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Rules for Naming Inorganic Compounds[*]

Report of the Committee of the International Union of Chemistry for the Reform of Inorganic Chemical Nomenclature, 1940

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Introduction

The aim of these Rules is the unification of Inorganic Chemical Nomenclature and the removal of names which are out of date or incorrect.

An attempt has been made to produce a uniform, rational nomenclature for inorganic compounds, especially for scientific purposes. As it was nearly always possible to have recourse to the system of naming already in use, the problem was chiefly that of separating, in any particular systematic series, names which agreed with the general plan of the series from those which did not and replacing the latter by other suitable names.

Indexing of inorganic compounds, *e. g.*, for journals, lies outside our province, although unification of inorganic nomenclature is evidently of importance for systematic reporting. These Rules were accordingly worked out with the help of colleagues who had special experience in this field.

The naming of individual elements has not been considered, since the Committee on Atomic Weights deals with this matter.

A. General

Names and Formulas.—A chemical compound can be designated in two ways: (1) by means of the formula, (2) by means of the name.

(1) Formulas should be widely used in designating inorganic compounds since they provide the simplest and clearest method of doing this. Their significance is, moreover, the same in all languages and for brevity and saving of space they are unequalled.

Formulas are of particular use when dealing with complicated compounds. They have a special significance in the wording of descriptions of preparative procedure, since they prevent misunderstanding. Their use must naturally be avoided in cases where any uncertainty might be introduced.

Examples: Precipitation with H_2S; treat with gaseous HCl; aqueous or alcoholic HCl solution; passing the gas through KOH solution.

(2) When giving names to compounds there are

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[*] These Rules were drawn up by a committee of the International Union of Chemistry consisting of Professors H. Bassett (Reading, England), A. Damiens (Paris), F. Fichter (Basle), W. P. Jorissen (Leyden) and H. Rémy (Hamburg), which met in Berlin, January 28 and 29, 1938, and in Rome, May 16, 1938. Dr. E. Pietsch, Editor of "Gmelin," attended the Berlin meetings in an advisory capacity by invitation of the committee. The Rules are based on a report drawn up by Professor Rémy on behalf of the German Chemical Society and in collaboration with some of its members, of whom Professor A. Stock was the most active. Professor Bassett is responsible for the English translation of the original German version of the Rules and for certain omissions and modifications rendered necessary by differences between the two languages. Certain further modifications, chiefly in spelling, as sulfur instead of sulphur, have been made in the Report as here published to conform with usage in the publications of the American Chemical Society. All of these latter modifications are minor ones made with an understanding that it was not the intent of the Committee to interfere with the written forms peculiar to the languages of individual countries. Furthermore, a few footnotes have been added to point out differences between the German and English versions. Those footnotes marked B, as 1B, accompanied the translation by Professor Bassett and those marked A were added by Miss Janet D. Scott, Associate Editor of *Chemical Abstracts*. Reprints of this Report can be obtained from the undersigned.—E. J. Crane, *Chairman*, Nomenclature, Spelling and Pronunciation Committee of the American Chemical Society, The Ohio State University, Columbus, Ohio.

two possibilities: (*a*) systematic names, (*b*) trivial names.

(*a*) In the case of systematic names it is not always necessary to indicate stoichiometric proportions in the names unless there is some special reason for doing so, because a glance at the formula shows at once the quantitative and atomic composition.

In many cases sufficient abbreviation of the systematic name can be secured by omitting all numbers, indications of valency, etc., which are not needed in the given circumstances. For instance, indication of the valency or atomic proportions is generally not required with compounds of elements of essentially constant valency.

Examples: Aluminum sulfate instead of aluminum (III) sulfate; potassium chloroplatinate instead of potassium hexachloroplatinate (IV); potassium cyanoferrate (II) instead of potassium hexacyanoferrate (II); potassium cyanoferrate (III) instead of potassium hexacyanoferrate (III).

(*b*) In the case of trivial names one must distinguish between: (*aa*) pure trivial names, (*bb*) incorrectly formed names.

(*aa*) Pure trivial names are those which are free from false scientific significance or other wrong indications. In most cases they originate from the people who use the compounds. Examples of such names are saltpeter, caustic soda, quicklime. The use of such pure trivial names is permissible.

(*bb*) Incorrectly formed names are those which were originally constructed to bring out certain ideas on the composition or constitution of the compounds in question, but which are now contrary to our present views and knowledge. Such names are sulfate of magnesia, carbonate of lime, nitrate of potash, acetate of alumina. Their use is widespread, but scientifically they are incorrect.

Such names should not be used under any circumstances and they should be eliminated from technical and patent literature.

B. Binary Compounds

I. Position of Constituents in Names and Formulas.—The electropositive constituent should always be put first in the formula and in the name whenever it is recognizable from the character of the compound—as in salts or salt-like compounds. The name of the electronegative constituent is given the termination *-ide.* In the case of nonpolar compounds and of those in which it is not known which constituent in the compound is to be regarded as electropositive, that constituent should be placed first which has the more electropositive character *in the free condition.*

Examples: Sodium chloride, silver sulfide, lithium hydride, boron carbide, oxygen difluoride.

The above rule summarizes the customary usage in English and German. Exactly the opposite applies in French and Italian so that in these languages the order of constituents in formulas will also be just the opposite to that which is correct in English and German. Such differences are due to the very nature of the several languages and cannot be eliminated. Names are also in use in some languages which are obtained by simple juxtaposition of the separate names of the constituents without any termination. This method of name construction is used in German more particularly for the easily volatile compounds of hydrogen. It should be rigidly restricted to nonpolar compounds (though, even for them, the rule given first is to be preferred), and the constituent should be placed first which is the more *electronegative* in the free condition.

Examples: Chlorwasserstoff, Siliciumwasserstoff.—Schwefelkohlenstoff, Chlorstickstoff (but better: Kohlendisulfid, Stickstofftrichlorid); but *not:* Chlornatrium, Bromkalium, Schwefelsilber. But *only:* Natriumchlorid, etc.

II. Indication of the Proportions of Constituents.—There are two possible ways of indicating the proportions of the constituents in chemical compounds. It can be done: (1) by indicating the valency, (2) by giving the stoichiometric composition, or the functional nature.

(1) Indication of the electrochemical valency in the names of compounds should be made only by Stock's method. This is done by means of Roman figures, placed in parentheses and following, without hyphen, immediately after the names of the elements to which they refer.

Examples:		
	$CuCl$	Copper (I) chloride
	$CuCl_2$	Copper (II) chloride
	FeO	Iron (II) oxide
	Fe_3O_4	Iron (II, III) oxide

The system of valency indication by terminations such as -ous, -ic (ferrous, ferric) which was previously in use has proved unsatisfactory and should now be avoided not only in scientific but also in technical writing.

If the valency needs to be shown in formulas or when using symbols for the elements, then the

Roman figures should be placed just above the appropriate symbols on the right-hand side.

Examples: Cu^{I} salts
$\mathrm{Fe}^{\mathrm{II}}$ compounds

(2) Indication of the stoichiometric composition should be made by means of Greek numerical prefixes which should precede, without hyphen, the constituent to which they refer. This method of showing the composition in names instead of by means of the valency is customary more especially with nonpolar compounds. It is also indicated in cases where the composition differs from that to be expected from the usual valency or in those in which the electrochemical valency is unknown. The prefix "mono" can generally be omitted; 8 should be indicated by "octa," 9 by "ennea." Greek prefixes above 12 are replaced by Arabic figures (without hyphen) as they are more easily understood. Arabic figures are also used for indicating fractions of molecules, although $^1/_2$ can also be expressed by "hemi." The functional system of naming compounds can be employed instead of the stoichiometric. This is used more particularly in French.

Examples:

	Stoichiometric system	Functional system
N_2O	Dinitrogen (mon)oxide	
NO	Nitrogen oxide	
N_2O_3	Dinitrogen trioxide	Nitrous anhydride
NO_2	Nitrogen dioxide	
N_2O_4	Dinitrogen tetroxide	
N_2O_5	Dinitrogen pentoxide	Nitric anhydride
Ag_2F	Disilver fluoride	
$Fe(CO)_4$	Iron tetracarbonyl	
FeS_2	Iron disulfide	

The formula is to be preferred to an awkward name. Thus one should never say for $Na_{12}Hg_{13}$, 12 sodium 13 mercuride. In such cases always use the formula.

Out of date and superfluous terms such as Oxydul, Sulfür, Cyanür, Chlorür, etc., for compounds of lower valency stages, should vanish from the German language, both because they lack precision and because of the way in which many of these terms are used in French.[1B]

III. Designation of Intermetallic Compounds.—Intermetallic compounds do not follow the usual laws of constant composition and must often be regarded rather as phases having a range of existence over which they are more or less homogeneous. There is lacking at present a clear understanding and grouping together of the laws which govern this class of compounds so that any attempt at a rigid system of nomenclature for intermetallic compounds would be premature.

For this reason the use of names in this field should be avoided and formulas alone should be used in all cases, and these should give the exact numbers of atoms if possible. A simplified formula which represents the compound in a satisfactory manner can be used in those cases where either the exact number of atoms cannot be stated or where it is a question of an intermetallic compound which has a wide range of composition. To avoid any danger of confusion with a compound of definite composition, a bar should be placed over the formula to show that the composition is variable.

Example: AuZn occurs as β-phase in the system Au–Zn as an intermetallic compound with properties which differ from those of the components Au and Zn. It is homogeneous over the range of 41 to 58 atom % Zn, so that all formulas $Au_{59}Zn_{41}$ to $Au_{42}Zn_{58}$ would be correct. The shortened form AuZn or $\overline{\mathrm{AuZn}}$ may be used.

Compounds such as $\overline{\mathrm{AuZn}}$ which do not have a constant composition should be called "non-Daltonian" compounds to distinguish them from "Daltonian" compounds of constant composition.

A future systematic nomenclature of intermetallic compounds will have to consider also the field of mixed crystals and superstructures.[2B]

IV. Indicating the Mass, Atomic Number and State of Ionization on the Atomic Symbols.—When dealing with nuclear reactions, the ordinary representation of an element by the plain symbol is not sufficient. The latter must be expanded so as to show the atomic mass and atomic number.

An index on the right and below the symbol is already used to show the stoichiometric proportion, while another on the right above the symbol shows the state of ionization. The corresponding positions on the left are available for the atomic number and mass.

We then have:

right lower index....the number of atoms
right upper index....the state of ionization
left lower index.....the atomic number
left upper index.....the mass

Example: ${}^{35}_{17}\mathrm{Cl}^{+1}_{2}$

[1B] In French, "sulfure," "cyanure," "chlorure," etc., have the same significance as sulfide, cyanide, chloride, etc., in English.

[2B] The Committee wishes to draw the attention of workers in this field to the urgent need for some consistency in the notation used for distinguishing different modifications and intermediate phases.

This represents a singly ionized chlorine *molecule* Cl_2, each atom of which has the atomic number 17 and mass 35.

The following is an example of an equation for a nuclear reaction:

$$^{26}_{12}Mg + ^{4}_{2}He \longrightarrow ^{29}_{13}Al + ^{1}_{1}H$$

V. Group Names.—Compounds of the halogens are to be called *halogenides* (not haloids nor halides), while the elements oxygen, sulfur, selenium and tellurium may be called *chalcogens* and their compounds *chalcogenides.*

The alkali metals should not be called "alkalies" nor the alkaline earth metals "alkaline earths," since these names are old-fashioned terms for the oxides of these metals and should be avoided in scientific language. If compounds are concerned, the use of "alkali" or "alkaline earth" as an abbreviation for "alkali metal" or "alkaline earth metal" is general and permissible, *e. g.*, alkali chlorides.

In German "Kohlen-" is permissible as an abbreviation for "Kohlenstoff" in many carbon compounds.

C. Ternary, Quaternary, etc., Compounds

The preceding rules which have been developed for binary compounds are valid, when suitably extended, also for compounds of more than two elements.

Radicals having special names are treated like the elementary constituents of a compound when constructing names.

Examples:	NH_4Cl	Ammonium chloride
	KCN	Potassium cyanide
	$Fe(SCN)_3$	Iron (III) thiocyanate
	$Pb(N_3)_2$	Lead azide

If several electropositive constituents are combined with one electronegative, then the rule holds that the more electropositive constituent is to be placed first, just as in the case of binary compounds.

In the same way, if a compound contains several electronegative constituents these should be placed, both in the name and in the formula, in order of increasing electronegative character so far as this is possible.

Sulfur replacing oxygen in an acid radical should always be indicated by "thio" (see under D), so that compounds of the radical SCN should be called "thiocyanates"[3B] not sulfocyanates and not sulfo- nor thio-cyanides.

Names such as the following are permissible for mixed salts: lead chlorofluoride, lead sulfochloride.

The terms alumino-, boro-, beryllo-, etc., silicates should only be applied to such silicates as contain Al, B, Be, etc., in place of Si.

Examples:

Orthoclase, $K[AlSi_3O_8]$, is an aluminosilicate (potassium aluminotrisilicate)

Spodumene, $LiAl[Si_2O_6]$, is an aluminum silicate (lithium aluminum disilicate)

Muscovite, $KAl_2[AlSi_3O_{10}](OH)_2$, is an aluminum aluminosilicate

D. Oxygen Acids[4A]

Well-established names for the majority of the important simple oxygen acids have been in use for a long time, and their alteration is neither desirable nor necessary. It is only necessary to consider a number of cases in which uncertainty or confusion has arisen in the course of time owing to the employment of some names which are incorrect.

In the following tables are shown the names which should be used for the more important acids of sulfur, nitrogen, phosphorus and boron as well as their salts.

Formula	Acid	Salt
	Acids and Salts of Sulfur	
H_2SO_2	Sulfoxylic acid	Sulfoxylate
$H_2S_2O_4$	Dithionous acid	Dithionite
H_2SO_3	Sulfurous acid	Sulfite
$H_2S_2O_2$	Thiosulfurous acid	Thiosulfite
$H_2S_2O_5$	Pyrosulfurous acid	Pyrosulfite
H_2SO_4	Sulfuric acid	Sulfate
$H_2S_2O_3$	Thiosulfuric acid	Thiosulfate
$H_2S_2O_7$	Pyrosulfuric acid	Pyrosulfate
H_2SO_5	Peroxy(mono)sulfuric acid	Peroxy(mono)sulfate
$H_2S_2O_6$	Dithionic acid	Dithionate
$H_2S_xO_6 (x = 3, 4, \text{etc.})$	Polythionic acids	Polythionates
$H_2S_2O_8$	Peroxydisulfuric acid	Peroxydisulfate

[3B] "Rhodanide" is the usual German name.

[4A] "Oxy-Acids" is used in the English version (cf. *J. Chem. Soc.*, **1940**, 1408) and "Sauerstoffsäuren" in the German version (cf. *Ber.*, **73A**, 60 (1940)).

Formula	Acid	Salt
	Acids and Salts of Nitrogen	
$H_2N_2O_2$	Hyponitrous acid	Hyponitrite
H_2NO_2	Nitroxylic acid	Nitroxylate
HNO_2	Nitrous acid	Nitrite
HNO_3	Nitric acid	Nitrate
HNO_4	Peroxynitric acid	Peroxynitrate
	Acids and Salts of Phosphorus	
H_3PO_2	Hypophosphorous acid	Hypophosphite
H_3PO_3	Phosphorous acid	Phosphite
$H_4P_2O_5$	Pyrophosphorous acid	Pyrophosphite
$H_4P_2O_6$	Hypophosphoric acid	Hypophosphate
H_3PO_4	(Ortho)phosphoric acid	(Ortho)phosphate
$H_4P_2O_7$	Pyrophosphoric acid	Pyrophosphate
HPO_3	Metaphosphoric acid	Metaphosphate
H_3PO_5	Peroxy(mono)phosphoric acid	Peroxy(mono)phosphate
$H_4P_2O_8$	Peroxydiphosphoric acid	Peroxydiphosphate
	Acids and Salts of Boron	
H_3BO_2	Borous acid	—
$H_4B_2O_4$	Hypoboric acid	Hypoborate
H_3BO_3	Orthoboric acid	Orthoborate
HBO_2	Metaboric acid	Metaborate
$H_2B_4O_7$	Tetraboric acid	Tetraborate

For other polyboric acids see under F. II.

Decisions made on six points arising out of the above tables must be explained.

(1) $H_2S_2O_4$ Dithionous acid, and not *hydro*sulfur*ous* or *hypo*sulfur*ous* acid; salts are dithionites.

(2) $H_2S_2O_3$ *Thio*sulfur*ic* acid, and not *hypo*sulfur*ous* acid; salts are thiosulfates.

(3) H_2SO_5 *Peroxymono*sulfur*ic* acid, and not *per*sulfur*ic* acid.

(4) H_2NO_2 *Nitroxylic* acid, and not *hydro*nitr*ous* acid; salts are nitroxylates.

(5) $H_2B_4O_7$ *Tetra*bor*ic* acid, and not *pyro*bor*ic* acid; salts are tetraborates.

(6) H_2PO_3 Salts to be called hypophosphates.

Notes to (1) *and* (2): The name "hydrosulfurous acid" for the compound $H_2S_2O_4$ was proposed by its discoverer, Schützenberger, because of the erroneous assumption that the salts had the formula RHS_2O_4. This name has lost its justification since the later proof by Bernthsen and Bazlen that the salts of the acid are free from hydrogen and have the formula $R_2S_2O_4$, for the term "hydro" has no sense for compounds containing no hydrogen for which it is an unsatisfactory abbreviation in any case.

The name "hyposulfurous acid" proposed by Bernthsen and others for the compound $H_2S_2O_4$ also appears to be unsatisfactory quite apart from the fact that its employment might give rise to confusion so long as the use of the name "hyposulfite" for "thiosulfate" has not been entirely abandoned.

It is customary to apply the name "hypo...ous" to that acid in which each atom of the acid-forming element is less oxidized by two valency stages than the corresponding atoms in the acid to which the name ending in "-ous" is given (compare chlorous with hypochlorous acid; nitrous with hyponitrous acid).

Each atom of sulfur in the acid $H_2S_2O_4$ is, on the average, two valency stages less oxidized than each atom of sulfur in dithionic acid. It follows that $H_2S_2O_4$ should be called *dithionous* acid to fall into line with the general rules employed in naming the oxygen acids. This name does not imply any assumption as to the constitution of the compound; it was first proposed by Noyes and Steinour (THIS JOURNAL, **51**, 1409 (1929)). It is quite wrong to use the name "hyposulfurous acid" for $H_2S_2O_3$, though this is still frequently done. The acid $H_2S_2O_3$ is derived from sulfuric acid, H_2SO_4, by replacement of one oxygen atom by sulfur. It must accordingly be called *thiosulfuric* acid since the presence of sulfur which has taken the place of oxygen is in general indicated by the prefix "thio" (see later).

The name "hyposulfurous acid" would be justified for the acid H_2SO_2 but the well-established name "sulfoxylic acid" should be retained for this compound. The names "hyposulfurous acid" and "hyposulfite" should therefore cease to be used at all.

Note to (3): A distinction must be made between those acids or salts which are derived by substitution from hydrogen peroxide and in consequence contain peroxidic oxygen —O—O— and those which are derived from the highest oxidation stages of some elements and are free from peroxidic oxygen. The last-named are correctly called *per* salts (such as $NaClO_4$, $KMnO_4$).

The first group, such as $R_2S_2O_8$ and R_3PO_5, must be separated from the genuine per salts and called *peroxy* salts, the corresponding acids being *peroxy* acids.

Examples:	H_2SO_5	Peroxymonosulfuric acid
	$H_4P_2O_8$	Peroxydiphosphoric acid
	NH_4BO_3	Ammonium peroxyborate

In the same way the oxides derived from H_2O_2 should be called *peroxides*, and not superoxides or hyperoxides.

Note to (4): The acid H_2NO_2 has been called "hydronitrous acid," but it is more correctly called "nitroxylic acid" by analogy with sulfoxylic acid. The sodium salt, Na_2NO_2, obtained by Zintl is, correspondingly, sodium nitroxylate.

Note to (5): The prefixes "ortho," "meta," and "pyro" are used generally in the sense that the term "ortho" is applied to the most hydroxylated acid known either in the free state or as salts or esters.

Examples:	H_3BO_3	Orthoboric acid
	H_4CO_4	Orthocarbonic acid
	H_4SiO_4	Orthosilicic acid
	H_3PO_4	Orthophosphoric acid
	H_6TeO_6	Orthotelluric acid
	H_5IO_6	Orthoperiodic acid

The pyro and meta acids are derived from the ortho acids by removal of water in stages. Pyro acids are those which have lost 1 molecule of H_2O from 2 molecules of ortho acid. (*Examples:* $H_2S_2O_7$, $H_2S_2O_5$, $H_4P_2O_7$, $H_4P_2O_5$.) This rule does not apply, however, to the polyboric acid $H_2B_4O_7$ (= $2B_2O_3{\cdot}H_2O$), which contains less water than metaboric acid, HBO_2 (= $B_2O_3{\cdot}H_2O$). To avoid breaking the rule the acid $H_2B_4O_7$ should not be called "pyroboric acid," but "tetraboric acid" in agreement with the proposals for the naming of isopoly acids (see F. II).

Replacement of O by S.—Acids which are derived from oxygen acids by replacement of O atoms by S atoms are to be called *thio* acids, their salts *thio* salts.

Examples:

H_2CS_3	Trithiocarbonic acid
Na_3SbS_4	Trisodium tetrathioantimonate (sodium thioantimonate for short)

The group $[H_3O]^+$.—When the hydrogen ion is considered to occur (in aqueous solution or in a compound) in the form $[H_3O]^+$, it is advisable to call it the *hydronium* ion (not *hydroxonium* ion).

E. Salts

I. General.—Salts should always be named so that the name of the metal or electropositive radical precedes that of the acid radical which carries the termination -ate, -ite or -ide.

Examples: Silver nitrate, magnesium sulfate, calcium carbonate, sodium nitrite, iron sulfide, potassium cyanide.

Names such as "nitrate of silver," "sulfate of magnesium" are permissible but it is wrong to use in this way the name of the metal oxide in place of that of the metal, so that "sulfate of magnesia," "carbonate of lime," etc., are definitely wrong, and should not be employed (see A.).

Names derived from the German names of the acids, such as "salpetersaures Silber," "schwefelsaures Magnesium," "kohlensaures Calcium," may be used in popular writing (German) but should be avoided in scientific language (in this case also the name of the metal oxide must not be used in place of that of the metal). The use in English of names such as "copper vitriol" or "blue vitriol" for $CuSO_4{\cdot}5H_2O$ and "oil of vitriol" for sulfuric acid is analogous to the above German usage. Such names are still used to some extent in technical literature and in chemical works though only relatively few compounds are affected. There is little to be said in favor of these archaic names and it would be better if they went out of use.

In the case of *mixed or double salts* the rules given under C should be applied.

Examples:

$KNaCO_3$	Potassium sodium carbonate
$KCaPO_4$	Potassium calcium phosphate
NH_4MgPO_4	Ammonium magnesium phosphate

Salts of nitrogen compounds, if regarded as coordination compounds like ammonium chloride, NH_4Cl, are to be designated as "-onium" or "-inium" compounds.

Examples: Tetramethylammonium chloride, hydrazinium chloride, pyridinium chloride.

If, however, the nitrogen compounds are regarded as addition compounds, then the rules derived for these will apply (See F. V).

II. Acid Salts (Hydrogen Salts).—The rational names for acid salts are formed by using "hydrogen" for the hydrogen atoms which they contain. The hydrogen is to be named last of the electropositive constituents.

Examples:	$KHSO_4$	Potassium hydrogen sulfate
	$NaHCO_3$	Sodium hydrogen carbonate
	Na_2HPO_4	Disodium hydrogen phosphate
	NaH_2PO_4	Sodium dihydrogen phosphate

In complicated cases use formulas.

Examples:

$4K_2SO_4{\cdot}3H_2SO_4$ = $K_8H_6(SO_4)_7$ rationally: Octapotassium hexahydrogen heptasulfate

$5K_2SO_4{\cdot}3H_2SO_4$ = $K_5H_3(SO_4)_4$ rationally: Pentapotassium trihydrogen tetrasulfate

If it is desired to emphasize the type of compound rather than its composition, the term *acid salts* (monoacid, diacid, etc.) can be used as well as such expressions as primary, secondary, tertiary salts. Designation in terms of the acid:base ratio by means of "bi" is not in agreement with the fundamental principles of rational nomenclature. It is therefore wrong to say "bicarbonate," "bisulfate," "bisulfite."

III. Basic Salts.—Basic salts which can be shown to contain hydroxyl groups and which can be considered and named as addition compounds of hydroxides to neutral salts are called *hydroxy salts.*

Example: $Cd(OH)Cl$ Cadium hydroxychloride

When the hydroxyl group is bound in a complex Werner's system of notation should be used, according to which the hydroxyl groups are designated *hydroxo* or *ol* groups. Basic salts in which there are oxygen atoms as well as acid radicals attached to the metal are called *oxy* salts. If they contain radicals with special designations, names derived from these can be employed.

Examples:

BiOCl	Bismuth oxychloride or bismuthyl chloride
$UO_2(NO_3)_2$	Uranium (VI) dioxynitrate or uranyl nitrate

For oxygen atoms bound in a complex, the Werner notation applies and the oxygen atoms are to be called *oxo* atoms.

F. Higher-Order Compounds

I. Complex Compounds (Coördination Compounds). General.—The nomenclature devised by A. Werner still regulates the naming of coördination compounds and its value lies in the fact that it permits of uniform treatment of the whole range of compounds. An alteration is needed only as regards the indication of valency. In order to get a uniform method of indicating valency, both for simple and for coördination compounds, Stock's method, already applied to the former, has been extended to the latter.

In the case of *complex cations* the Roman figures expressing the valency are placed in parentheses after the names of the elements to which they relate (as with the simple compounds).

Examples:

$[Cr(OH_2)_6]Cl_3$	Hexaaquochromium (III) chloride
$[Cr_3Ac_6(OH)_2]X$	Hexaacetatodihydroxotrichromium (III) salt

In the case of *complex anions of acids or salts* the valency of the central atom is given in parentheses after the name of the complex which ends in -ate. The Latin names of metals must often be used in this connection for reasons of euphony.

Examples:

$H_2[PtCl_6]$	Hydrogen hexachloroplatinate (IV)[5A]
$H_4[Fe(CN)_6]$	Hydrogen hexacyanoferrate (II)
$K_4[Fe(CN)_6]$	Potassium hexacyanoferrate (II)
$K_3[Fe(CN)_6]$	Potassium hexacyanoferrate (III)
$K_3[Co(NO_2)_6]$	Potassium hexanitrocobaltate (III)
$K[Au(OH)_4]$	Potassium tetrahydroxoaurate (III)

In the case of *neutral complexes* (nonelectrolytes) it is not necessary to give the valency of the central atom. If it is desired to emphasize it specially, this can be done as in the case of the complex cations. Mention of the valency is not necessary when the number of the ionized atoms or groups is given in the name.

Examples:

$[Cr(OH_2)_6]Cl_3$	Hexaaquochromium trichloride
$K_4[Fe(CN)_6]$	Tetrapotassium hexacyanoferrate
$K_3[Fe(CN)_6]$	Tripotassium hexacyanoferrate

This method of naming is, however, only to be recommended in those cases where the electrochemical valency of the central atom is not known or not with certainty, as for instance with compounds containing NO in the complex.

Order of the attached atoms or groups.—Atoms or groups coördinated in the complex are to be mentioned in the name in the order (i) *acidic groups* such as chloro (Cl), cyano (CN), cyanato (NCO), thiocyanato (NCS), sulfato (SO_4), nitro (NO_2), nitrito (ONO), oxalato (C_2O_4) and hydroxo (OH); (ii) *neutral groups:* aquo (H_2O), substituted amines [$C_2H_4(NH_2)_2$ = en] and last of all ammine (NH_3).

II. Isopoly Acids and their Salts.—As isopoly acids in the widest sense are to be understood those acids which can be regarded as resulting from two or more molecules of one and the same acid by elimination of water. In this sense the pyro and meta[6A] acids which are formed from ortho acids by removal of water are also to be included among the isopoly acids.

Even though the rule holds for the poly acids in an accentuated form, that formulas should be used for characterizing compounds in complicated cases, there is yet need for a rational nomenclature if only for designating the groups of compounds. There belong to the isopoly acids as especially important representatives the boric, silicic, molybdic, tungstic and vanadic acids. Rules will be considered with reference to them, therefore.

It is proposed that the empirical formulas should always be resolved into the base anhydride: acid anhydride ratios. For this it is unnecessary to go into the still obscure and unsettled questions of the constitution of these compounds, and this avoids introducing into the method of designation any essential factor that might have to be changed in consequence of an eventual change in conception of the constitution.

This procedure gives a method of representa-

(5A) The corresponding names given in the German version are "Hexachloroplatin(IV)-säure" and "Hexacyanoeisen(II)-säure" (cf. *Ber.*, **73A**, 65 (1940)).

(6A) Only the pyro acids are included in the German version (cf. *ibid.*, 66).

tion for this class of compounds which is clear and straightforward and very suitable for systematic treatment. Characterization by means of the base anhydride:acid anhydride ratio has already thoroughly justified itself in the systematic description of the poly acids and their salts in Gmelin's "Handbuch der anorganischen Chemie." It has always made possible a classification which was free from contradictions.

The following equally satisfactory methods for constructing names are available:

(1) The composition, referred to the simplest empirical formula, is given by means of Greek numerical prefixes just as with other compounds (compare B. II).

(2) The simplest formula which expresses the analytical results for the compound in terms of base anhydride and acid anhydride is resolved into these. The ratio base anhydride:acid anhydride is shown in the name by means of Arabic figures in parentheses.

In both cases the basic component is to be named before the acid. Acid hydrogen atoms are to be indicated by "hydrogen" and should always be given (also in the names of the free acids).

These proposals have been carried out for a number of borates, silicates, molybdates, tungstates and vanadates as shown in the following tables.

Empirical formula	Name formation by Greek numerical prefixes	Resolved formula	Name formation by base anhydride: acid anhydride ratio	Present customary name
		Borates		
Na_3BO_3	Trisodium (mono)borate	$3Na_2O \cdot B_2O_3$	Sodium (3:1) borate	Orthoborate
$Na_4B_2O_5$	Tetrasodium diborate	$2Na_2O \cdot B_2O_3$	Sodium (2:1) borate	Pyroborate
$NaBO_2$	Monosodium (mono)borate	$Na_2O \cdot B_2O_3$	Sodium (1:1) borate	Metaborate, monoborate
$Na_2B_4O_7$	Disodium tetraborate	$Na_2O \cdot 2B_2O_3$	Sodium (1:2) borate	Tetraborate, pyroborate
NaB_3O_5	Sodium triborate	$Na_2O \cdot 3B_2O_3$	Sodium (1:3) borate	Hexaborate, triborate
$Na_2B_8O_{13}$	Disodium octaborate	$Na_2O \cdot 4B_2O_3$	Sodium (1:4) borate	Octaborate, tetraborate
NaB_5O_8	Sodium pentaborate	$Na_2O \cdot 5B_2O_3$	Sodium (1:5) borate	Decaborate, pentaborate
$Na_2B_{12}O_{19}$	Disodium dodecaborate	$Na_2O \cdot 6B_2O_3$	Sodium (1:6) borate	Dodecaborate, hexaborate
		Silicates		
Na_4SiO_4	Tetrasodium (mono)silicate	$2Na_2O \cdot SiO_2$	Sodium (2:1) silicate	Orthosilicate
$Na_6Si_2O_7$	Hexasodium disilicate	$3Na_2O \cdot 2SiO_2$	Sodium (3:2) silicate	Pyrosilicate
$Na\ Si_3O_{10}$	Octasodium trisilicate	$4Na_2O \cdot 3SiO_2$	Sodium (4:3) silicate	Pyrosilicate
Na_2SiO_3	Disodium (mono)silicate	$Na_2O \cdot SiO_2$	Sodium (1:1) silicate	Metasilicate
$Na_6Si_4O_{11}$	Hexasodium tetrasilicate	$3Na_2O \cdot 4SiO_2$	Sodium (3:4) silicate	Metasilicate
$Na_4Si_3O_8$	Tetrasodium trisilicate	$2Na_2O \cdot 3SiO_2$	Sodium (2:3) silicate	Metasilicate
$Na_2Si_3O_7$	Disodium trisilicate	$Na_2O \cdot 3SiO_2$	Sodium (1:3) silicate	Metasilicate
		Molybdates		
Na_2MoO_4	Disodium (mono)molybdate	$Na_2O \cdot MoO_3$	Sodium (1:1) molybdate	Normal molybdate
$Na_2Mo_2O_7$	Disodium dimolybdate	$Na_2O \cdot 2MoO_3$	Sodium (1:2) molybdate	Dimolybdate
$Na_{10}Mo_{12}O_{41}$	Decasodium dodecamolybdate	$5Na_2O \cdot 12MoO_3$	Sodium (5:12) molybdate	Paramolybdate
$Na_2Mo_3O_{10}$	Disodium trimolybdate	$Na_2O \cdot 3MoO_3$	Sodium (1:3) molybdate	Trimolybdate
$Na_2Mo_4O_{13}$	Disodium tetramolybdate	$Na_2O \cdot 4MoO_3$	Sodium (1:4) molybdate	Tetramolybdate
		and so on up to $Na_2O \cdot 16MoO_3$		
		Tungstates		
Na_2WO_4	Disodium (mono)tungstate	$Na_2O \cdot WO_3$	Sodium (1:1) tungstate	Normal tungstate
$Na_4W_3O_{11}$	Tetrasodium tritungstate	$2Na_2O \cdot 3WO_3$	Sodium (2:3) tungstate	Normal tungstate
$Na_2W_2O_7$	Disodium ditungstate	$Na_2O \cdot 2WO_3$	Sodium (1:2) tungstate	Ditungstate
$Na_{10}W_{12}O_{41}$	Decasodium dodecatungstate	$5Na_2O \cdot 12WO_3$	Sodium (5:12) tungstate	Paratungstate
$Na_2W_3O_{10}$	Disodium tritungstate	$Na_2O \cdot 3WO_3$	Sodium (1:3) tungstate	Tritungstate
$Na_2W_4O_{13}$	Disodium tetratungstate	$Na_2O \cdot 4WO_3$	Sodium (1:4) tungstate	Tetratungstate (with water metatungstate)
$Na_2W_8O_{25}$	Disodium octatungstate	$Na_2O \cdot 8WO_3$	Sodium (1:8) tungstate	Octatungstate
		Vanadates		
Na_3VO_4	Trisodium (mono)vanadate	$3Na_2O \cdot V_2O_5$	Sodium (3:1) vanadate	Normal orthovanadate
$Na_4V_2O_7$	Tetrasodium divanadate	$2Na_2O \cdot V_2O_5$	Sodium (2:1) vanadate	Pyrovanadate
$NaVO_3$	Sodium (mono)vanadate	$Na_2O \cdot V_2O_5$	Sodium (1:1) vanadate	Metavanadate
$Na_2V_4O_{11}$	Disodium tetravanadate	$Na_2O \cdot 2V_2O_5$	Sodium (1:2) vanadate	Tetravanadate
NaV_3O_8	Sodium trivanadate	$Na_2O \cdot 3V_2O_5$	Sodium (1:3) vanadate	Hexavanadate

In more complicated cases the formula itself is best employed. Even though a correct systematic name is possible in such cases, it is generally unwieldy, as, for instance:

$Ba_2(VO_2)H_2(V_6O_{16})$ Dibarium vanadyl dihydrogen pentavanadate

In a similar way, for example, the compounds of the tungstic acids with organic bases are grouped together as "tungstates of organic bases." Subordinated to this group are the subgroups "methylammonium tungstates," "propylammonium tungstates" and so on, of which the individual compounds then follow with their formulas only, since an attempt to form names for each compound would lead to a cumbersome representation of their composition.

III. Heteropoly Acids and their Salts.—The formulas of the heteropoly acids and their salts are resolved into their constituent base and acid anhydrides as in the case of the isopoly acids, and for this purpose the simplest formula which expresses the analytical composition is employed.

This resolution is made for the *acid* into: nonmetallic acid, oxide of the acid-forming metal, water; for the *salt* into: salt of the nonmetallic acid (resolved perhaps into base anhydride–acid anhydride ratio),[7B] oxide of the acid-forming metal, water.

The numbers of atoms of the two acid-forming elements derived from the *simplest* formula[8A] are shown in the name by means of Arabic figures or Greek numerical prefixes. As a rule, names are used here only for the collective designation of groups of compounds. For individual compounds formulas are used for the most part.

Examples:

$R_3PO_4 \cdot 12MoO_3$	Dodecamolybdophosphate	or $3R_2O \cdot P_2O_5 \cdot 24MoO_3$	24-Molybdo-2-phosphate
$R_3PO_4 \cdot 12WO_3$	Dodecatungstophosphate	or $3R_2O \cdot P_2O_5 \cdot 24WO_3$	24-Tungsto-2-phosphate
$2R_5PO_5 \cdot 17WO_3$	17-Tungstodiphosphate	or $5R_2O \cdot P_2O_5 \cdot 17WO_3$	17-Tungsto-2-phosphate
$R_5BO_4 \cdot 12WO_3$	Dodecatungstoborate	or $5R_2O \cdot B_2O_3 \cdot 24WO_3$	24-Tungsto-2-borate
$R_8SiO_6 \cdot 12WO_3$	Dodecatungstosilicate	or $4R_2O \cdot SiO_2 \cdot 12WO_3$	12-Tungstosilicate

IV. Double Salts.—The name of the double salt is formed by putting together the names of the simple salts from which it is formed. The order of the cationic constituents should be that of decreasing electropositive character. Constituents common to both salts should be mentioned only once.

Examples:

$KCl \cdot MgCl_2$	Potassium magnesium chloride
$Na_2SO_4 \cdot CaSO_4$	Sodium calcium sulfate
$3CaO \cdot Al_2O_3 \cdot CaCl_2 \cdot 10H_2O$	Calcium chloroaluminate[9A]
$KCl \cdot MgSO_4$	Potassium chloride magnesium sulfate

In the third example only the group name is given, under which all the single members are collected.

V. Hydrates, Ammoniates and other Addition Compounds.—The collective names *hydrate*, *peroxyhydrate* (not perhydrate) and *ammoniate* should be applied to compounds which contain molecules of H_2O, H_2O_2 and NH_3, respectively.

Either Greek numerical prefixes or Arabic figures can be used to show the number of such molecules present.

Examples:

$CaCl_2 \cdot 6H_2O$	Calcium chloride hexahydrate or calcium chloride 6-hydrate
$CaCl_2 \cdot 4H_2O$	Calcium chloride tetrahydrate or calcium chloride 4-hydrate
$CaCl_2 \cdot 2H_2O$	Calcium chloride dihydrate or calcium chloride 2-hydrate
$CaCl_2 \cdot H_2O$	Calcium chloride monohydrate or calcium chloride 1-hydrate
	Collective name: Calcium chloride hydrates.
$NaOOH \cdot H_2O_2$	Sodium hydrogen peroxide peroxyhydrate
$AlCl_3 \cdot xNH_3$	Aluminum chloride ammoniate

If it needs to be shown that the molecule in question forms part of a *complex*, then the compounds are to be named as *aquo* compounds, *peroxyhydrato* compounds and *ammines* (compare F. I).

Examples:

$[Cr(NH_3)_6]Cl_3$	Hexamminechromium (III) chloride
$[Cr(OH_2)_6]Cl_3$	Hexaaquochromium (III) chloride
$[Cr(OH_2)_4Cl_2]Cl \cdot 2H_2O$	Dichlorotetraaquochromium (III) chloride dihydrate

Other addition compounds.—Addition compounds containing added PCl_3, NOCl, H_2S, C_2H_5OH, etc., are better shown by the formula than by a special name. For systematic consideration of this field it is advisable to make use of a group name.

Examples:

$AlCl_3 \cdot 4C_2H_5OH$	Compound of aluminum chloride with alcohol
$AlCl_3 \cdot NOCl$	Compound of aluminum chloride with nitrosyl chloride
$AlCl_3 \cdot H_2S$	Compound of aluminum chloride with hydrogen sulfide

Group names: "Compounds of aluminum chloride with organic compounds," "with sulfur compounds," etc.

(7B) If by so doing simpler numerical relations can be obtained.

(8A) The German version has an additional clause at this point: "according to whether the formula has been resolved into the base anhydride–acid anhydride ratio or not" (cf. *Ber.*, **73A**, 69 (1940)).

(9A) The German version has "Calciumchloridaluminat" (cf. *ibid.*, **73A**, 69 (1940)).