the dextro-configuration but displays an actual lævorotation, and similarly *l*(+) indicates a compound that has the lævo-configuration but is dextrorotatory.

Although *d* and *l* ought to be used only to denote configurational relationship, they are still sometimes used to indicate the direction of rotation. In order to avoid this confusion some authors use *D* and *L* to denote configurational relationship only. For example, lævorotatory mandelic acid has the dextro-configuration; it is therefore *D*(—) mandelic acid. The benzoin derived from it is a *D*-benzoin which is lævorotatory in acetone and dextrorotatory in piperidine. So here is one and the same substance which is *D*(—) benzoin in one solvent and *D*(+) benzoin in another.

(7) *The Naming of Compounds.*—The fundamental rule is that an atom or a group is regarded as being substituted for hydrogen in a chain or a ring or for hydrogen in a radical. In the latter case the name of the substituent must appear in the name of the radical, not in the main name of the compound. For example, $C_6H_4{<}{CO \atop CO}{>}NMe$ is phthalomethylimide, the methyl group replacing hydrogen of the imido-group. (An " o " may always be inserted or omitted for the sake of euphony.) The substance having this formula is often wrongly named methylphthalimide. $C_6H_3Me{<}{CO \atop CO}{>}NH$ is methylphthalimide, the word methyl appearing in the main name because the group is substituted for hydrogen of the

ring. The correct name for the compound $Cl{\cdot}CO{\cdot}OEt$ is ethyl chloroformate, chlorine being substituted for hydrogen in ethyl formate : the name ethyl chlorocarbonate indicates chlorine replacing the hydroxyl of a carbonate, which is contrary to the rule.

According to the above rule, therefore, in naming a compound one mentally replaces the substituents by hydrogen atoms until one gets a suitable parent name. Take, for example, $CH_3{\cdot}CO{\cdot}CH_2{\cdot}CH_2{\cdot}O{\cdot}CO{\cdot}CH_3$. Replacing the acetyl group by hydrogen, one gets ethyl acetate ; replacing the acetoxy-group by hydrogen, one gets methyl ethyl ketone. Which of these two names is selected depends on the nature of the subject under discussion. If ketonic properties are the main feature, the substance is named methyl β-acetoxyethyl ketone. If the ester character is to be emphasised, the substance is named β-acetylethyl acetate. A foreigner probably could not interpret either of these names, but he would understand the international name, but-3-onyl ethanoate.

In sugar chemistry one has to make an exception to the rule. 2 : 4-Dimethylglucose (written as one word) would according to the rule denote glucose in which methyl is substituted for the two hydrogen atoms attached to carbon atoms 2 and 4. Actually, of course, the methyl is substituted for the hydrogen of the two hydroxyl groups. The convention is to write the name as two words, 2 : 4-dimethyl glucose. In other cases, where methyl is substituted for hydrogen in hydroxyl or thiol or an amino-group the name may be made by writing *O*-methyl, *S*-methyl, or *N*-methyl, followed by the name of the parent compound: *e.g.*, $OMe{\cdot}C_6H_4{\cdot}CHO(2)$ must not be named methylsalicylaldehyde : it is *o*-methoxybenzaldehyde or *O*-methylsalicylaldehyde.

At the end of the Chemical Society's Collective Index for 1913—1922 there is a list of the names and formulæ of nearly 400 radicals which is of great help in the naming of compounds.

The radicals in the name of a compound should be given in the order shown in the following table :

Table of Radicals.

Order of the Radicals in Names of Compounds.

Cl
Br
I
F
NO_2
NO
NH_2
NH
OH
CHO
CO
CN
NCS
CO_2H
O·COR* (R = alkyl or aryl group).
OR*
COR*
R*
H

* Closed-chain radicals precede open-chain radicals : *e.g.*, benzoyl, acetyl; phenyl, methyl. Within the same section, (1) more saturated radicals precede less saturated : *e.g.*, *cyclo*hexyl, phenyl, styryl; (2) less complex precede more complex : *e.g.*, phenyl, naphthyl; methyl, ethyl.
Univalent radicals precede bivalent radicals : ethyl, ethylidene.

Examples : chloronitrobenzene, not nitrochlorobenzene ; phenyl styryl ketone, not styryl phenyl ketone ; bromohydroxyethoxybenzoic acid.

The order may be changed to avoid ambiguity : *e.g.*, phenyldichloroarsine, $PhAsCl_2$, as dichlorophenylarsine might be $C_6H_3Cl_2{\cdot}AsH_2$.

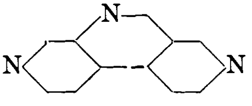
Amido and amino : NH_2 is named amido if it is attached to a negative radical, and amino if attached to a positive radical : $CH_3{\cdot}CO{\cdot}NH$ is acetamido (not acetylamino), and $CH_3{\cdot}CH_2{\cdot}NH{\cdot}$ is ethylamino.

Arsonic and arsinic acids. The names of an important class of compounds have been changed within the last few years, *viz.*, acids of the type $R{\cdot}XO_3H_2$, where X is P, As, Sb, or Bi. The acid $C_6H_5{\cdot}AsO(OH)_2$ used to be named phenylarsinic acid. It is illogical, however, that the same suffix inic should denote an acid of arsenic in its higher state of valency and an acid of sulphur not in its highest state of valency. The name arsinic acid has therefore been given to the acids of tervalent arsenic, and the acids of quinquevalent arsenic are named arsonic acids, analogously to the sulphonic acids :

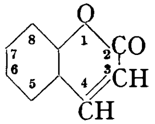
$C_6H_5{\cdot}SO_2{\cdot}OH$ Benzenesulphonic	$C_6H_5{\cdot}AsO(OH)_2$ Phenylarsonic	$(C_6H_5)_2AsO{\cdot}OH$ Diphenylarsonic
$C_6H_5{\cdot}SO{\cdot}OH$ Benzenesulphinic	$C_6H_5{\cdot}As(OH)_2$ Phenylarsinic	$(C_6H_5)_2As{\cdot}OH$ Diphenylarsinic
$C_6H_5{\cdot}S{\cdot}OH$ Benzenesulphenic	—	—

Heterocyclic compounds. Regarding the most difficult problem of nomenclature, the naming of heterocyclic compounds, the International Union has at present done little beyond stating that the names of heterocyclic compounds which are universally adopted will be retained, that the hetero-atoms in a ring will take the termination " a " (oxa for O, thia for S, aza for N), and that names of heterocyclic compounds may be formed from those of the corresponding homocyclic compounds by insertion of the appropriate prefix. This rule is likely to be of great service. For example, the compound (I) is 2 : 7 : 9-triazaphenanthrene.

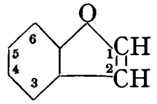
The names and numbering officially used by the Chemical Society are those given in Richter's " Lexikon der Kohlenstoff Verbindungen." For modern requirements his system is unsuitable in some respects. For example, the pair of atoms common to two cyclic structures is not numbered and hetero-atoms are sometimes numbered (II) and sometimes not (III). In these days of fully hydrogenated cyclic compounds it is necessary to number every atom of a ring.



(I.)

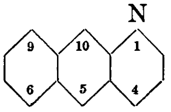


(II) Coumarin.

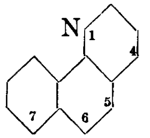


(III) Coumarone.

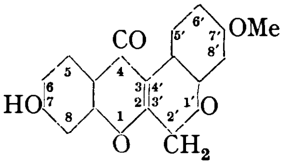
Again, Richter's system is sometimes illogical. Anthrapyridine (IV) would nowadays be named naphthapyridine, and naphthaquinoline (V) would be benzquinoline. Moreover, in the course of years inaccuracies have crept into the literature. The task of re-



(IV.)



(V.)

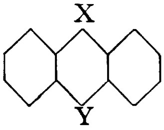


(VI.)

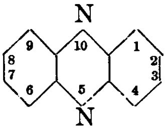
forming the nomenclature of cyclic compounds is so difficult that one naturally shrinks from attempting it. We can, however, see to it that future names are constructed on sound principles. The best way of naming a polycyclic structure is to make the name from those of simpler structures which are universally accepted. For example, I will take one of Professor Robertson's compounds (VI). This is a fusion of the chromone and the chromene structure and therefore the name is 7-hydroxy-7′-methoxychromeno-3′ : 4′ : 2 : 3-chromone. Named on the system proposed by the International Union of Chemistry, the compound would be 6-hydroxy-9-keto-4′-methoxy-4 : 9-dihydro-3 : 10-dioxa-1 : 2-benzanthracene.

(Be)	(B)	(C)	N	O
Hg		Si	P	S
		Sn	As	Se
		Pb	Sb	Te

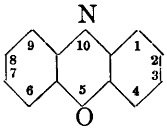
I find that some authors are doubtful about the correct numbering of compounds of type (VII), where X and Y are hetero-atoms. The commonest hetero-atoms are shown in the preceding table and the rule for numbering (devised by Prof. A. M. Patterson of Ohio, U.S.A.) is : the lower number is given to the hetero-atom of a higher group in the periodic table and (within the same group) of lower atomic number. Thus we get the names and numbering :



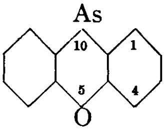
(VII.)



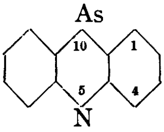
Phenazine



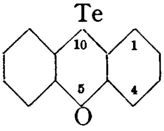
Phenoxazine



Phenoxarsine



Phenarsazine



Phenoxtellurine

Time does not permit me to deal more fully with the work of Prof. A. M. Patterson, who has spent many years in formulating rules for the numbering and the graphical presentation of cyclic structures.

In conclusion, may I make a plea for the chemists of the future. For them the modern craze for brevity in names is storing up trouble. Fifty years hence, students will have to learn the empirical names and the formulæ of, possibly, thousands of compounds, and we now could save them all that mental labour by using systematic names instead of empirical ones. Tetralin and decalin are industrial names, but they have got into scientific literature because the systematic names tetrahydro- and decahydro-naphthalene involve the trouble of writing a few more letters. Recently I had to deal with the name thionessal, coined more than fifty years ago. How many of you could offhand give the scientific name and the formula of this compound? From what I have said to-night you might guess that it is an aldehyde containing the thione radical. You would be wrong. When the compound is named 2 : 3 : 4 : 5-tetraphenylthiophen, you all know what it is and can write the formula.