

# The Classification of the Chemical Elements

## The Fundament of Chemistry

By Ingo W. D. Hackh

"Everything in its beginning proceeds from the incomplete to the complete." This procedure we call progress, for progress is measured by the increase in value, spiritual or material.

The history of Science in general and of Chemistry in special is a vivid illustration of the progress of human knowledge, of its growths. However it does not grow with equal speed throughout the centuries, but once begun accelerates its growth and progresses in geometrical proportion. As the parabola approaches both a perfect ring and a straight line, so the entireness of human wisdom drifts toward perfection, yet never reaches its goal.

The labors of the scientist today, thanks to the improved ways of recording and transmitting thoughts and discoveries, are for the benefit of all and as in every quarter of the globe, in peace and war, research is going on the sum total of the sage's effort piles ever on and calls for specialists in every field. It was not very long ago when a man was still able to master all of what was known in the science of chemistry; to-day it takes the sweat of one's brow to keep abreast in a side-branch of it. But in every science there are certain fundamentals and the better one understands the basis of the science the clearer and more definite becomes the conception of ideas. Chemistry of today enters in every phase of life and sad to say it is a drudgery to many a student and mature person who needs the science, but lacks the foundation.

### WHAT'S WHAT?

Now to dwell a little upon the "What's what in chemistry." This is not only a very interesting theme but also reveals a wonderful and systematic view of the structure of the universe and illustrates the orderly sequence of the great mystery of nature. Perhaps no other natural law, besides some fundamental astronomical doctrines, has been so complete and fully revealed by the human race, as the system of matter, commonly known as the periodic system of the elements. It took centuries to grasp the idea of chemical elements as being the bricks of the universe and that out of these building stones all matter is composed.

**Number of Elements.**—From many facts it is apparent today that there are 92 of these bricks or elements, and of these five have not yet been discovered or found. Naturally not all of them are of equal importance, about 14 are of great general interest, as forming the greater part of the mass of the solid portion of the earth, of the water and atmosphere and of all animal and vegetable matter, the corner-stones of the universe. (See in Fig. 1 the elements of the first two periods, marked with a longer bar in the last column). About thirty elements claim interest on account of special uses made of them; these occur not so frequently and not in such large quantities as the first group and are not essential for the formation of organic matter, yet they are used for various purposes in everyday life. (Marked in Fig. 1 by a shorter bar). The rest of about 45 elements are found in small quantities in nature and they are more or less of scientific interest, the decorative stones of the universe which complete the structure.

**Groups of Elements.**—It was natural that with an increase of knowledge and the discovery of new elements a classification was attempted. With the discovery of oxygen the foundation of chemistry was laid and the first definite modern idea of an element based upon experiment and not upon speculation was formed. Although not many elements were known it was possible to group some of them according to their properties in groups of three, the "triads" of Doebereiner (1829), e. g. Ca-Sr-Ba, P-As-Sb, Cl-Br-I, Cu-Ag-Au. Incidentally it was found that the atomic weights of these elements had a certain relationship to each other, that is the atomic weight of the member in the middle was approximately the mean of the two outer members. This idea was further developed as more new elements were discovered by Cooke (1854), DeChancourtois (1865) and Newlands (1865), the latter applying the idea in a different sense in his "law of octaves" by showing, that as in musical notes, the seventh element has relationship to the first one if they are arranged with increasing atomic weight. His idea

was at first ridiculed, but became prominent when in 1869 Mendeleeff and independently Lothar Meyer presented the so-called "natural system" or periodic system of the elements. The periodic table thus established remained until the end of the last century unchanged, it was incomplete and fragmentary, many empty spaces were there, and while in some respects it served wonderfully well, it was unsatisfactory in others, for it was only the partial recognition of a natural law.

**Interelements.**—Two great discoveries of the last two decades completed our knowledge and at the same time opened up new avenues of research with a new aspect of the universe. The first discovery was the isolation of "rare gases" by Ramsay which began in 1894 with Argon. These elements: He, A, Ne, Kr, and Xe are absolutely inert gases, that is they do not enter into any combination with any other element, form therefore no compound, and are in small quantities present in the atmosphere. This inertness was something entirely new; up to that time all elements could be brought into combination, although some were more "aristocratic" or "noble" than others, like gold or platinum for example. What to do now with elementary gases which have no chemical property? Elements without chemistry they were and so they were assigned to a "zero group" either at the beginning or end of the periods in the periodic system. And lo! once there they fitted in so snugly and furnished a long felt but not recognised "missing link" for they combined the two extreme ends of a period, they formed the bridge from a non-metallic halogen (electro-negative element) to a metallic alkali (electro-positive element). For this reason we may speak of these elements, the rare or inert gases, as the terminals of the periods, which are either positive nor negative, and whose electro motive force we consider to be  $\pm \infty$  and whose electrons form a stable system and can therefore have no valency.

When now the elements are arranged according to increasing atomic weight, as done in Fig. 1, the line is a continuous one with periodic changes and does not contain the awkward break between the negative halogen and positive alkali-metal.

**Radioactive Elements.**—The continuity of the periodic line thus established, the next question is the limits of this line. This found its answer by the second great discovery, namely the discovery of the radio active substances in 1899. This revealed gradually the fact, that the elements with the highest atomic weight, thorium and uranium, spontaneously and slowly break apart into elements of lower atomic weight. That is to say the atom of such an element has become so complex that they are under the present cosmic conditions of our earth unstable and disintegrate. These elements therefore form the upper limit of the line. Uranium is thus the last member of the line of terrestrial elements. But what about the lower limit? Hydrogen is the lightest known element and possesses the lowest atomic weight and is therefore assumed to be the first member of the line. Although there are some indications that elements lighter than hydrogen exist in some celestial objects, like "coronium" in the sun corona and "nebulium" in the nebulosities, as these "celestial" elements have however never been found so far upon our earth they need not to be considered in the periodic system of the "terrestrial" elements. And even if they should be found, they would complete the "zero" period, whose only member at present is hydrogen.

### THE PERIODIC SYSTEM.

The arrangement of the elements given in Fig. 1 is the basis of the periodic system. Taking the "inert gases" as the terminals or the starting and endpoints, there are five well defined periods from one inert element to the other. These are designated in the first column as I, II, III, IV and V and they are found to be of unequal length, namely the first two containing 8, followed by two with 18 and finally one with 32 elements. The first three elements following an inert gas are always strong positive, while the last three before an inert gas are always strong negative and thus a kind of a transition is formed by the fourth element, or the elements of the carbon group. This is best illustrated by the following schema:

group	0	1	2	3	4	5	6	7	8 or 0
E.M.F.	$+\infty$	+++	++	+	+0	-	- -	---	$+\infty$
I per	2	3	4	5	6	7	8	9	(10)
II "	10	11	12	13	14	15	16	17	(18)
III "	18	19	20	21	22	23	24	25	(26)
IV "	36	37	38	39	40	41	42	43	(44)
V "	54	55	56	57	58	59	60	61	(62)
					72	73	74	75	(76)
					82	83	84	85	(86)

In this schema the numbers correspond to the "atomic number," which is also found in the second column of Fig. 1.

**Atomic Number.**—This number is not only of the successive character as indicated in Fig. 1, but is also derived from the relative position of the first line in the X-ray spectra of an element. All elements emit under certain physical conditions vibrations or frequencies, which extend over a wide range of wave lengths. A certain section of these wave lengths is visible to the eye as "color" and "light." Thus e. g., in the visible sun spectrum the Fraunhofer lines are caused by certain elements. But the series of wave lengths extend much farther and near the beginning in the invisible region, with very short wave lengths, vibrations which can neither be seen nor photographed, but detected only by the electroscope, a "spectrum" of definite lines for certain elements can be obtained. By arranging now the elements according to the first line of these X-ray spectra, these first lines show a mathematical relationship to each other and form a mathematical series. In this series beginning with H and ending with U are five gaps, the first one being between the spectra of molybdenum and ruthenium and it is assumed that an element whose spectrum should fall between these two known elements, has not yet been discovered. Numbering now the members of the series, by beginning with H as 1 the so-called atomic numbers are obtained, which correspond exactly to the successive numbers of the elements, when arranged with increasing atomic weight, as in Fig. 1.

**Periods and Groups.**—As already indicated the elements from one noble gas to the other form a period, in each period the character of the elements changing from strong positive to strong negative, the transition being formed by an element of the carbon group. The longer periods are characterised by two or three elements of the carbon groups, and there are then respectively one or two subperiods. Writing now the periods horizontally and under each other, as in the above schema, certain relationship exists in the vertical direction, and these elements form closely related groups, as e. g., in the schema the elements of group 1 would consist of those with atomic numbers 3, 11, 19, 37 and 55. (Li-Na-K-Rb-Cs). Only the first and last four members of each period show characteristic group-relationship, the members of the subperiods exhibit only traces of this group-relationship (for simplicity sake they are therefore eliminated from the above schema). The properties of the elements of the subperiods are more closely related in the same subperiod and can therefore be spoken of as "period-relationship." These two types of relationship are best illustrated in Fig. 2, in which the elements are arranged in a spiral.

**The Helix Chemica.**—The spiral or helix<sup>2</sup> is instructive in many respects, for it illustrates the position of each element in the system very well. The terminals and transition elements are distinctly characterised and the classification is shown into the three great classes of Nonmetals, Lightmetals and Heavymetals. For the study of the underlying principle the spiral is ideal, but for practical purposes its technical construction is cumbersome and a tabular representation is given in Fig. 3. This table, while not so perfect as the spiral, has many advantages superior to the old classical table of Mendeleeff and Meyer, usually given in text-books. Whatever will be said of the table, should be studied on the spiral also.<sup>3</sup>

**Physical Properties.**—Both the figure and the table are something like a map or chart of matter on which

<sup>2</sup>See also Emerson, Am. Chem. Journ., 45, p. 160, 1911.

<sup>3</sup>See also Hackh, A modification of the Periodic Table, Am. Journ. of Science, 46, p. 481, 1918.

<sup>1</sup>Eudemus.

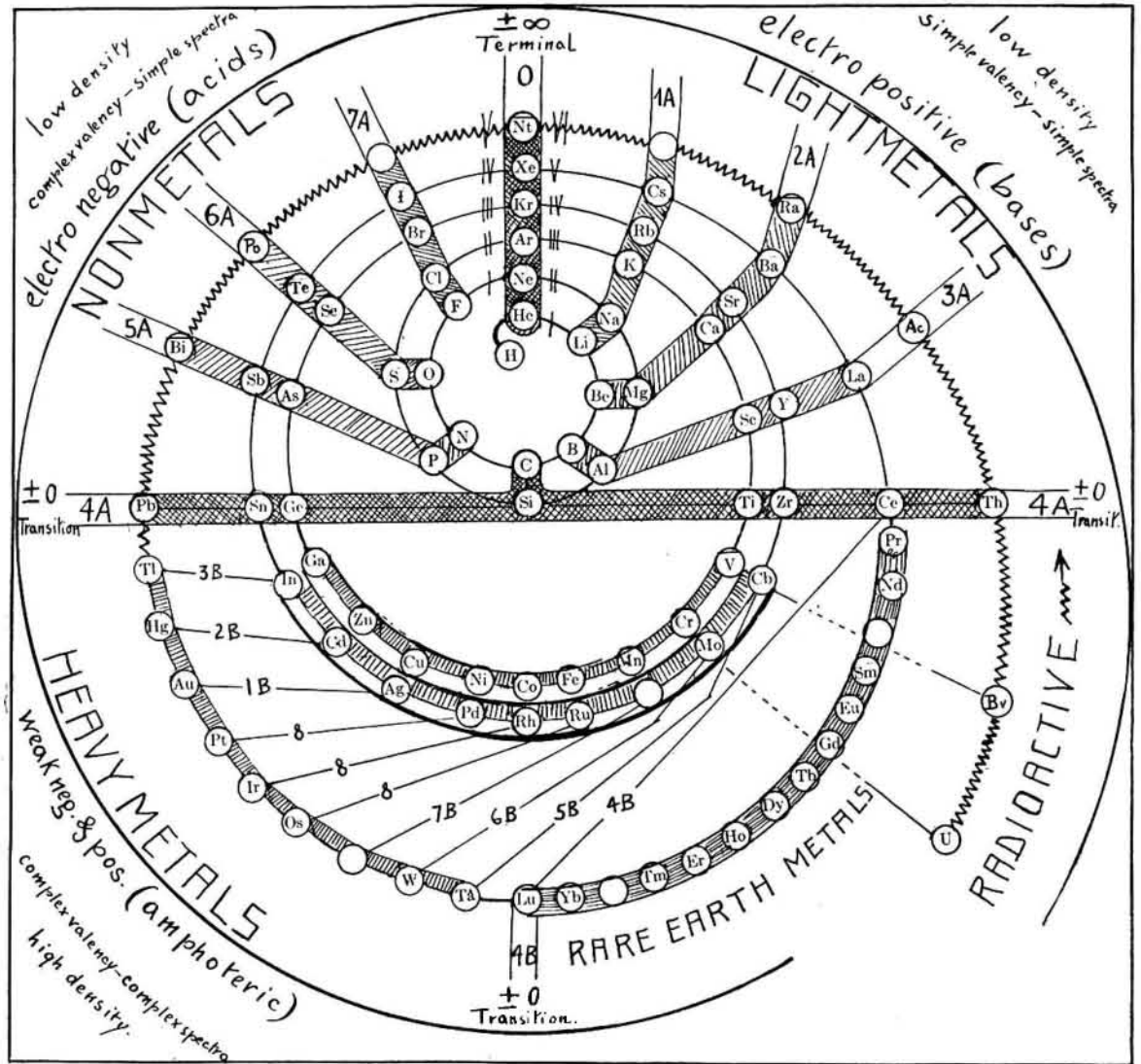
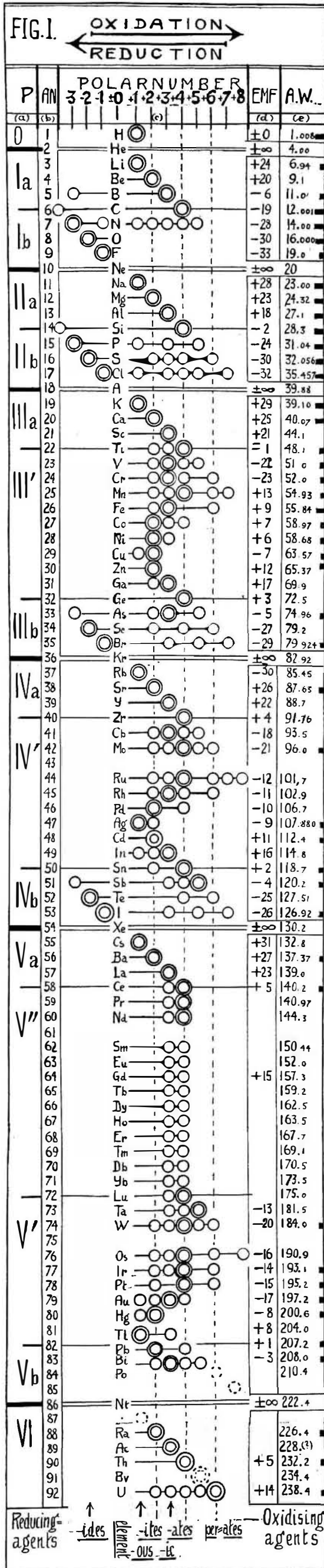


Fig. 2. The periodic spiral of the elements

In this figure the periodic chain (fig. 1) is bent in such a way that elements of similar properties come together. NOBLE GASES are the terminals, the elements of the CARBON GROUP the transition points. The elements between the terminals form a PERIOD, those between the transition points a SUBPERIOD. The first two periods have only two subperiods each, e. g., Ia and Ib. The next two periods have three subperiods each, e. g., IIIa, III' and IIIb. The very long period has four subperiods namely Va, V', Vb and Vb.

LIGHTMETALS are the elements of the a-subperiod, NONMETALS are the elements of the b-subperiod, HEAVY METALS are the elements of the ' -subperiod, RARE EARTH METALS are the elements of the " -subperiod. In the upper half of the spiral the properties of the elements are along the axis (group-relationship), while in the lower part the similarities are along the radius (period-relationship). (See also EMERSON, Am. Chem. Journal, vol. 45, p. 160, 1911, and Science, vol. 34, p. 640, 1911.)

can be located boundary lines and zones of permeation between the maxima and minima of properties. Thus we have for the electro motive force the following diagram (to be superimposed upon the table):

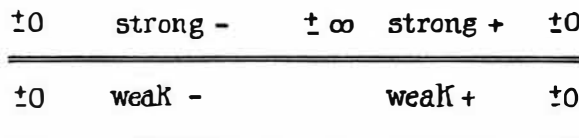
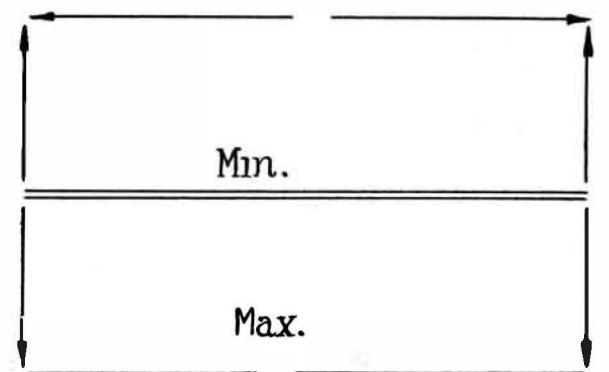


Fig. 1. The periodic chain of elements

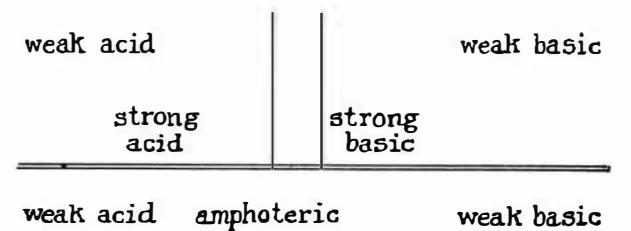
The elements are arranged according to increasing atomic number or atomic weight. The whole series from 1 to 92 is divided into six sections or PERIODS, which are again subdivided into subperiods (see figure 2). POLARNUMBER is the arithmetical expression of the valency. Some elements possess only one polarnumber and form therefore only one TYPE OF COMPOUNDS. Other elements may have two or more polarnumbers corresponding to two or more types of compounds. The circles in the figure give the value for the polarnumber or polarnumbers for each element. NOMENCLATURE or the names for the different types of compounds of an element are indicated at the bottom of the figure by the suffixes. For metals or cations—OUS indicates the lower, and —IC the higher polarnumber. For nonmetals or anions the order is —IDE, —ITE, —ATE and PER—ATE, beginning with the lowest, and ending with the highest polarnumber. Thus there are e. g. (polarnumbers in parenthesis) mercurous (1) and mercuric (2); cuprous (1) and cupric (2); ferrous (2), ferric (3) and ferrate (6); manganous (2), manganic (3), manganite (4), manganate (6) and permanganate (7); sulfide (-2), sulfite (4) and sulfate (6); chloride (1), chlorite (1), chlorate (3) and perchlorate (5). OXIDATION OR REDUCTION is involved whenever one type of compound changes to another type of compound. The polarnumber can either be augmented (increased) or diminished (decreased). The first process is OXIDATION. The augmentation is called OXIDATION, e. g. a change from ferrous to ferric, from ferric to ferrate, or from sulfide to free sulfur, from free sulfur to sulfite, from sulfite to sulfate. The diminution of the polarnumber is REDUCTION, e. g. from ferrate to ferric, from ferric to ferrous, from ferrous to free iron, or from sulfate to sulfite and free sulfur, etc. OXIDISING and REDUCING AGENTS are substances which bring about oxidation and reduction. In this process the oxidising agents are reduced, and the reducing agents are oxidised. In a general way: the greater the difference between the polarnumbers, the more active the substance. E. g., permanganates, perchlorates, etc., are strong oxidising agents, while sulfides, iodides, ferrous salts, etc., are reducing agents.

If the values for density of the elements are inserted a striking regularity is shown which can be expressed by arrows pointing toward increasing density. These arrows are located as follows:



indicating the minimum at hydrogen, the maximum at osmium. For all physical constants of the elements these tables or charts are very instructive, so e. g., for melting-point, boiling-point, compressibility, atomic refractivity and so on.

Chemical Properties. The chemical characteristics of the elements can equally well be studied, for there are the acid- and base-forming elements on the chart, whose zones gradually infiltrate from strong basic to weak basic to atmospheric to weak acid to strong acid or vice versa:



The strength of an acid or base being measured by the degree of ionisation, that is the formation of H<sup>+</sup> (hydrogen ion) in the case of acids, and OH<sup>-</sup> (hydroxide ion) in the case of bases, this phenomena is inversely proportional to the electro motive force.

The formation of compounds is illustrated by the simple diagram:

mostly colorless and soluble salts  
 many colored and insoluble salts, many double salts.

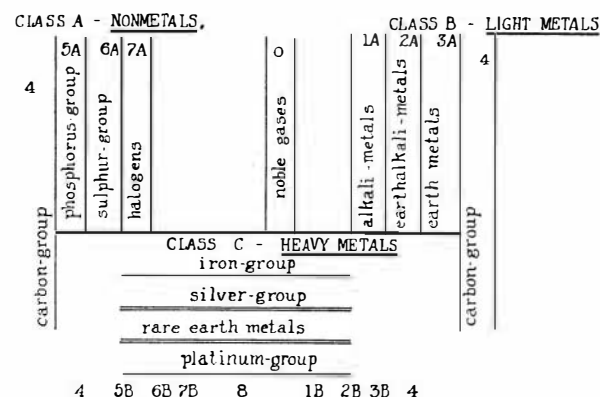
The occurrence of the elements in nature is interesting for this is in a certain way the expression of the chemical affinity among the elements. There is no doubt, that the "affinity" or force that unites the atoms of different elements is not purely electric in character. Many phenomena cannot be explained by electro motive force alone but point to a selective tendency among the elements. This elective force is hinted at in the following diagram showing the natural occurrence of the elements. A comparison of this diagram with the diagram of the e.m.f. is interesting and instructive.

occur native sulfides are common easily reducible	occur never native oxides are common difficult to reduce
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occur never native oxides are common difficult to reduce	occur native sulfides are common easily reducible
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Thus the nonmetals and the weak electro-positive metals occur native and in the form of their single or double sulfides, they are very easily reduced (and difficult to oxidise). The reverse holds true for the lightmetals and the weak electro-negative metals.

**Classification of Elements.** In a very general way some properties of the elements have been outlined and some boundary lines more or less sharply indicated. In all the diagrams one general characteristic is noticed: In the upper part the noble gases form the transition between abrupt changes in the properties, while in the lower part of the table there is a gradual transition. An intelligent study of chemistry uses therefore this natural system and draws the following lines of demarcation as a classification of the elements:



The classes and groups are:

**Class A—Light Metals** or basylous elements possess from one to three valence electrons, are therefore strongly electro-positive. Their oxides form with water the bases which unite with acids to form the salts.

**GROUP 1A—Alkali-Metals:** Li, Na, K, Rb, Cs. monovalent; sulfides, oxides, carbonates and many salts soluble in water; melting point low; density low; decompose water at ordinary temperatures, oxidise rapidly.

**GROUP 2A—Earthalkali-Metals:** Be, Mg, Ca, Sr, Ba. bivalent; sulfides and oxides soluble, carbonates insoluble; decompose water at ordinary temperature slowly, oxidise less rapidly.

**GROUP 3A—Earth-Metals:** B, Al, Sc, Y, La. trivalent; sulfides soluble, oxides and carbonates insoluble, decompose water at 100-200°, oxidise at higher temperature.

**Class B—Heavy Metals** or amphoteric elements possess from one to eight free valence electrons which may be interchangeable. They may be either weak electro-negative or weak electro-positive, and form either weak bases or weak acids.

**GROUP 3B — Ga, In, Tl.**

**GROUP 2B — Zn, Cd, Hg.**

**GROUP 1B — Cu, Ag, Au.**

**GROUP 8 — Fe, Co, Ni; Ru, Rh, Ru; Os, Ir, Pt.**

**GROUP 7B — Mn.**

**GROUP 6B — Cr, Mo, W, U.**

**GROUP 5B — V, Nb, Ta.**

Only the first and last groups are sharply characterised, the other groups toward the center merge into each other (period-relationship), thus e. g. the iron-group embraces Cr, Mn, Fe, Co, Ni, Cu. The sulfides, oxides, carbonates and many salts are insoluble in water. The higher the atomic weight the less oxidised.

**Class C—Nonmetals** or acidulous elements possess from five to seven free valence electrons and are therefore strongly electro-negative. They form the acids.

**GROUP 5A—Phosphorus-group:** N, P, As, Sb, Bi. pentavalent and trivalent;

**GROUP 6A—Sulphur-group:** O, S, Se, Te. hexavalent and bivalent.

**GROUP 7A—Halogens:** F, Cl, Br, I. hepta- penta-, tri- and mono-valent.

**Class D—Transition Elements** are the two groups of elements which form the bridge from one class to the other:

**GROUP 4A—Carbon-group:** C, Si, Ti, Ge, Zr, Sn, Ce, Lu, Pb, and Th. They are tetravalent, and as according to the newer theories the electrons of stable compounds form systems of "eight," these elements may combine with themselves just as readily, as with the atoms of another element. Thus e. g. a carbon-atom has to another carbon-atom the greatest affinity, forming the many thousands of carbon-compounds of organic life. Silicon is predominant in the mineral world and Titanium is in the spectra of all heavenly bodies.

The carbon-group forms the transition from the Light-metals to the Non-metals and Heavy-Metals, in other words the framework of the system.

**GROUP 4B—Rare Earth Metals—Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb.** Tetravalent and apparently tri-valent. From the preceding carbon group these elements differ in their more metallic properties. They are characteristic for their similar chemic properties. In compounds they occur as double-atoms, that is e. g. Pr<sub>2</sub>Cl<sub>6</sub>, and not PrCl<sub>3</sub>, and their structure indicates therefore tetra-valency:

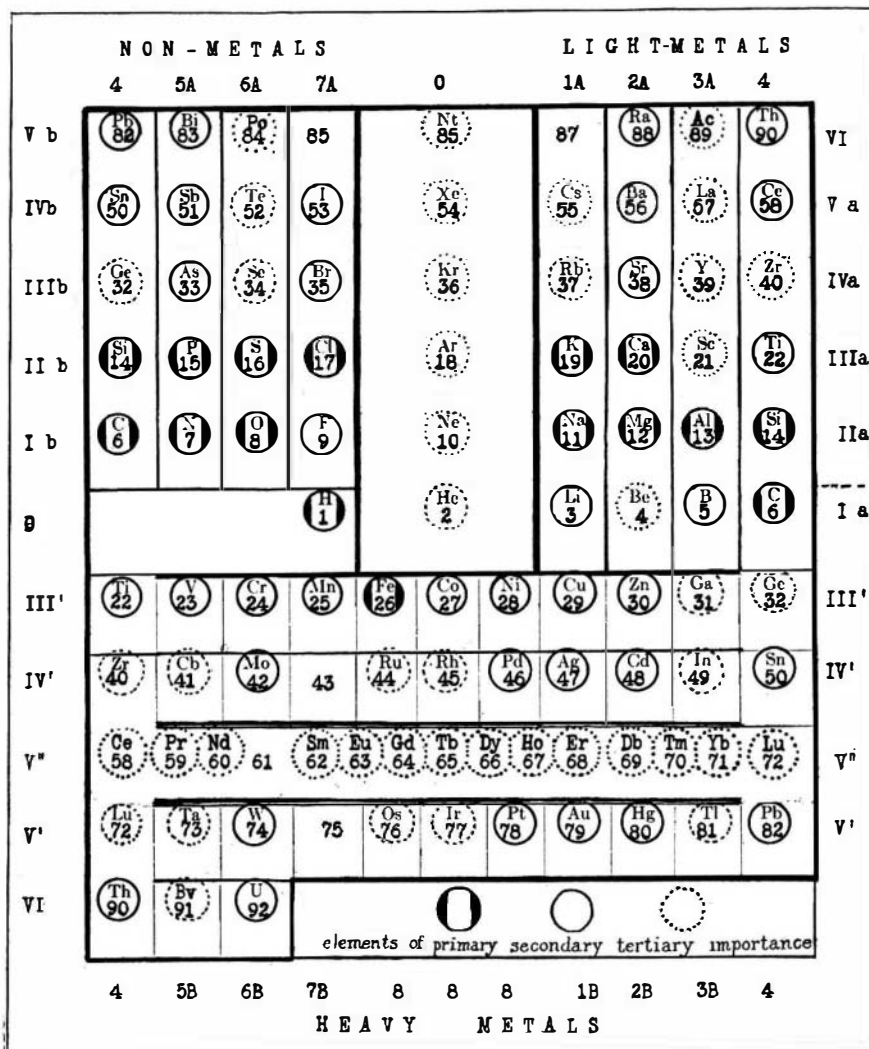


Fig. 3. The periodic table of the elements

This figure is a tabular arrangement of the spiral (fig. 2) and represents a "chart of matter" with the longitudes or groups and latitudes or periods. The position of an element in this table indicates its properties. (See text and also HACKH. Am. Journ. of Science, vol. 46, p. 481, 1918; Journ. Am. Chem. Soc., vol. 40, p. 1043, 1918.)

In the upper half of the table GROUP-RELATIONSHIP (similarity in vertical direction) prevails, while in the lower half of the table PERIOD RELATIONSHIP (similarity in horizontal direction) is predominant.

A heavy circle marks the elements of PRIMARY importance, these occur abundantly in the nature (lithosphere, hydrosphere and atmosphere) and are essential to life (biosphere). They are the fundament of every industry and of universal use.

A plain circle marks the elements of SECONDARY importance which occur less abundantly and are of special use in industries.

A dotted circle indicates the elements of TERTIARY importance, which are of rare occurrence and have no or little practical use, and are therefore of scientific interest only.

**GROUP 0—Noble Gases or Inert Elements:** He, Ne, Ar, Kr, Xe, possess eight valence electrons which form a stable "system of eight." They enter into no chemic combination, and form the transition from the halogens to the alkali-metals, that is the elements with the strongest electro-potential.

The elements, or bricks of the universe are thus classified and in making as many charts as possible, the student will become familiar with the relationships existing among the elements. These relationships are so marked and often related by mathematical laws, that many modern ideas of the constitution of the atoms have been built upon it. They are more or less interesting but cannot here be dealt with, where the practical aspects are mainly in view.

How's How?

Having classified the "What's what" the next logical step is to consider how the elements react with each other. The number of compounds is very large, yet this number is not unlimited, but greatly limited by the properties of an element and it depends mainly upon the valency or polarnumber.

VALENCY AND POLARNUMBER.

The term valency is familiar to the reader, it is the relative combining-power of an atom in regard to hydrogen. Polarnumber is the arithmetical expression of this valency, the value of which can have either plus or minus signs and can also be zero. In the free state an element has the polarnumber of zero, because it entered into no union with another element. In compounds the polarnumbers are arrived at by assigning to oxygen the value -2 and to hydrogen the value +1. In each stable compound the sum of the polarnumbers must be zero. Thus we have e.g. for water H<sub>2</sub>O

$$\begin{aligned} \text{for hydrogen } 2 \times (+1) &= +2 \\ \text{for oxygen} &= -2 \\ \text{and therefore the total} &= 0 \end{aligned}$$

In order to find the polarnumber of any element in a compound one proceeds from the known ones and assigns the residual value to the unknown, e.g. the polarnumber of sulphur in H<sub>2</sub>SO<sub>4</sub>= sulfuric acid, is found as follows:

$$\begin{aligned} \text{Hydrogen } 2 \times (+1) &= +2 \\ \text{Oxygen } 4 \times (-2) &= -8 \\ &= -6 \end{aligned}$$

+6 remains for sulfur therefore in order to make the total sum ±0. In a similar way one finds the polarnumber for sulfur in sulfurous acid H<sub>2</sub>SO<sub>3</sub>, be +4, and for sulfur in hydrogensulfide H<sub>2</sub>S to be -2. For sulfur there are therefore the polarnumbers -2 (in H<sub>2</sub>S), ±0 (in free S), +4 (in H<sub>2</sub>SO<sub>3</sub>), +6 (in H<sub>2</sub>SO<sub>4</sub>). The recognition of these different polarnumbers is of fundamental importance and one of the most common errors is the belief that an element can only exist with one valency or polarnumber. The different polarnumbers of the elements represent the different series of compounds. Thus some elements, like the alkali-metals, form only one series of compounds with polarnumber of +1. Other elements form two, three or more different types of compounds.

TYPES OF COMPOUNDS.

These different types of compounds of one and the same element have distinctly different properties and need not resemble each other, but can by certain chemical means be transformed from one into the other type. Thus there has been recognised for a long time the ferrous-compounds and the ferric-compounds, cuprous and cupric, chromous and chromic and so on.

NOMENCLATURE.

An indication of the nomenclature of these compounds is given in table 1, where at the bottom of the table the suffixes are recorded. The metallic elements with lower polarnumber are always the -ous-compounds, those with higher polarnumbers the -ic-compounds. The nonmetals, when negative, are the -ides, like e.g. sulfide, nitride, selenide, carbide, etc. In their oxy-compounds the nonmetals have a positive polarnumber and the lower one is the -ite, the higher one the -ate, and perhaps the per- -ate. Thus there are e.g.

Chloride (−1) Chlorite (+3) Chlorate (+5)  
 Perchlorate (+7)  
 Sulphide (−2) Sulfito (+2) Sulfate (+4)  
 Nitride (−3) Nitrite (+3) Nitrate (+5)  
 and among the amphoteric metals there are e.g.  
 Chromous (+2) Chromic (+3) Chromate (+6)  
 Manganous (+2) Manganic (+3) Manganate (+6)  
 Permanganate (+7)

This nomenclature is indicated in table 1.

OXYDATION AND REDUCTION.

Whenever one type of compound is transformed into another type of compound, the chemical reaction is then called oxydation and reduction. If the polar-number is increased or augmented it is oxydation, and if the polar-number is decreased or diminished it is reduction. Thus the transformation of chloride to chlorine is oxydation. From chlorine to chlorite, from chlorite to chlorate is also oxydation. The reverse reaction, e.g. from perchlorate to chlorate or chlorite, from chlorate to chlorite or chlorine, from chlorine to chloride is reduction. In table 1 the arrows indicate the direction in which a transformation is either oxydation or reduction. Both terms have come down from the early modern chemistry, where it was believed that oxygen is essential to an oxydation, and hydrogen essential to a reduction. Today the terms have been enlarged to describe a certain class of reactions and it is unfortunate that the terms are thus misleading. Augmentation for oxydation, diminution for reduction would perhaps better indicate the nature of the reactions. The majority of the students at our universities are laboring under the misconception of the principle of "oxydation and reduction," which is based upon the different types or series of compounds and a close study of table 1, constantly used as a reference, will be of benefit in understanding certain chemical phenomena. If the classification and suggestions of this paper will prove to be an incentive to further study, or if it will give a different aspect of the subject matter, its mission will be fulfilled. However everything has to be "chewed well" before it can be digested, and if at the first reading a thing is not understood, it will become clearer by repeated study and then—interesting.

Fishing with Spider's Webs\*

By E. W. Gudger, Professor of Biology, State Normal College, Greensboro, N. C.

LOUIS BECKE, author of many interesting books on the life and customs of the South Sea islanders and on the habits of the fauna found therein, in one of these books, 'Neath Austral Skies (London, 1909), tells the following interesting story: He says that many years ago he was discussing the customs, habits, and manner of life of the inhabitants of western Polynesia with Dr. J. S. Kubary, a German naturalist and traveler of high standing. They were at the time traversing a path through the mountains of Ponapé, one of the islands of the Caroline Archipelago, lying northwest of New Guinea.

It was early in the morning and spiders' webs with the dew on them were found everywhere. They were very large, so much so that occasionally one of them would obstruct the path of the travelers, and would have to be broken through with a stick. The size, strength and beauty of these webs were so extraordinary as to attract Becke's attention, and he spoke to Kubary of them. However, the German assured him that these were nothing compared to those which he had heard were to be found in the vicinity of Astrolabe Bay on the northeastern coast of that strange island-continent, Papua or New Guinea.

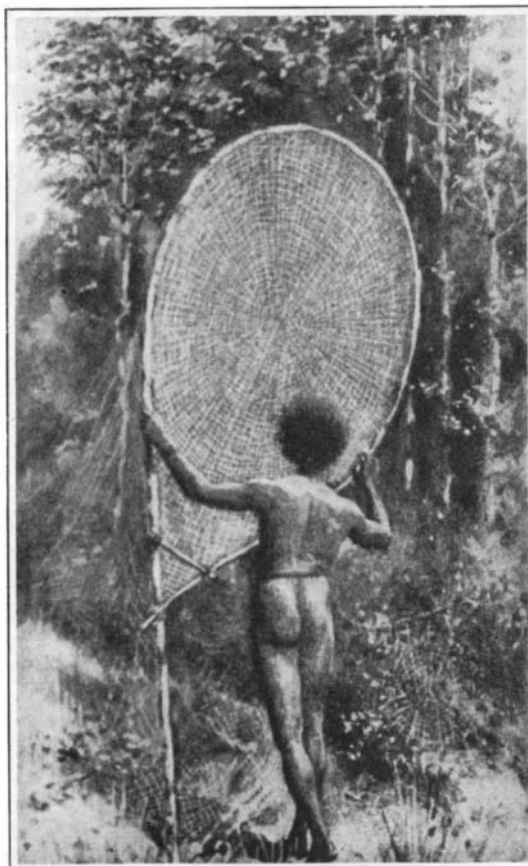
Kubary told his companion that he had read in either a letter or a publication by the distinguished Russian naturalist, Baron Nicolai Miklucho-Maclay, the statement that the mountain-dwelling tribes about Astrolabe Bay used similar spider-web nets for catching fish in their mountain streams.

Now Miklucho-Maclay was a scientist of high standing, especially in ichthyology, a traveler of wide acquaintance among the savage cannibals of New Guinea and the South Sea Islands, and had for some time resided among the tribes inhabiting the shores of Astrolabe Bay.

Whether or not the Baron had actually seen the natives use the large spider-webs for catching fish, Kubary could not say; but he certainly believed that the former had grounds for making the statement. Kubary's own notion was that the natives somehow or other were able to remove the nets whole and uninjured from the branches of the trees between which they had been spun, and having fastened them with proper supports across the narrow streams, drove the fish into them.

\*From the Bulletin of the New York Zoological Society.

Becke next relates that years later, in a conversation with Sir John Robertson, Premier of New South Wales and father-in-law of Miklucho-Maclay, he spoke of the death of the latter from fever in New Guinea, and expressed great regret that the loss of the collections, journals, etc., of the naturalist probably made it impossible ever to trace down the spider-web fish-net story. Sir John, however, laughed at the story and expressed his belief that his son-in-law was simply playing on the credulity of the German. I have had careful search made of all the works available in the

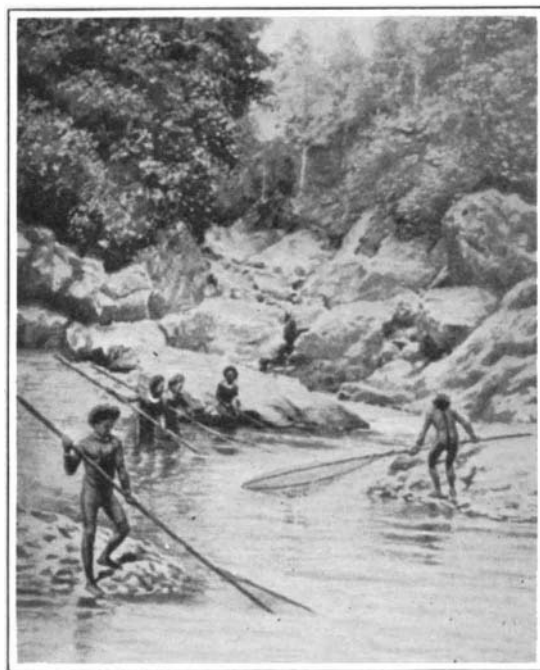


New Guinea native and his spider-web net

Reproduced from Two Years Among New Guinea Cannibals

Library of Congress of both Kubary and Miklucho-Maclay, but with barren results so far as finding anything confirmatory of this interesting story.

However, from another source we now come to a most important confirmation of the spider-web fish-net story. During the past summer while at work in the American Museum of Natural History, New York City, on the Bibliography of Fishes, under the editorship of Dr. Bashford Dean and Dr. Charles R. Eastman, I examined a considerable number of books of travel to get



Natives of New Guinea fishing

Reproduced from Two Years Among New Guinea Cannibals

fish references. Among these was one entitled Two Years Among New Guinea Cannibals: a Naturalist's Sojourn Among the Aborigines of Unexplored New Guinea (London, 1906). The author is Mr. E. A. Pratt, a natural history collector of standing, and Gill Memorialist, 1891, of the Royal Geographical Society of Great Britain. Mr. Pratt spent two years in New Guinea, mainly among the aborigines in the vicinity of Yule Bay on the southeast coast where he collected insects and birds-of-paradise. This book gives an in-

teresting account of his experiences during this time. On pages 266 and 267 is found the following remarkable account of fishing with the spider-web nets. The accompanying figures are reproductions of Mr. Pratt's plates:

"One of the greatest curiosities that I noted during my stay in New Guinea was the spiders' web fishing-net. In the forest at this point (Waley, near Yule Bay), huge spiders' webs, six feet in diameter, abounded. These were woven in a large mesh, varying from one inch square at the outside of the web to about one-eighth inch at the centre. The web was most substantial, and had great resisting power, a fact of which the natives were not slow to avail themselves, for they have pressed into the service of man this spider which is about the size of a small hazel-nut, with hairy, dark-brown legs, spreading to about two inches. This diligent creature they have beguiled into weaving their fishing-nets. At the place where the webs are thickest they set up long bamboos, bent over in a loop at the end. In a very short time the spider weaves a web on this most convenient frame, and the Papuan has his fishing-net ready to his hand.

"He goes down to the stream and uses it with great dexterity to catch fish of about one pound in weight, neither the water nor the fish sufficing to break the mesh. The usual practice is to stand on a rock in backwater where there is an eddy. There they watch for a fish, and then dexterously dip it up and throw it on to the bank. Several men would set up bamboos so as to have nets ready all together, and would then arrange little fishing parties. It seemed to me that the substance of the web resisted water as readily as a duck's back."

Since writing the above, a third brief reference to the spider's-web fish-net has come to light. In 1913, Captain C. G. Rawling, a fellow of the Royal Society of Great Britain, published in London a work bearing the title "The Land of the New Guinea Pygmies. An Account of the Story of a Pioneer Journey of Exploration into the Heart of New Guinea." His explorations were done in Dutch New Guinea, on the southern side of the western end of the island beginning in 1910 and covering about a year and a half. On page 289 is found this interesting statement:

"The bushes round the camp (at the village at Atabo on the coast) contained large numbers of an immense spider; I do not know its name, but it is well known in other parts of New Guinea. They have soft balloon-like bodies, and spin a web of great strength. It has been commonly stated that these webs are utilized by the natives as fishing-nets, and that large fish are secured, but I am afraid that this is an unsubstantiated yarn. Nevertheless, it is a fact that the children do take the webs off entire by slipping a ring of cane below, and that in them they will carry fish the size of sprats."

In a former Bulletin I published a short article on the spider-web fish-net, giving all the accounts then at hand of this interesting fishing apparatus. Since that time, however, some additional data have come to hand and it seems desirable to put these on record, and all the more so because many people have thought the first article a "fish story" and not worthy of credence. The data now to be presented will amply confirm the accounts previously given.

The account in question had its origin in a communication from the distinguished Russian traveller, Miklucho-Maclay, to the German explorer, Kubary, and by him passed on to Louis Becke, the Australian South Sea trader and writer of charming books on South Sea Life and customs. In addition to a search made for me at the time of the writing of the first article through the available publications of Miklucho-Maclay, I have myself made during the past summer a careful search through his bibliography for all titles bearing on New Guinea. The New Guinea papers were all gone through one by one and page by page, but nowhere was there found any account of the spider-web fish-net story as related by Kubary. The record, if any was made, seems to have been lost.

As opportunity has offered during the past six months, notes have been made of unusually strong spider-webs. And interesting in themselves as well as furnishing corroboratory evidence, some paragraphs may well be devoted to such accounts.

As early as 1725, Sir Hans Sloane in his book on Jamaica wrote of a large wood spider which made nets "so strong as to give a man inveigled in them trouble for sometime" and he quotes Jan de Laet that at Cumana there were spiders' webs so strong that considerable force was needed to break them. Laet wrote somewhere in the sixteen hundreds, but I have not been able to verify the citation, nor one from Oveido to the same effect for the West Indies.

Later on (1745), Wm. Smith records the fact that