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THE PERIODIC SYSTEM OF ELEMENTS.

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I.—The chemical and physical properties of the elements are functions of their atomic weights, in the periodic system of elements. The periodicity is all embracing and complete extending to practically all properties. However, if an attempt is made to represent this periodicity graphically, in tabular form, it is a failure. The usual form of representation is given in the table, Fig. 1, where however the last column again precedes the first column, that is, the representation should be on a cylinder, with Li following He, and Na following Ne, etc., or on a spiral.

The first period of 8 elements, from Li to Ne, is followed by the second period of 8 elements, from Na to A, which are close homologs of the first period. The third period starts with A, K and Ca, close homologs of the corresponding elements of the first 2 periods, but gradually the analogy becomes less in V, Cr, Mn, though there still are some analogies to the corresponding elements of the preceding periods: P, S, Cl. Then, in the triplet Fe, Co, Ni, the analogy with Ne and A entirely disappears. Then a partial analogy appears again in Cu, Zn, as sub groups of K, Ca, and finally, at the end of this period, in Se, Br, Kr, close homologs with S, Cl and A are again reached. We thus here have a double period of 18 elements. Then follows a second double period of 18 elements from Kr to I. Plotted in a table of 8 columns, Fig. 1, this double periodicity is not represented, and each column does not contain a series of homologs,

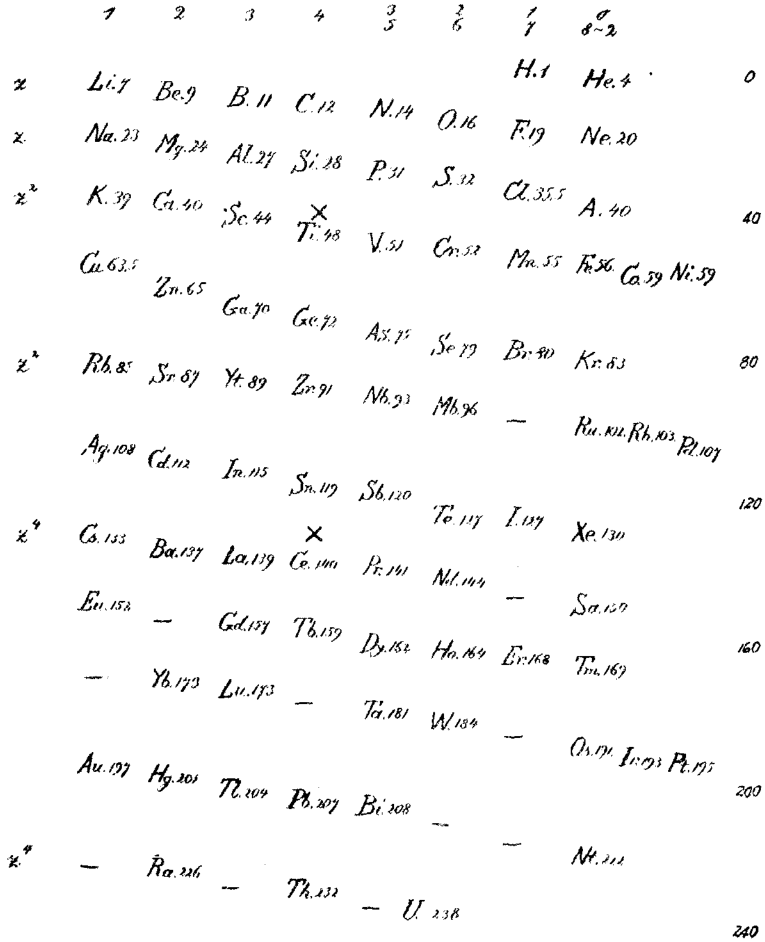

Fig. 1.

but 2 series, a main group: Li, Na, K, Rb, Cs, and a sub group: Cu, Ag, Au.

Plotting the periodic system in the form of Table I, shows the periodicity of the double periods, but does not show the periodicity between groups and sub groups, thus also gives an incomplete representation.

TABLE I.

..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	H
He	Li	Be	B	C	..	..	..	..	..	..	..	..	..	..	N	O	F
Ne	Na	Mg	Al	Si	..	..	..	..	..	..	..	..	..	..	P	S	Cl
A	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br
Kr	Rb	Sr	Yt	Zr	Nb	Mb	..	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I
Xe	Cs	Ba	La	Ce	Pr	Nd	..	Sa	..	..	Eu	..	Gd	Tb	Dy	Ho	Er
..	Tm	Yb	Lu	..	Ta	W	..	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	..	..
Nt	..	Ra	..	Th	..	U	..	..	..	..	..	..	..	..	..	..	..

Going now beyond the 2 double periods, we come apparently to a quadruple period: starting with Cs and Ba as homologs to Rb and Sr, we then leave the analogy with the previous periods, in the rare elements from La to Lu, then return to homologs of the sub group, from Ta to Hg, and then to homologs of the main group, up to Nt. Then apparently follow some fragments of a second quadruple group.

Table I obviously would not represent the quadruple period.

The periodic system thus comprises 2 single periods, 2 double periods and a quadruple period with some fragments of a further period.

No way exists to represent graphically, by table, this multiple periodicity and thereby to show the periodic relation satisfactorily.

However, no reason exists, why this periodicity should be representable graphically on a plane, as in a table: if the properties of the elements are functions of their atomic weights, this function may be representable on a plane, or it may not. It is nothing uncommon that a mathematical function can not be represented in a plane. For instance, the distances of the cities on the earth are a function of their location, but this function can not be represented on a plane—but only on a sphere, because the earth is a sphere—and all geographical representations thus are necessarily distorted.

It is interesting to note for instance, that the double periods, from A to Kr, or from Kr to Xe, can be represented on a single sided ring, as shown in photographic representation in Figs. 2 and 3: as seen, this representation shows both periodicities: Xe comes beneath Kr; Ag comes beneath Rb, but on the other side of the paper—and Cs again becomes beneath Rb, though on the other side of Ag, but coincident with it, thus showing the partial periodicity between sub group and main group, and at the same time the complete periodicity within the main groups, or within the sub groups.

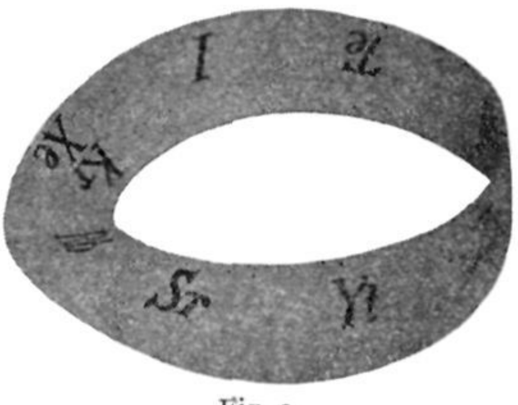

Fig. 2.

Fig. 3.

It follows herefrom, that the periodicity function of the atomic weights can not be represented on a plane. The single sided ring, Figs. 2 and 3, only represents the double periods, but not the entire periodic system.

II.—However, when considering the representation of the function representing the elementary properties by their atomic weight, in the periodic system, the natural procedure obviously is to consider the various functional representations devised in the theory of functions of mathematics, and it can be seen then, that the periodic system of elements, with its single, double and quadruple periodicities, can be completely represented by a Riemann surface with 2 singular points, at —40 and —130 approximately.

Let two planes A and B be related to each other so that the points $Z = x + jy$ of the plane A correspond to the points $W = u + jv$ of the plane B—where x and y, respectively, and u and v are the coördinates, and the points represented in the usual manner by a general number or complex quantity. Z for instance may represent the structure, W the atomic weight of the element.

Let now the relation between Z and W be given by an equation of the form

$$Z = \sqrt{W + 40} - 6.32. \qquad (1)$$

Suppose now, on the plane W, we start from a point W_0 and trace a line—over $W_1, W_2 \ldots$ back to W_0, in Fig. 4. Then the corresponding point Z moves from Z_0 over $Z_1, Z_2 \ldots$ back to Z_0. This however occurs only, if the path of W does not encircle the point $W = -40$.

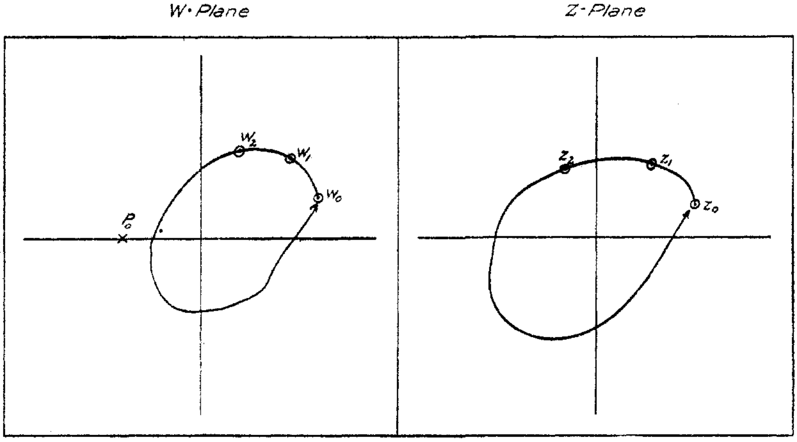

Fig. 4.

If however, in Fig. 5, the path of W encircles the singular point—P_0: $W = -40$, then, when completing the circuit from W_0 back to the same point, the path of Z does not close, but, beginning at Z_0, ends at Z_0', at a different point. Thus, functionally, the point W_0', to which we returned, although apparently coincident with W_0, is not the same point, as it corresponds to a different point Z_0'. Traversing once more a closed path, from W_0', corresponding to Z_0', then when returning to the starting point of W, we reach the starting point of Z_0, thus return to the starting point of W_0. Hence, if the path of W encloses the singular point -40, a double circuit of W corresponds to a circuit of Z. In other words, W is a double plane, and the two planes have one point $P_0 : W = -40$, in common, so that any closed path of W, which does not enclose $W = -40$,

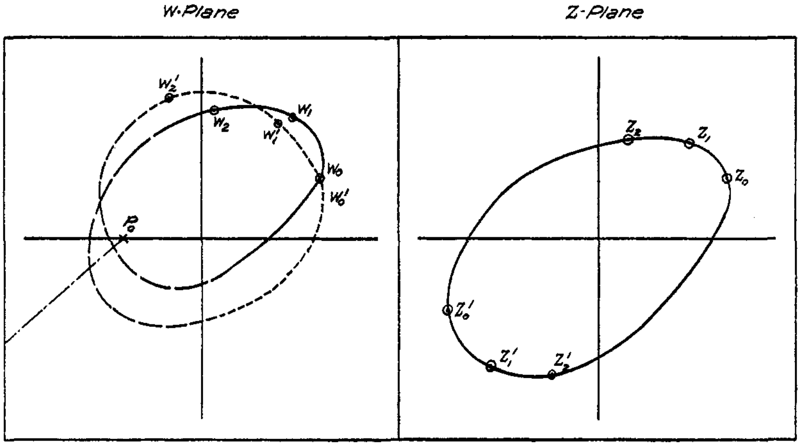

Fig. 5.

remains completely in one plane; a path of W, however, which encloses the singular point, does not close, but passes from the one plane to the other, and returns to the first plane and closes itself only after the second circuit, in other words gives a double periodicity.

Such a Riemann double plane with singular point at P_0, can be pictured as two planes fastened together at P_0, and intersecting each other, so that the lower plane passes into the upper, and the upper into the lower. This physically would require the two planes to intersect on a line from P_0 to ∞; the Riemann double plane however does not intersect, but only has the point P_0 in common, and thus is not physically representable, that is, the mathematical relations given above can not be represented in a physical plane, but nevertheless, show the functional relations quite real. Of the same nature apparently is the functional relation of the periodic system, and as such is represented by a Riemann plane.

Equation 1 represents only the single and the double periods, but not the quadruple periods, but to represent the latter, besides the singular point $P_0 = -40$, a second singular point of higher order would exist at $P_0' = -130$, thus giving a quadruple plane, with singular points at P_0 and P_0'. However, since the object of the discussion is merely to show the possibility of the complete representation of the periodic system by a Riemann plane, we do not need to enter further into the mathematics.

In Fig. 1 then are marked the singular points by crosses.

In Fig. 6 then is represented as illustration the first single period of the periodic system, from He to Ne. The *Z* plane shows the spiral giving the periodic relation, and the *W* plane the atomic weights as represented on the Riemann surface, in this case, on one plane of it.

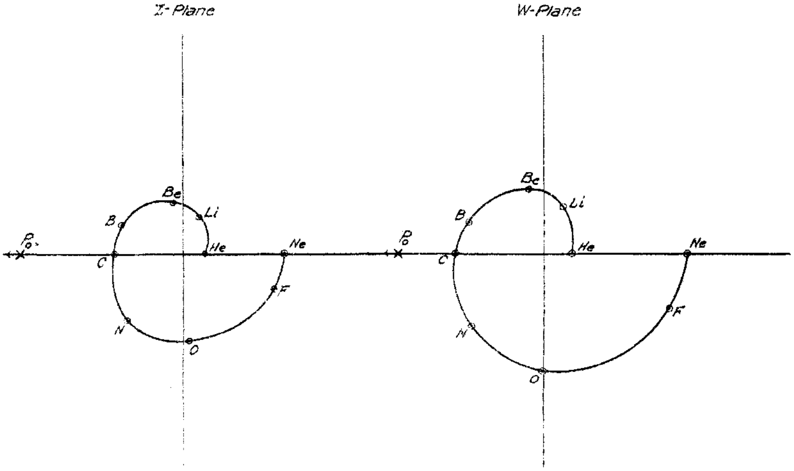

Fig. 6.

Fig. 7 shows the representation of the second double period, from Kr to Xe. The *Z* plane gives the single spiral functional relation, the *W* plane the corresponding representation of the atomic weights on the Riemann surface; starting from Kr and following the spiral over Rb, Sr, etc., when

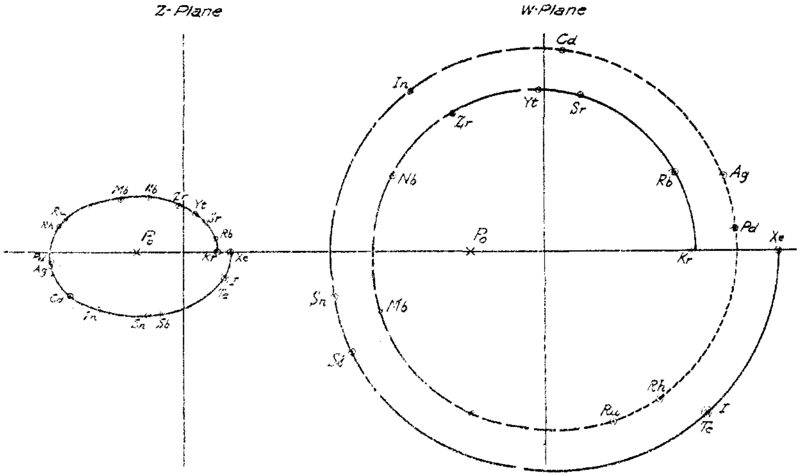

Fig. 7.

we come around again to Rh, Pd, Ag, we are in the other plane, and, following the spiral further, over Cd, In, etc., coming around once more, at Te, I, Xe we are again in the first plane.

As further illustration is shown diagrammatically, in Fig. 8, the *W* or Riemann plane graphically representing the quadruple periodicity of the atomic weights from Xe to Nt, or the first quadruple period.

It follows herefrom:

The periodic system of elements, with its single, double and quadruple periodicities, can not be graphically illustrated on a plane, cylinder, etc., but it can be correctly represented on a Riemann surface with singular points at —40 and —130.

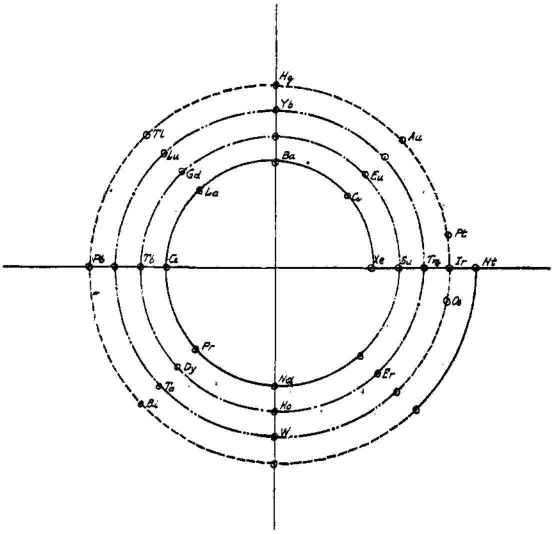

Fig. 8.

[Contributions from the Research Laboratory of Physical Chemistry of the Massachusetts Institute of Technology. No. 113.]

THE POTENTIALS OF THE BISMUTH-BISMUTHOXYCHLORIDE AND THE COPPER-CUPROUS-CHLORIDE ELECTRODES.

By Arthur A. Noyes and Ming Chow.

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1. Outline of the Investigation.

The purpose of this investigation was to determine the specific (or normal) potential of the electrode Bi + BiOCl, $\left\{\begin{matrix}H^+\\Cl^-\end{matrix}\right.$ and that of the