Predicting Undiscovered Elements

Part Two

"A Classic of Science"

Prediction of Ekasilicon, Now Known as Germanium, and Elements of Series 10 Including Radium and the New 87

THE NATURAL SYSTEM OF ELEMENTS AND ITS USE FOR THE PREDICTION OF PROPERTIES OF THE UNDISCOVERED ELEMENTS. By D. Mendelyev, in Journal of the Russian Chemical Society, Vol. 3 St. Petersburg, 1871. Translated for the SCIENCE NEWS LETTER by Taisia Stadnichenko.

Ekasilicon

BUT it seems to me that the most interesting of the undoubtedly absent metals will be that which belongs to group IV of the analogues of carbon, namely, to the third series. It will be the metal directly following silicon, and therefore we will call it Ekasilicon. Ekasilicon must have an atomic weight of about 72, because it is followed in this series by arsenic. In character, Ekasilicon will have properties intermediate between silicon and tin, just as Ekaluminium must have properties intermediate between aluminium and indium. Es (rather easily reduced from EsO_2 and K_2EsF_6) must have a volume of about 13, as the volume of Si is 11 and the volume of Sn is 13. We will get the same results if we refer to the third series and go in the direction of Zn, the volume of which is 9, then to El, Es, then As, the volume of which is 14, and then go to Se$=18$ and Br$=27$. In this, as in the following odd series, the volume gradually increases from Cu to Br. Consequently free Es must have a specific weight of about 5.5. Its remaining properties will resemble the properties of Si and As to such an extent as the properties of As itself resemble the properties of P and Se, that is, it will at any rate be a fusible metal capable at high temperatures of volatilizing and oxidizing. It will decompose water vapor with difficulty. It will have almost no action on acids, that is, it will not liberate hydrogen and it will form very unstable salts. Alkalies will react on it similarly to their action on zinc and arsenic. EsO_2 must have a specific volume close to 22, because that is the volume of the oxide of silicon and of the oxide of tin, and therefore a similar volume will be obtained by reasoning from the properties of other oxides of elements belonging to the third series. Thus the specific weight of the oxide of this metal must be close to 4.7. In regard to the basic properties of this oxide, they must be very slight, for in silica they are almost absent and in the tin oxides they are also slightly developed, and therefore the properties of this oxide must be expected to be closer to those of titanic acid. Undoubtedly it will form a gelatinous hydrate which can be dissolved in alkalies and acids, from which it can be separated easily in various ways, as is noted with titanic acid. However, in comparison with the latter, the oxide of Es will possess more clearly defined acidic properties. Thus if Es accompanies titanium in its compounds we must think that, all other conditions being equal, Es would precipitate from an acid medium before titanic acid, while in an alkaline medium it would come down after titanic acid. By these few indications pointing to it, one can be guided in research for these elements in compounds of titanium and zirconium in which many investigators have already tried to find new elements.

Will be decomposable . . .

Es, like all metals of this group, will form with HF an acid of the composition H_2EsF_6, which can form salts isomorphic with the salts of hydrofluosilicic acid, but it is most likely that Ekasilicon fluoride itself will not be a gaseous compound, as zirconium fluoride and tin fluoride are not gaseous. Ekasilicon chloride will be decomposable by water, as are silicon chloride and tin chloride, and in this relation it will present properties intermediate between the latter two. It is possible that it will be a liquid, and will have a partial volume of about 113, because the volume of silicon chloride is 112 (at O° Pierre) and the volume of tin chloride 115 (at O° Pierre), hence the specific weight of Ekasilicon chloride will be about 1.9. The ability to deoxidize into lower forms of oxides will be slightly developed in Es and in this relation as in the others it will come nearer to titanium. The boiling temperature of Ekasilicon chloride must be close to 90°. It will undoubtedly form metallo-organic compounds, as they are formed by Si, Sn, Zn and As. It will be "atomo-logic" with them. In this it will differ from Ti and Zr, in which this property is not developed. $EsEt_4$ will boil at 160°, and will have a specific gravity of 0.96. We might expect that it will have a hydrogen compound and its properties will be very definite, namely EsH_4 will readily decompose into water and metal, because even arsenic hydride possesses this property similarly to lithium hydride. At any rate, the existence of hydrogen compounds with this metal is more probable than it is for tin, and even for tin we might expect tin hydride, SnH_4, as a gaseous substance but very unstable. Based on this indication it seems to me more probable to find Es in the compounds of titanium and zirconium, although the purification of the minerals containing these elements, owing to the weak oxides of Ti and Zr, presents considerable experimental difficulty. It seems to me most advisable to search for Es in perovskite (perofskite), i.e., a calcium titanite salt sometimes found in nature. I think this because oxide of titanium possesses very weak acidic properties, nevertheless with lime it forms well crystallized cubic perovskite whose occurrence is probably to some extent due to the fact that part of the titanic acid is replaced by the oxide of Ekasilicon. It may be that the majority of ordinary titanium compounds, especially those that are obtained from $TiFeO_3$, eshenite, and similar ones, contain besides titanium an admixture of some similar element with a higher equivalent, because on comparing the equivalent of titanium with the equiva-

lent of the neighboring elements we can see that it is somewhat high. The transition from Ca=40 to Ti=50 is too rapid and from Ti=50 to V=51 is too slow, and if Ti in reality possessed an atomic weight of about 48 the relation of its atomic weight to the weights of the other neighboring elements would be more regular. It may be, again, that the determination of its atomic weight is not correct because titanic compounds can not be prepared in a very pure state because the properties of titanic acid are not distinct. There are only two forms in which titanium can be separated well from admixture, namely, volatile titanium chloride—but of course no substance has yet been obtained in a pure state in the form of a volatile compound —and another form, TiK_2K_6, but such compounds are also formed by Ekasilicon. At any rate, more accurate experiments on the determination of the atomic weight of titanium are not devoid of great interest.

Full right to judge . . .

The above given indications for the properties of expected elements could not appear to anybody as devoid of a firm foundation, and it would be a considerable addition to the theoretical side of the problem if one of the expected elements should be definitely discovered and its properties should prove such as might be expected through a comparison based on the natural system in which we have placed the elements according to their atomic weights. Besides these certainly probable ones, there is a possibility of other undiscovered elements, even whole groups of others, whose existence is to some extent doubtful because we know nothing of the nature of the forces which produce the so-called elementary forms of matter. We have full right to judge of the elements that are found in the center of the system within the limits in which many of the elements are well known, but we cannot say the same of the elements that must be placed at the ex-

treme parts of the system. It may be that certain equilibria, i.e., the existence of certain "atomologues", are simply impossible, just as certain members of homologous series, under all the conditions necessary for the formation, are not obtained but are tranformed into other, more stable polymeric or different forms, as in the case of methylene, for instance. It is possible also that there exist elements with lower atomic weight, between 1 and 7, occurring between hydrogen and lithium, and elements in Group VIII with atomic weights of about 20, i.e., located between fluorine and sodium, like the iron group found between manganese and copper. I would like to draw attention to a striking fact, that in the system of elements at present 17 elements are absent (i.e., a complete two-series period) having atomic weights from 138 to 182. This phenomenon could hardly be accidental, since among the elements with lower atomic weights and also among the elements with higher atomic weights we already know many members. Into this space it is possible to put some of the cerium metals, because if we give to their oxides the composition of R_2O_3 or RO_2 we obtain for them atomic weights from 140 to 180, if the accepted equivalents as determined at present are sufficiently accurate. Among other elements with small atomic weight we might expect one more analogous with manganese than with titanium, belonging to the platinum group having a smaller atomic weight than ruthenium, namely about 100, referred to Group VII and dapable of forming a salt KRO_4 similar to potassium permanganate. It may be that the elements analogous with sodium in Group I and possessing atomic weights close to copper and silver exist, although the lighter metals are able to form, like sodium, the compounds RHO, ROl, etc. and therefore it may be that they make the transition from elements of the eighth group to elements of the second. Among the heavy metals, that is, those with large atomic weights, we might expect an element analogous with tellurium and having an atomic weight greater than bismuth. It ought to have distinctly metallic properties, the ability to form an acid similar to sulphuric acid, but an even stronger oxidizing agent than telluric acid. The oxide of this element RO_2 found in VI-9 ought to be a fairly strong base, like the oxide of bismuth—we cannot expect acid properties for the oxide RO_2 in this place. This element ought to form metallo-or-

ganic compounds. Hydride compounds very likely will not exist because with increased atomic weight and increasing basic metallic character of the element, the tendency to combine with hydrogen, as has been noted in the transition from chlorine to bromine and iodine, decreases. Then in the tenth series we might expect basic elements belonging to Groups I, II, and III. They must have atomic weights of about 210-230. The first of them must have the oxide R_2O, the second RO, and the third R_2O_3. The first will be similar to cesium, the second to barium, and all their oxides will have the character of strong bases, because in this series (10) even thorium in its oxide ThO_2 has distinctly basic properties, and even uranium of the same series in its oxide UO_3 still has a clearly basic character. Between thorium and uranium in this series we must expect another element with basic properties, although slightly developed, with an atomic weight of 235. This element must form an oxide of higher degree of oxidation with the composition R_2O_5, like columbium and tantalum, with which it ought to be analogous. It is possible that in the minerals containing these elements small amounts of weak acids formed by this metal are found.

Many acid-forming elements . . .

The tenth series ends the elements now known, and as in the series of typical elements we found many acid-forming elements while that phenomenon was not repeated in the following series, so in the tenth series we found many base-forming elements and this also is not repeated in the other series, from this we can conclude that here we are close to the end of the possible forms of elementary compounds. Confirmation of this supposition can be seen in the fact that the atomic weights of the elements in the first series differ between the groups by about 16, but in the following series this difference reaches 25 and even more, while the difference between neighboring elements in the last series is again decreasing.

The use of the principle of periodicity in the search for undiscovered elements and in the determination of their properties, in my opinion, presents the most striking form of the discussion as to the practical application in scientific research of the chemical data derived from the natural system of the elements as based on the sum total of knowledge at hand concerning the already known elements. Without undue exaggeration

of the apparent advantages of such a system, we must finally recognize its correctness, at any rate when the unknown elements predicted on the basis of it, are confirmed by actual discovery. As we must admit, heretofore chemistry did not have any means of foreseeing the existence of new simple bodies and if they were discovered they were found only by means of actual observation. I think that the use of the proposed system of elements for comparison of the elements themselves as well as the compounds which they form presents, even at present, advantages which have not been given by any conception used in chemistry heretofore. But for the final proof of the correctness of the conclusions based on the use of the system, the establishment of certain additional facts is necessary, especially more accurate determination of the atomic weight of certain elements and determination of the physical properties of some of their compounds. When it becomes possible to subject the periodic function of the properties of atomic weight and "atomologic" relationship of the elements to exact laws, then we will approach a closer understanding of the real essence

of the difference between the elements themselves. Then of course chemistry will be able to leave the field of hypothetical conceptions ruling it at present and then it will be possible to give it dynamic direction already so fruitfully employed in the study of many physical phenomena.

Nov. 29, 1870.

Science News Letter, November 7, 1931

MEDICINE

Cancer Only One of Nobel Prizeman's Research Lines

CANCER, biological physics, and the respiratory function of the tissues are the three chief subjects of research by Prof. Otto Warburg of the Kaiser Wilhelm Institute for Biology, Berlin, who has just been awarded the Nobel Prize in medicine for 1931. Prof. Warburg has made very important contributions in all three of these fields.

Most attention has probably been attracted by his work on cancer.

He showed that cancer cells have quite a different metabolism from ordinary tissue cells. They can get all the energy they need to live and grow and reproduce from the breaking down of sugar. Uulike other cells, they do not need oxygen but can live without it, much as some disease germs do. This does not mean that cancer is caused by germs, however. It is the suffocation of normal cells by lack of oxygen that gives the cancer cells a considerable advantage in the competition of growth, according to Prof. Warburg's views on the subject.

Prof. Warburg also investigated the photochemistry of plant cells, that mysterious process by which the cells turn carbon dioxide and water into food in the presence of light. He measured very exactly the light absorbed by these green cells and compared it with the amount of carbon dioxide they used. He was then able to show a certain quantum relation between the two. This research of Prof. Warburg's was one of the first pieces of work in which biological physics was compared with the quantum theory.

Other work of Prof. Warburg's was in the field of cell metabolism. He demonstrated the constitution and action of the ferment in the tissue cells which controls the conveyance of the oxygen of the air from the lungs to the muscles and other tissues of the body.

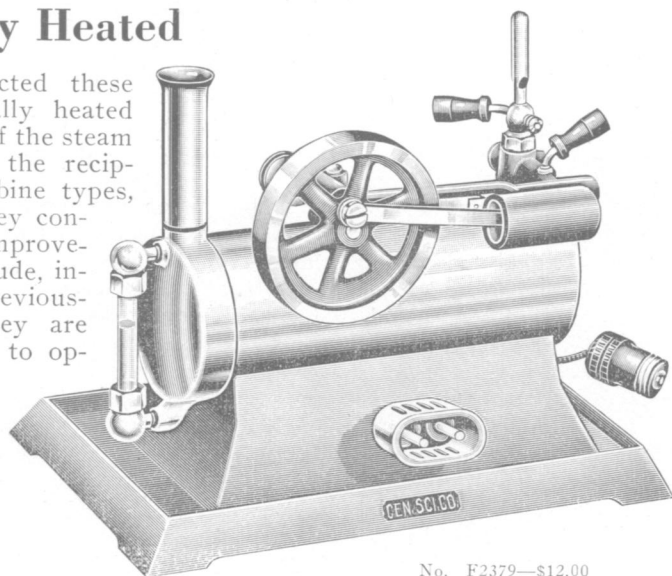*Science News Letter, November 7, 1931*

MEDICINE

Physiologist Appraises Dr. Warburg's Work

A SCIENTIST'S estimate of the achievements of Dr. Otto Warburg in recognition of which he has been chosen for the Nobel Prize in medicine and physiology for 1931 are contained in a statement made to Science Service by Dr. W. H. Howell, chairman of the Division of Medical Sciences of the National Research Council. Dr. Howell was for many years director of the School of Hygiene