XXXIX.—*Contributions to the Notation of Organic and Inorganic Compounds.*

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THE typical formulæ generally used to represent the different great families of organic compounds are far from fulfilling their functions in an equally perfect manner. Of the types in general use, those employed in the formulation of the artificial organic bases and the organo-metallic bodies are alone satisfactory; on the other hand, the water, hydrochloric acid, and hydrogen types fail more or less completely to give an intelligent representation of the atomic arrangement of the bodies which are formulated upon them.

The cause of this comparative success in the one case and failure

* Proc. Roy. Soc. 1864, 303.

† Ann. Ch. Pharm. cxxxiii, 241.

‡ Chem. Soc. J. [2] ii, 163.

in the other is doubtless to be found in the almost exclusively synthetical origin of the alkaloïdal and organo-metallic compounds. The number and nature of the constituent radicals of these bodies became thus invested with a degree of certainty which, until recently, was almost entirely wanting in other families of organic compounds.

The rapid progress that has of late been made in the application of synthetical methods to the production of most of the other great organic families, has rendered it possible to apply, with some prospect of success, a mode of notation, the principles of which were suggested in a lecture which I delivered at the Royal Institution in the year 1858.* This method was founded upon the carbonic acid, or, as it is now sometimes called, the marsh-gas type. The adoption of this type was, however, nothing more than the application to the compounds of the tetrad carbon atom, of the principles which I had previously employed in the notation of organo-metallic bodies containing metals of various degrees of atomicity.† As examples of the application of this mode of notation to some of the chief organic families, the following may be adduced:—

Alcohols.	Ethers.	Fatty acids.	Aldehydes.	Ketones.
$\text{C}^{\text{iv}} \left\{ \begin{array}{c} \text{CH}_3 \\ \text{H} \\ \text{H} \\ \text{OH} \end{array} \right.$	$\text{C}^{\text{iv}} \left\{ \begin{array}{c} \text{CH}_3 \\ \text{H} \\ \text{H} \\ \text{OC}_2\text{H}_5 \end{array} \right.$	$\text{C}^{\text{iv}} \left\{ \begin{array}{c} \text{CH}_3 \\ \text{O} \\ \text{OH} \end{array} \right.$	$\text{C}^{\text{iv}} \left\{ \begin{array}{c} \text{CH}_3 \\ \text{O} \\ \text{H} \end{array} \right.$	$\text{C}^{\text{iv}} \left\{ \begin{array}{c} \text{CH}_3 \\ \text{O} \\ \text{CH}_3 \end{array} \right.$
Ethylic alcohol.	Ethylic ether.	Acetic acid.	Acetic aldehyde.	Acetone.

The meaning of these formulæ is so obvious as scarcely to require description; that of ethylic alcohol, for instance, represents an atom of tetrad carbon united first to the carbon of methyl, secondly to each of two atoms of hydrogen; and lastly, to oxygen, the latter dyad element being likewise united to an atom of hydrogen, which is thus linked, as it were, to the first carbon atom without being actually united with it. This is a true representation of the internal arrangement of the atoms composing alcohol, not, indeed, of their relative positions with regard to each other in space, but of the mode in which they are held together. Thus of the six atoms of hydrogen in alcohol, two only are united with the atom of carbon which, in the formula, is placed to the left of

* Proceedings of the Royal Institution, vol. ii, page 540.

† Phil. Trans. for 1852, page 441.

the bracket. Of the remaining atoms of hydrogen, three are united with the second atom of carbon forming methyl, whilst the sixth is combined with oxygen. Each of these atoms has, without doubt, its own proper motion—vibratory or otherwise,—besides another motion common to the whole molecule; but the formula indicates certain chemical bounds, beyond which no atom can pass without causing decomposition of the compound. Thus, confining our attention to the hydrogen, the two atoms of this element in combination with the carbon to the left of the bracket are free to move about or in the neighbourhood of that carbon-atom. In like manner the three atoms of hydrogen in the methyl are free to move around or about the methylic carbon, so long as they do not escape from the dominion of their own peculiar atom of carbon. Of precisely the same nature is the bond between the remaining atom of hydrogen and the oxygen with which it is combined. The formula proclaims, however, that all these atoms of hydrogen must remain exclusively under the domination of their respective carbon and oxygen atoms so long as the compound continues to exist. Such a formula does not deny the exercise of a certain influence by each individual atom over every other atom in the compound, but it does not allow the conception of an exchange of the atom of hydrogen, for instance, in union with oxygen, for one of the atoms of hydrogen in union with carbon, without the application of an external force and the disruption of the compound. The formula asserts such an exchange to be just as impossible as the wandering of a satellite from planet to planet in our own solar system. On no other hypothesis than this of limited mobility can the facts of isomerism receive an intelligent explanation. Dibromosuccinic acid and iso-dibromosuccinic acid could not otherwise exist separate from each other, because the one would be every moment changing into the other, and consequently both fumaric and maleic acids ought to yield, when treated with bromine, the same product, viz. : a mixture of dibromosuccinic and iso-dibromosuccinic acids. Experiment proves however that fumaric acid gives dibromosuccinic acid alone, whilst maleic acid always gives iso-dibromosuccinic acid. It would be equally impossible for lactic and paralactic acids, and for itaconic, citraconic, and mesaconic acids to exist alone; in fact the conception of isomerism in vast numbers of cases becomes impossible, except on the assumption of limited mobility of the atoms of a chemical compound. This idea of limited atomic mobility, which is one of the fundamental bases of

constitutional formulæ, forms the essential difference between constitutional and merely typical formulæ.

The constitutional formulæ above given as examples may, of course, be written in several other ways, with the retention of the same fundamental ideas of internal arrangement. Thus ethylic alcohol may be written—

In this formula the two atoms of tetrad carbon united to each other, as expressed also in the previous formula, by one bond or equivalence of each, become hexadic with regard to the remaining elements of the compound, which are placed on the right of the bracket. The way in which these elements are distributed to each of the two atoms of carbon is shown by the horizontal line. Upon the same plan the formula of mesoxalic acid is thus written—

In this compound the three atoms of carbon by union with each other thus, C—C—C, form, taken together, an octadic group, the first and third atoms being each united with oxygen and hydroxyl, forming two atoms of oxatyl; whilst the second atom, which has obviously only two bonds free for union with other elements, is saturated by two atoms of hydroxyl. Such formulæ have been used by Mr. Duppa and myself in expressing the constitution of bodies belonging to the acetic, lactic, and acrylic series of acids.* Their simplicity, as symbolic expressions of ideas regarding the constitution of organic bodies, leaves little to be desired; but, although perhaps less unwieldy than some formulæ which have been written upon the so-called mixed types, they are sufficiently so to be open to serious objection. To obviate this defect I have

* Proceedings of the Roy. Soc. p. xiii, 140; xiv, 17, 79, 83, 191, 197; xv, 25. Chem. Soc. J. [2], iii, 133, and Phil. Trans. vol. clvi., p. 37.

devised a modified notation, by which the same structural ideas can be expressed in a more condensed form, without impairing either the simplicity or the structural character of the formulæ. I have also proved its practicability by using it, both for organic and inorganic compounds, throughout my course of lectures at the Royal College of Chemistry last autumn.

In this system of notation special symbols are employed for most compound radicals, so as to render the formulæ more compact, and to avoid the too frequent use of parentheses, which always give a confused appearance to a formula. Thus ethyl is expressed by Et instead of (C_2H_5) . Many of the symbols necessary for this purpose are already in common use, such as

Me = Methyl	Pr = Propyl
Et = Ethyl	Bu = Butyl
All = Allyl	Ay = Amyl.

These symbols of the monad alcohol-radicals, with the marks of atomicity proposed by Odling, are further employed to designate the derived dyad, triad, &c., radicals, thus:—

Me'' = CH_2	or Methylene
Me''' = CH	or Formyl
Et'' = C_2H_4	or Ethylene.
&c.	&c. &c.

These compound radicals, especially the monads, are frequently linked to other elements by oxygen; thus in acetic

ether $C \begin{cases} Me \\ O \\ OEt, \end{cases}$ ethyl is linked to carbon by oxygen. In all such

cases I propose to consider the radical and linking oxygen as a new compound radical. These radicals may be named *hydroxyl*, *methoxyl*, *ethoxyl*, &c., and they are symbolically represented by attaching the small letter o to the symbol of the constituent basylous radical, thus—

Ho = HO	= Hydroxyl	Meo'' = CH_2O_2	= Methyleneoxyl
Meo = CH_3O	= Methoxyl	Meo''' = CHO_3	= Formoxyl
Eto = C_2H_5O	= Ethoxyl	Eto'' = $C_2H_4O_2$	= Ethyleneoxyl
&c.	&c. &c.	&c.	&c. &c.

The use of any but the monad organic oxy-radicals is extremely rare.

The following are the names and formulæ of the inorganic radicals employed :—

	Atomic formulæ.	Symbols.
Hydrosulphyl	HS	Hs
Ammonium	NH ₄	Am
Ammonoxyl	NH ₄ O	Amo
Amidogen	NH ₂	Ad

In addition to these, the compounds of metals with the oxygen by which they are linked to other elements, compounds analogous to methoxyl, ethylenoxyl, &c., are also symbolized as radicals by the addition of the small letter o to the symbol of the metal, thus—

	Atomic formulæ.	Symbols.
Potassoxyl	KO	Ko
Zincoxyl	Zn''O ₂	Zno''
&c.	&c.	&c.

It is not necessary to dignify all these metallic compound radicals with names; but it must be borne in mind that the number of atoms of oxygen in any radical of this class depends upon its atomicity; thus a monad contains only one atom of oxygen, a dyad two, and a triad three atoms of oxygen. The use of any but monad and dyad metallic compound radicals is very rare.

In writing the formula of any compound upon this system, the symbol of the element possessing the highest atomicity is, as a rule, placed first, that is to the left, and the element so represented is always considered to be directly united with all the *active bonds* of the other elements, or compound radicals, following upon the same line; thus the formula of sulphuric acid (**SO**₂Ho₂) signifies that the hexad atom of sulphur is combined with the four bonds of the two atoms of oxygen, and also with the two bonds of the two atoms of hydroxyl; but in order to distinguish such a rational formula from a more or less empirical one, the first symbol, that is the symbol of what may be termed *the grouping element*, is printed in thick type.*

By the term *bond*, I intend merely to give a more concrete expression to what has received various names from different chemists, such as an atomicity, an atomic power, and an equivalence. A monad is represented as an element having one bond, a dyad as an

* In writing these formulæ, upon a black board for instance, this distinction is not usually necessary, because the writer, being present, can explain whether his formulæ are constitutional or not.

element possessing two bonds, &c. It is scarcely necessary to remark that by this term I do not intend to convey the idea of any *material* connection between the elements of a compound, the bonds actually holding together the atoms of a chemical compound being, in all probability, as regards their nature, much more like those which connect the members of our solar system.

The number of bonds possessed by an element, or its atomicity, is, apparently at least, not a fixed and invariable quantity; thus nitrogen is sometimes equivalent to five atoms of hydrogen, as in ammoniac chloride ($\text{N}^{\text{v}}\text{H}_4\text{Cl}$), sometimes to three atoms, as in ammonia ($\text{N}^{\text{iii}}\text{H}_3$), and sometimes to only one atom, as in nitrous oxide (ON_2). But it is found that this variation in atomicity always takes place by the disappearance or development of an even number of bonds; thus nitrogen is either a pentad, a triad, or a monad; phosphorus and arsenic, either pentads or triads; carbon and tin, either tetrads or dyads; and sulphur, selenium, and tellurium, either hexads, tetrads, or dyads.

These remarkable facts can be explained by a very simple and obvious assumption, viz., that *one or more pairs of bonds belonging to an atom of the same element can unite, and, having saturated each other, become, as it were, latent*. Thus the pentad nitrogen becomes a triad when one pair of its bonds becomes latent, and a monad when two pairs, by combination with each other, are, in like manner, rendered latent; and the hexad sulphur becomes, by a similar process successively a tetrad in triethylsulphine-iodide, and a dyad in sulphuretted hydrogen.

Adopting this hypothesis, it will be convenient to distinguish the maximum number of bonds of an element as its *absolute atomicity*, the number of bonds united together* as its *latent atomicity*, and the number of bonds actually engaged in linking it with the other elements of a compound as its *active atomicity*. The sum of the active and latent atomicity of any element must evidently always be equal to the absolute atomicity. Thus in sulphuric acid ($\text{S}^{\text{vi}}\text{O}_2\text{H}_2$) the absolute and active atomicities are both = vi, therefore the latent atomicity = 0. In sulphurous acid ($\text{S}^{\text{iv}}\text{OH}_2$) the active atomicity = iv, and consequently the latent = vi - iv = ii; whilst in sulphuretted hydrogen ($\text{S}^{\text{ii}}\text{H}_2$) the active and latent atomicities are respectively ii and iv.

The apparent exceptions to this hypothesis disappear on investigation: thus iron, which is a dyad in ferrous compounds (as FeCl_2), a tetrad in cubical pyrites (FeS_2), and a hexad in ferric acid

(FeO_2Ho_2), is apparently a triad in ferric chloride (FeCl_3); but the vapour-density of ferric chloride shows that its formula must be doubled—that, in fact, the two atoms of the hypothetical molecule of iron (Fe_2) have not been completely separated. The formulæ of the ferrous and ferric chlorides and of ferric acid then become :

Ferrous chloride	$\text{ivFe}''\text{Cl}_2$
Ferric chloride	$''' \text{Fe}'''_2\text{Cl}_6$
Ferric acid	$\text{Fe}^{\text{vi}}\text{O}_2\text{Ho}_2$

Again, mercury is apparently a monad in mercurous chloride (HgCl), and a dyad in mercuric chloride ($\text{Hg}''\text{Cl}_2$); but there are strong reasons for believing that the formula of calomel ought to be doubled, in which case mercury would assume the dyad form in both compounds :

Mercurous chloride	$\text{'Hg}'_2\text{Cl}_2$
Mercuric chloride	$\text{Hg}''\text{Cl}_2$

It will be remarked that the number of bonds, supposed to be combined with each other in the atom of iron in ferrous chloride, is expressed in the above symbol by the atomicity-numeral *iv* placed to the left of the symbol, whilst the analogous union of three bonds of each atom of iron in ferric chloride is expressed by the three dashes''' to the left of the symbol Fe_2 . I do not, however, use these co-efficients of latent atomicity, unless two or more atoms of the same element are joined together under such circumstances, that the number of bonds uniting them cannot be found by subtracting the co-efficient of active atomicity from the absolute atomicity of the element; as in hydric persulphide, hydro-sulphyl ($\text{'S}'_2\text{H}_2$), for instance, which might otherwise be viewed as $''' \text{S}'_2\text{H}_2$, or $\text{vS}'_2\text{H}_2$.

In rare cases, where oxygen links together two elements or radicals in the same line, a hyphen is placed before and after the symbol O, thus :—

The bracket has been employed in various senses in chemical formulæ, but I now propose to restrict its use to one purpose only, viz., for expressing chemical combination between two or more elements which are placed perpendicularly with regard to each

other and next to the bracket in a formula. Thus in the following cases—

the formula No. I signifies that two atoms of carbon are directly united with each other, No. II that two atoms of carbon are linked, as it were, together by an atom of oxygen, the latter being united to both carbon-atoms, whilst in like manner No. III expresses the fact that one atom of oxygen in the formula of the upper line is linked to another atom of oxygen in the formula of the lower line, by an atom of barium.

When the elements so connected together by a bracket, are united by more than one bond, this circumstance is indicated by atomicity-marks placed to the left of the bracket, thus:

Inasmuch as no difference is at present recognised in the value of the bonds of polyad elements, the order of precedence given to the elements or radicals placed to the right of the first or grouping element of a formula is a matter of perfect indifference; and, in like manner, where the formula is written in two lines, the transposition of these lines does not affect its value. Thus all the following formulæ for lactic acid have exactly the same meaning and convey precisely the same ideas regarding the constitution of this acid:

It is nevertheless desirable to maintain as much uniformity as possible in constitutional formulæ, and I therefore propose to place oxygen-atoms next to the grouping element, to give the next precedence to alcohol-radicals in the order of their atomic weights, then to hydrogen and the metals, and lastly to place hydroxyl and analogous compound radicals, such as sodoxyl (Nao), &c., to the extreme right, unless oxatyl comes upon the same line, in which case it is placed after hydroxyl. Thus I

always write the formula of lactic acid as in No. I, and that of citric acid as follows :—

It will be readily understood that, should it become necessary (which is far from improbable) to distinguish between the values of the different bonds of an element—of carbon, for instance—nothing would be easier than to assign such different values to the first, second, and third places after the symbol **C**.

The atomicity of an element is indicated, where necessary, according to Odling's plan; but in order to avoid the unnecessary use of atomicity-marks, I never attach them to a monad, nor to oxygen which is always a dyad. Neither need the atomicity-coefficient be attached to the tetrad element carbon, in the formulæ of organic bodies, unless this element plays the part of a dyad—an occurrence of extreme rarity. When not otherwise marked, therefore, carbon is always understood to be a tetrad.

It will also, as a rule, be unnecessary to mark the atomicity of the elements which are expressed by symbols in thick type, because their atomicity is clearly indicated by the sum of the atomicities of the elements or compound radicals placed to their right, or connected with them perpendicularly by a bracket. Thus in the formula

each atom of carbon is united with three atoms of the monad chlorine, whilst the bracket indicates that the two atoms of carbon are also united by one bond of each, thus stamping **C** as a tetrad element.

Whilst it is desirable for all ordinary purposes to use formulæ as compact as possible, it is not unfrequently necessary to develop them, so as to show more minute details. The system I am now describing affords peculiar facilities for such developments, since even the most compact and condensed formula contains within itself the complete history of the constitution of the compound, which can at pleasure be more minutely revealed. This quality of the new formulæ will be best rendered evident by studying an example. For this purpose we may examine the formula of caproic

acid, which may be written according to this system in any of the following ways:—

Now all these formulæ represent exactly one and the same constitutional idea. No. 1 affirms that caproic acid is composed of an atom each of amyl (Ay) and oxatyl (**COHo**)—a fact which may be considered as completely proved, firstly, by the synthesis of caproic acid from oxalic acid (the molecule of oxatyl $\left\{ \begin{array}{l} \text{COHo} \\ \text{COHo} \end{array} \right\}$ and amyl* ; secondly, by the formation of caproic acid from amylic cyanid† ; and thirdly, by the production of amyl in the electrolysis of caproic acid‡. In fact, applying Crum Brown's remark respecting the constitution of acetic acid to caproic acid, it may be as correctly said of the latter that it is a compound of amyl and oxalic acid, as that hydrochloric acid is a compound of hydrogen and chlorine, for

Reverting to the above alternative formulæ, No. 2 expresses exactly the same thing as No. 1 ; but in addition it partially unfolds the constitution of amyl and asserts the latter to be butylated methyl (**CBuH₂**)—an assertion the truth of which is proved by the

* Phil. Trans. vol. clvi, p. 341.

† Ann. Ch. Pharm. lxxv, 288.

‡ Chem. Soc. Qu. J. iii, 210.

production of valerianic acid from amylic alcohol, and by the elimination of butyl in the electrolysis of valerianic acid. In like manner the remaining formulæ gradually complete the development of amyl; No. 3 affirms butyl to be propylated methyl; No. 4 represents the propyl contained in the latter as ethylated methyl; whilst No. 5 resolves ethyl into methylated methyl; and No. 6 shows the formula of caproic acid fully developed.

Of course by a process the reverse of that just described, No. 6 can, with the greatest facility, be reduced to No. 1. I find this vertical development and subsequent contraction of formulæ of considerable service in enabling students readily to comprehend the structure of very complex organic compounds, whilst it effectually guards them from the evils inseparable from the use of fixed and immutable typical formulæ. Such developments are also of value in showing the difference between normal and secondary or tertiary radicals, for compounds containing the two latter descriptions of radical cannot be fully developed vertically; thus diethacetic acid, which is isomeric with caproic acid, gives the following results on development, the isomeric amyl contained in this acid being conveniently designated by the symbol $Ay\beta$:—

A glance at these formulæ shows that at stage No. 4, diethacetic acid has reached its extreme vertical development, Nos. 5 and 6 exhibiting the complete unfolding of the atom of ethyl still remaining in No. 4, which can, however, only take place horizontally. The cause of this anomalous behaviour of bodies containing secondary and tertiary radicals is also clearly seen from No. 5, which shows that diethacetic acid contains an atom of carbon—the second from the bottom of the vertical line—which is united with *three* other atoms of carbon—a form of combination that only occurs in secondary compounds, which are thus almost infallibly detected.

Formulae written in one line and under one dominant atom, I term *monadelphic formulae* as No. I in the above series. Those written in two lines under two dominant atoms like No. II. *diadelphic formulae*, &c. For most purposes the diadelphic form is the most useful for organic, and the monadelphic for inorganic compounds, and it is rarely necessary to employ any other, except for triacid, tetracid, &c. alcohols and their derivatives; which, as a rule, require for their satisfactory formulation the number of lines indicated by the acidity of the alcohols. Thus glycerin and tartronic acid each require three, and tartaric acid four lines.

Glycerin.

Tartronic acid.

Tartaric acid.

The following examples of the application of this mode of notation to the chief families of organic compounds will serve, better than any description, to illustrate its capabilities:

Monad Basylous Radicals.

Normal amyl.

β amyl, or
Diethylated methyl. γ Amyl, or Ethylated
dimethylated methyl.

Chlorous Monad Radicals.

Cyanogen.

Oxatyl.

Dyad Basylous Radicals.

Ethylene.

Ethylidene*.

Mon-acid Alcohols.

$\text{C}_n\text{H}_{2n+1}\text{Ho}$ Series.

Propylic alcohol.

Isopropylic acid.

Pseudobutylic alcohol.

* For a description of the difference between these two isomers, see Phil. Trans. vol. clvi, p. 351.

$\mathbf{C}_n\mathbf{H}_{2n-1}\mathbf{Ho}$ Series.

Normal.

Allylic alcohol.

 $\mathbf{C}_n\mathbf{H}_{2n-7}\mathbf{Ho}$ Series.

Normal.

Benzylic alcohol.

Secondary.

Cresylic alcohol.

The monacid alcohols of the $\mathbf{C}_n\mathbf{H}_{2n+1}\mathbf{Ho}$ series have been divided by Kolbe into three classes, viz.: normal (or primary), secondary, and tertiary, and doubtless both the $\mathbf{C}_n\mathbf{H}_{2n-1}\mathbf{Ho}$ series and the $\mathbf{C}_n\mathbf{H}_{2n-7}\mathbf{Ho}$ series will, when explored, be found to include corresponding divisions. A normal monacid alcohol is one which, on oxidation, exchanges two atoms of hydrogen for one of oxygen, yielding an acid containing the same number of atoms of carbon as the alcohol from which it was derived—a reaction which proves that the two atoms of hydrogen so exchanged must be in combination with the particular atom of carbon which is united with hydroxyl. This atom of carbon and its three dependents occupy the lower line of the above diadelphic formula of propylic alcohol. The transformation of a normal alcohol into the corresponding acid consequently always takes place by the conversion of the group $\mathbf{CH_2Ho}$ into oxatyl ($\mathbf{COHo}$), whilst the other portion of the alcohol remains entirely unaffected by the change.

It is obvious, from an inspection of the above formula for normal propylic alcohol, that a normal alcohol may contain a secondary or even a tertiary radical. Thus if dimethacetic acid ($\left\{ \begin{array}{l} \mathbf{CMe_2H} \\ \mathbf{COHo} \end{array} \right.$) were reduced to an alcohol, it would undoubtedly yield a normal alcohol, isomeric both with ordinary butylic alcohol and with Butlerow's pseudo-butylic alcohol. In like manner the action of nascent hydrogen upon methylated acetone ($\left\{ \begin{array}{l} \mathbf{CMeH_2} \\ \mathbf{COMe} \end{array} \right.$) would doubtless yield isobutylic alcohol, the true homologue of isopropylic alcohol. The exact constitution of these alcohols is expressed in the following formulæ:

Normal butylic alcohol.

Normal β butylic alcohol from dimethacetic acid.

Secondary or isobutylic alcohol from methylated acetone.

Tertiary or pseudo-butylic alcohol.

It might be asked if a body of the formula $\left\{ \begin{array}{l} \mathbf{CH_3} \\ \mathbf{CEtHo} \end{array} \right.$ would not

represent a fifth butylic alcohol. In answering such a question, the system of notation I am now describing is of especial service in preventing the possibility of an erroneous reply; it pronounces decisively that the above formula is only *apparently* different from that of isobutylic alcohol. In this and other similar cases it is only necessary to reduce both formulæ to the monadelphic type in order to establish their identity or dissimilarity, thus:

Isobutylic alcohol.

Supposed 5th butylic alcohol.

In like manner it can be proved that the above four formulæ represent the only possible forms of butylic alcohol, unless the separate bonds of carbon possess different values, in which case the number of possible isomers must be much more numerous.

A secondary monacid alcohol of the $\text{C}_n\text{H}_{2n+1}\text{Ho}$ series is one which, on oxidation, loses two atoms of hydrogen, but does not at the same time take up oxygen in their place, a ketone instead of an acid being produced. The above formula for isopropylic alcohol $\left(\left\{ \begin{array}{l} \text{CH}_3 \\ \text{CMeHHo} \end{array} \right. \right)$ indicates this peculiarity by showing that the atom of carbon which is united with hydroxyl, instead of being also combined with two atoms of hydrogen, as in normal propylic alcohol, is united with an atom of methyl, and, consequently, with only one atom of hydrogen; it is therefore evidently impossible for the group CMeHHo to pass, without loss of carbon, into oxatyl (COHo) by oxidation.

A tertiary monacid alcohol of the $\text{C}_n\text{H}_{2n+1}\text{Ho}$ series is one which, on oxidation, forms neither an acid nor a ketone containing the same number of atoms of carbon as the original alcohol. The molecule of a tertiary alcohol breaks up on oxidation, so as to give two products, each containing less carbon than the body from which it is derived.

Diacid Alcohols or Glycols.

Ethylenic glycol.

Propylenic glycol.

Ethers. *Haloid Ethers.* *Aldehydes.* *Monobasic Acids.*

I. ACETIC SERIES.

II. LACTIC SERIES.

For the application of this notation to the eight families of these acids, see "Philosophical Transactions," vol. 156, page 345.

III. GLYOXYLIC SERIES.

IV. PYRUVIC SERIES.

V. ACRYLIC SERIES.

Dibasic Acids.

I. SUCCINIC OR ACETOÏD SERIES.

II. MALIC OR LACTOÏD SERIES.

III. TARTARIC OR GLYOXYLOÏD SERIES.

IV. FUMARIC OR ACRYLOÏD SERIES.

In this series there are three isomeric acids containing four atoms of carbon, viz.: the fumaric, maleic, and isomaleic acids, and the same number containing five carbon atoms, viz., itaconic acid, citraconic acid, and mesaconic acid.

Rational notation allows us to predict the existence of a fourth acid belonging to the four-carbon group. The following are the only four possible formulæ for these acids, but we are not yet able to assign its own particular formula to each of the three known acids:—

For the five-carbon group of these acids there are no less than eleven possible formulæ, consequently we may safely predict a great addition to the number of known isomeric acids belonging

to this group. The following four formulæ may suffice as examples:—

In these formulæ the symbol *''C* signifies carbon with two of its bonds latent, as in carbonic oxide *''CO*.

Tribasic Acids.

I. TRICARBALLYLIC OR ACETOÏD SERIES.

II. CITRIC OR LACTOÏD SERIES.

III. DESOXALIC SERIES.

IV. ACONITIC OR ACRYLOÏD SERIES.

Anhydrides.

Ketones.

Ethereal Salts.

Organic Bases and their Compounds.

In the following examples of the notation of these bodies I have inserted atomicity marks, in order to distinguish triad from pentad nitrogen; these marks are, however, unnecessary except in such cases as that of diethylene-triammonic monochloride.

Alkalamides. *Amides.*

In these, as well as in the nitrogenous compounds above formulated, either carbon or nitrogen may be employed as the grouping element; in the case of the organic bases, there are certain advantages in thus employing nitrogen, whilst, in the case of amides, carbon lends itself better for this purpose; as the following instances will sufficiently exemplify:—

I have already mentioned that this constitutional notation is equally applicable to inorganic compounds; the following examples may serve to illustrate its application in this direction:—

Argentichloride	AgCl
Zincic oxide	ZnO
Potassic nitrate	NO₂Ko
Cupric sulphate	SO₂Cuo''
Potassic sulphate	SO₂Ko₂
Hydric potassic sulphate	SO₂HoKo
Microcosmic salt.....	POHoAmoNao
Ammonic carbonate	COAmo₂
Zincic nitrate	$\left. \begin{array}{c} \text{NO}_2\text{O} \\ \text{Zn}'' \\ \text{NO}_2\text{O} \end{array} \right\} \text{ or } \text{N}_2\text{O}_4\text{Zno}''$
Chloric acid.....	$\left\{ \begin{array}{c} \text{OCl} \\ \text{OHo} \end{array} \right.$
Sodic nitrosulphate	SO(NO)₂Nao₂

Sulphuric acid	SO_2Ho_2
Sulphosulphuric acid (<i>Hyposulphurous acid</i>)	$\text{SS}''\text{OHo}_2$
Nordhausen sulphuric acid	$\left\{ \begin{array}{l} \text{SO}_2\text{Ho} \\ \text{O} \\ \text{SO}_2\text{Ho} \end{array} \right.$
Dithionic acid (<i>Hyposulphuric acid</i>) ..	$\left\{ \begin{array}{l} \text{SO}_2\text{Ho} \\ \text{SO}_2\text{Ho} \text{ or } \text{S}^{\text{v}}_2\text{O}_4\text{Ho}_2 \end{array} \right.$
Trithionic acid (<i>Sulphodithionic acid</i>)....	$\left\{ \begin{array}{l} \text{SO}_2\text{Ho} \\ \text{S}'' \\ \text{SO}_2\text{Ho} \end{array} \right.$
White crystalline compound from sulphuric acid chambers.....	$\left\{ \begin{array}{l} \text{SO}_2(\text{N}^{\text{v}}\text{O}_2) \\ \text{O} \\ \text{SO}_2(\text{N}^{\text{v}}\text{O}_2) \end{array} \right.$
Anhydrous sodic bisulphate (<i>Disodic disulphate</i>)	$\left\{ \begin{array}{l} \text{SO}_2\text{Nao} \\ \text{O} \\ \text{SO}_2\text{Nao} \end{array} \right.$
Dizincic sulphate	SOZno''_2
Trizincic sulphate	SZno''_3
Crystallised gypsum (<i>Tetrahydric calcic sulphate</i>)	$\left\{ \begin{array}{l} \text{SHo}_4\text{Cao}'' \end{array} \right.$
Gypsum dried at 100° C (<i>Dihydric calcic sulphate</i>)	$\left\{ \begin{array}{l} \text{SOHo}_2\text{Cao}'' \end{array} \right.$
Gypsum dried at 260° C (<i>Calcic sulphate</i>)	$\text{SO}_2\text{Cao}''$
Zircon	SiZro''_2
Diopside	$\left\{ \begin{array}{l} \text{SiO} \\ \text{SiO} \text{ Cao}''\text{Mgo}'' \end{array} \right.$
Steatite	$\left\{ \begin{array}{l} \text{Si}_4\text{O}_5\text{Mgo}''_3 \\ \text{SiHoMgo}'' \end{array} \right.$
Meerschaum (<i>Tetrahydric dimagnesian trisilicate</i>)	$\left\{ \begin{array}{l} \text{O} \\ \text{SiHo}_2 \\ \text{O} \\ \text{SiHoMgo}'' \end{array} \right.$
Anorthite (<i>Aluminic calcic disilicate</i>)	$\text{Si}_2(\text{Al}_2'''\text{O}_6)^{\text{vi}}\text{Cao}''$
Felspar (<i>Dipotassic aluminic hexasilicate</i>)	$\left\{ \begin{array}{l} \text{Si}_6\text{O}_8(\text{Al}_2'''\text{O}_6)^{\text{vi}}\text{Ko}_2 \\ \text{SnHo}_3 \\ \text{O} \\ \text{SnHo}_2 \\ \text{O} \\ \text{SnO} \\ \text{O} \\ \text{SnHo}_2 \\ \text{O} \\ \text{SnHo}_3 \end{array} \right.$
Metastannic acid (dried at 100° C)	

Ditanic dinitride.....	$\left\{ \begin{array}{l} \text{TiN}''' \\ \text{TiN}''' \end{array} \right.$
Phosphoric acid	POHo_3
Metaphosphoric acid	PO_2Ho
Pyrophosphoric acid	$\text{P}_2\text{O}_3\text{Ho}_4$
Hexasodic tetraphosphate (Fleitmann & Henneberg)	$\text{P}_4\text{O}_7\text{NaO}_6$
Dodecasodic decaphosphate (Fleitmann & Henneberg).....	$\text{P}_{10}\text{O}_{19}\text{NaO}_{12}$
Apatite (<i>Francolite</i>)	$\text{P}_3\text{O}_3\text{CaO}_4 \left(\begin{array}{l} \text{O} \\ \text{F} \end{array} \text{Ca}'' \right)$
Pyromorphite	$\text{P}_3\text{O}_3\text{Pbo}''_4 \left(\begin{array}{l} \text{O} \\ \text{Cl} \end{array} \text{Pb}'' \right)$
Trisulphoplumbic sulphantimonite (<i>Boulangerite</i>)	$\text{Sb}_2\text{Pbs}''_3$
Sulphargentic metasulphantimonite (<i>Miargyrite</i>)	$\text{SbS}''\text{Ags}$
Bismuthous nitrate dihydrate (<i>Basic bismuthous nitrate</i>)	$\text{NO}_2(\text{Bi}'''\text{OHo}_2)$
Sulpho-plumbic sulphobismuthite (<i>Kobellite</i>)	$\text{Bi}_2\text{Pbs}''_3$
Bleaching powder (<i>Calcic chloro-hypochlorite</i>)	$\text{Ca}(\text{OCl})\text{Cl}$
Dolomite	$\left\{ \begin{array}{l} \text{CO} \\ \text{CO} \end{array} \text{Cao}''\text{Mgo}'' \right.$
Guanite (<i>Diammonic dimagnesian diphosphate</i>)	$\left\{ \begin{array}{l} \text{POAmo} \\ \text{POAmo} \end{array} \text{Mgo}''_2 \right.$
Dihydric pentazincic dicarbonate tetrahydrate (<i>Basic zincic carbonate</i>)	$\left\{ \begin{array}{l} \text{CHo}(\text{OZn}''\text{Ho})_2 \\ \text{Zno}'' \\ \text{CHo}(\text{OZn}''\text{Ho})_2 \end{array} \right.$
Mercurioso-diammonic dichloride	$\left\{ \begin{array}{l} \text{NH}_3\text{ClHg} \\ \text{NH}_3\text{ClHg} \end{array} \right.$
White precipitate (<i>Mercuric-ammonic chloride</i>).....	$\text{NH}_2\text{Hg}''\text{Cl}$
Blue malachite	$\left\{ \begin{array}{l} \text{CHoCuo}'' \\ \text{Cuo}'' \\ \text{CHoCuo}'' \end{array} \right.$
Malachite	$\text{CO}(\text{OCu}''\text{Ho})_2$
Diopside	$\text{SiOHo}(\text{OCu}''\text{Ho})$
Gibbsite	$\left\{ \begin{array}{l} \text{AlHo}_3 \\ \text{AlHo}_3 \end{array} \right.$
Diaspore	$\text{'Al}'''_2\text{O}_2\text{Ho}_2 \text{ or } \left\{ \begin{array}{l} \text{AlOHo} \\ \text{AlOHo} \end{array} \right.$
Spinnelle	$\text{'Al}'''_2\text{O}_2\text{Mgo}'' \text{ or } \left\{ \begin{array}{l} \text{Al} \\ \text{Al} \end{array} \text{O}_2\text{Mgo}'' \right.$

Potash alum	$\left\{ \begin{array}{l} \text{SO}_2\text{Ko} \\ \text{SO}_2\text{---} \\ \text{SO}_2\text{---} \\ \text{SO}_2\text{Ko} \end{array} \right\} (\text{Al}'''_2\text{O}_6)^{\text{vi}}, 24\text{OH}_2$
Porcelain clay.....	$\left\{ \begin{array}{l} \text{SiHo} \text{---} \\ \text{O} \text{---} (\text{Al}'''_2\text{O}_4\text{Ho}_2)^{\text{iv}} \\ \text{SiHo} \text{---} \end{array} \right\}$
Porcelain clay of Passan	$\left\{ \begin{array}{l} \text{SiHo}_2 (\text{Al}'''_2\text{O}_4\text{Ho}_2)^{\text{iv}} \\ \text{SiHo}_2 \end{array} \right\}$
Platinoso-diammonic dichloride (<i>Magnus's green salt</i>)	$\left\{ \begin{array}{l} \text{NH}_3\text{Cl} \\ \text{Pt}'' \\ \text{NH}_3\text{Cl} \end{array} \right\}$
Lanarkite (<i>Diplumbic sulphate carbonate</i>)..	$\left\{ \begin{array}{l} \text{CO} \\ \text{SO}_2 \end{array} \right\} \text{Pbo}''_2.$
Potassic chromate	CrO_2Ko_2
Dipotassic dichromate (<i>Bichromate of potash</i>)	$\left\{ \begin{array}{l} \text{CrO}_2\text{Ko} \\ \text{O} \\ \text{CrO}_2\text{Ko} \end{array} \right\}$
Dipotassic trichromate (<i>Terchromate of potash</i>).....	$\left\{ \begin{array}{l} \text{CrO}_2\text{Ko} \\ \text{O} \\ \text{CrO}_2 \\ \text{O} \\ \text{CrO}_2\text{Ko} \end{array} \right\}$
Manganite	$\left\{ \begin{array}{l} \text{MnOHo} \\ \text{MnOHo} \end{array} \right\}$
Varvicite	$\left\{ \begin{array}{l} \text{MnO} - \text{O} \text{---} \\ \text{Mno}'' (\text{Mn}^{\text{iv}}\text{Ho}_2)'' \\ \text{MnO} - \text{O} \text{---} \end{array} \right\}$
Brown hæmatite.....	$\left\{ \begin{array}{l} \text{FeOHo} \\ \text{FeHo}_2 \\ \text{O} \\ \text{FeHo}_2 \\ \text{FeOHo} \end{array} \right\}$
Needle iron ore	$\left\{ \begin{array}{l} \text{FeOHo} \\ \text{FeOHo} \end{array} \right\}$

In conclusion I append a table of elements classified according to their atomicities as employed in this plan of notation.

Monads.	Dyads.	Triads.	Tetrads.	Pentads.	Hexads.
1st Section. Hydrogen.	1st Section. Oxygen.	1st Section. Boron.	1st Section. Carbon. Silicon. Tin. Titanium.	1st Section. Nitrogen. Phosphorus. Arsenic. Antimony. Bismuth.	1st Section. Sulphur. Selenium. Tellurium.
2nd Section. Fluorine. Chlorine. Bromine. Iodine.	2nd Section. Barium. Strontium. Calcium. Magnesium. Zinc.	2nd Section. Gold.	2nd Section. Thorium. Niobium. Tantalum. Zirconium. Aluminium.		2nd Section. Tungsten. Vanadium. Molybdenum.
3rd Section. Cæsium. Rubidium. Potassium. Sodium. Lithium.	3rd Section. Didymium. Lanthanum. Yttrium. Glucinum.		3rd Section. Platinum. Palladium.		3rd Section. Osmium. Iridium. Ruthenium. Rhodium.
4th Section. Thallium. Silver.	4th Section. Cadmium. Mercury. Copper.		4th Section. Lead.		4th Section. Chromium. Manganese. Iron. Cobalt. Nickel. Uranium. Cerium.