AN EXTENSION OF PROFESSOR MAYER'S EXPERIMENT WITH FLOATING MAGNETS.

BY E. R. LYON.

THE experiment with floating magnetic needles and an attracting bar magnet, known as Professor Mayer's experiment, has been frequently cited, as demonstrating the periodic grouping of a number of mutually repelling bodies, restrained by a central force. This experiment is often shown as an illustration of Sir J. J. Thomson's theory of the atom,[1] according to which the negative electrons are arranged in concentric rings in a positive sphere. The floating magnets take the place of the electrons and a bar magnet above them takes the place of the positive sphere. Reference may be made here to a paper by A. C. Crehore, PHYSICAL REVIEW, April, 1912, page 241. The hope of observing an even more complete analogy led the author in the winter and spring of 1911 to attempt an extension, in size and number, of the groups in the Mayer's experiment.

In the initial experiments a glass battery jar was employed for a container, and it was observed that, if the attracting bar magnet were removed, the floating magnetized needles would mutually repel one another to the wall of the jar, where they remained, partly held by their repulsion, and partly by the surface tension of the water. It was further observed that nearly a solid ring of magnets could thus be formed, and that the inward directed repulsion from this ring was, especially with respect to symmetry, even more efficacious in the formation of the Mayer's groups than was a centrally attracting bar magnet. Following this lead, a coil of wire of the same depth and position, and wound upon the outside of the jar, was substituted for the ring of magnets. This coil had forty turns of No. 18 enamelled wire, and a current of from one fourth to one half ampere was passed through it, in such manner that the magnetic field should repel the floating magnets towards the center of the jar. With this device it was observed that still more symmetrical groups could be obtained, and that, furthermore, groups of as high as thirty and forty needles could be easily studied, without any of the inconvenient over concentration at the group center, and sticking together of pairs of needles, such as had been observed when using the suspended bar magnet to produce the central force.

[1] Corpuscular Theory of Matter.

This suggested that any sized group might be obtained by simply constructing a sufficiently large containing tank and repelling coil. Accordingly, a circular zinc tank three feet in diameter and six inches deep was obtained, and wound with a coil of No. 18 enamelled wire. This coil had two layers of forty turns each, with separate leads brought out from each, so that one, or both combined, might be used at pleasure.

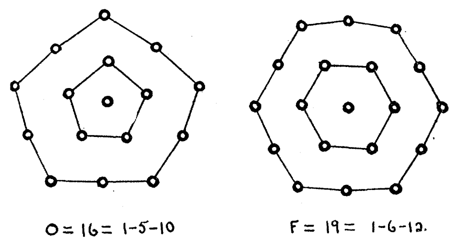

Fig. 1.

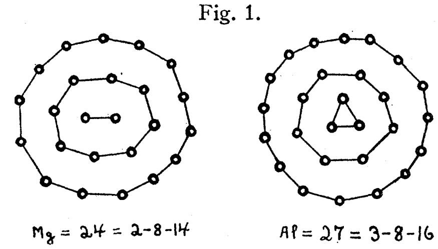

Fig. 2.

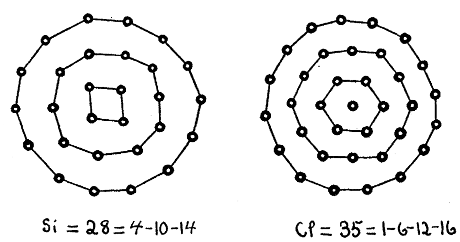

Fig. 3.

The width, or depth, of the coil was 3.8 centimeters, which was the same as the length of the needles employed. Moreover, care was taken that the tank should be filled to the level of the top of the coil, in order that the magnetic needles, suspended from corks, should float in the plane of the coil. A single layer of the coil, actuated by about one half ampere, was generally found to yield sufficient field intensity, and, as before, the direction of the current was such as to repel the magnets towards the center of the tank.

This tank was never tested to its full capacity, as the interval of one to seventy-five magnets, inclusive, soon proved to be of greatest interest.

Throughout this interval the groups were of the same general nature as is familiar in the Mayer's experiment, namely, the concentric ring formation, the nearly equidistant spacing, and the periodic reappearance of certain group characteristics. But the point of peculiar interest, made possible partly by the greater number of groups to which the comparison could be extended, and also by the nature of the field which was employed, was the appearance of successive groups, simulating, in certain of their structural relations, the relations of the maximum valencies to the atomic weights of nearly all the elements of weights, one to seventy-five inclusive. Figs. 1, 2 and 3 represent some of the groups obtained.

This simulation is as follows: The groups repeat themselves round the center members as shown in Fig. 4. These are: one in the center, two,

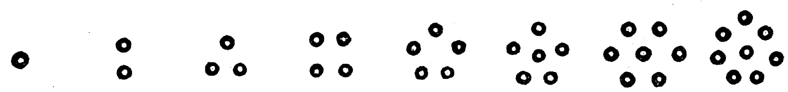

Fig. 4.

three, four, five, six, seven, and eight in the center. That is, we do not recognize as a center group any configuration greater than eight, and every member of this center group is to be counted. If the middle of a certain group consists of a ring of eight with one in the middle of it, this is to be regarded as a center group of one, not of nine. In the same way, two in the middle with ten round them would be counted as a center group of two. On the other hand, one in the middle with five round it would not be counted as one, but as six. Let this number, 1, 2, 3, 4, 5, 6, 7, or 8, of the center group represent the maximum, or oxygen, valency of an atom; then the total number of magnets in the whole of the given group will be equal to the integral number of the atomic weight of that atom. Thus one of the observed groups is 2–8–14, *i. e.*, two in the center, then a ring of eight, and around that a ring of fourteen. In this case the center group is two. The total number is twenty-four. An element of atomic weight, twenty-four, and valency, two, should correspond. This element is magnesium. Another group is 4–10–14. An element of valency, four, and atomic weight, twenty-eight, should correspond. This element is silicon. A beautiful hexagonal group is 1–6–12–16. The element, chlorine, with maximum valency, seven, and atomic weight, thirty-five, corresponds.

Notice that in the case of the center groups the attainment of an eight ring with one in the middle reverts the count to unity. Thus eight would appear as a stable group, toward which the center groups tend, as to a limit. As is well known, when the maximum valencies, five, six, and seven, are subtracted from eight, they yield the corresponding minimum, or hydrogen, valencies, three, two, and one; and these minima are the common active valencies of the elements which have the respective maxima. Thus, there is a group, 5–9. A maximum valency, five, should correspond, and an atomic weight, fourteen. The element is nitrogen, which has a maximum valency of five, and an active minimum of eight minus five, or three. As a tentative explanation, or rather picture, of the extra valency, let us assume a tendency, acting in the center groups, to form this relatively stable eight group; which tendency becomes effective when that group is already more than half attained, *i. e.*, when the center group is greater than four. Adopting the language of the electronic theory of valency, suppose electrons from time to time enter such an atom from without. By the tendency which we have assumed, a number of these would be retained, until the eight group was formed, in which case the atom would be retaining so many excess charges of negative electricity, and would hence have a proportionate electro-negative valency. A case in example is 1–5–10. This is oxygen, with maximum valency, six, and atomic weight, sixteen. To form a center group of eight would, in this case, require the acquisition of two more electrons, which would confer an electro-negative valency of two upon the atom.

It would also appear that, in the case of atoms having the little fragmentary center groups, one, two, three, and four, the electrons of these groups should be the most easily knocked out of any in the atom. So, if we conceive that in the jostlings of the atoms the little center groups are easily knocked free, then these atoms would be left with equivalent positive charges, which would confer upon them proportionate electro-positive valencies. Now suppose we should have, say, atoms of magnesium, 2–8–14, associated with atoms of oxygen, 1–5–10. The magnesium atoms lose their center groups and become $\frac{++}{1-7-14}$. The oxygen atoms gather up the electrons set free, forming $\frac{--}{1-7-10}$. By electrostatic attraction a $\frac{++}{1-7-14}$ ion will associate with a $\frac{--}{1-7-10}$ ion to form a molecule of magnesium oxide.

In this way the different valencies of particular elements can be provisionally explained, except those of elements in the eighth and zero groups. A peculiar relation is manifest between these groups. Where an element, or rather small group of elements, appears in the eighth group, the corresponding place in the zero group is unoccupied, and vice-versa. The eighth and zero groups may accordingly be thought of as divergent members of the same family, which have become differentiated on the apportionment of the maximum and minimum valencies. The members of the eighth group are characterized by the maximum valency of the family, eight. The members of the zero group, on the contrary, have taken the minimum valency, zero, or eight minus eight. The eighth and zero groups, when thus united into a single family, conform to our provisional explanation. Besides these, there are, of course, a number of minor valencies, which we can not now consider, except, in passing, to observe that some of the experimental groups also exhibit several arrangements, having instead of one, several possible configurations, but usually only one of a high order of stability.

The following is a list of the experimentally obtained groups from one to seventy-five, inclusive.

1	1	
2	2	
3	3	
4	4	
5	5	
6	1–5	
7	1–6	
8	1–7	
9	2–7	(1–8)
10	2–8	
11	3–8	(2–9)
12	4–8[1]	(3–9)
13	4–9	
14	5–9	(4–10)
15	1–5–9	
16	1–5–10	
17	1–5–11	
18	1–6–11	
19	1–6–12	
20	1–7–12	
21	1–7–13	
22	1–8–13	
23	1–8–14[1]	(2–8–13)
24	2–8–14	
25	2–8–15	
26	3–8–15	
27	3–8–16	(3–9–15)
28	4–10–14	
29	4–10–15	
30	5–10–15	
31	5–10–16	
32	1–5–10–16	
33	1–6–11–15	
39	1–8–12–18	
40	2–8–12–18	
41	2–8–13–18	
42	3–8–13–18	
43	3–9–13–18	
44	3–9–14–18	
45	3–10–14–18	
46	4–10–15–17	
47	4–9–15–19[1]	
48	4–10–16–18	(4–10–15–19)
49	4–10–16–19	
50	5–10–15–20	
51	5–10–16–20	
52	1–5–10–16–20	
53	1–5–10–16–21	
54	1–6–12–16–19	
55	1–6–12–16–20	
56	1–7–12–16–20	
57	1–6–12–17–21	
58	1–7–12–18–20	(2–6–12–18–20)
59	1–7–13–18–20	(2–7–12–18–20)
60	1–7–13–18–21	
61	1–7–13–18–22	
62	2–7–13–18–22	(1–8–13–18–22)
		(2–8–14–19–20)
63	1–8–12–18–24	(2–7–12–18–24)
64	2–8–13–18–23	(2–8–14–18–22)[1]
65	2–7–14–20–22	(2–8–14–19–22)
66	3–8–14–19–22	
67	3–8–14–19–23	(3–9–14–19–22)
68	3–10–14–19–22	(4–9–14–19–22)
69	3–10–14–20–22	
70	4–9–15–20–22	

34	1–6–12–15	71	4–10–15–20–22
35	1–6–12–16	72	4–10–16–20–22
36	1–7–12–16[1]	73	4–10–16–20–23 (5–10–16–20–22)[1]
37	1–7–13–16	74	4–11–16–21–22 (4–10–16–20–24)[1]
38	1–7–13–17	75	5–10–16–20–24

The table in Fig. 5 contains the first five series of Mendeléeff's table, showing the experimental groups corresponding to each element.

Series	O R	I RH R_2O	II RH_2 RO	III RH_3 R_2O_3	IV RH_4 RO_2	V RH_3 R_2O_5	VI RH_2 RO_3	VII RH R_2O_7	VIII — RO_4		
1		1 H									
2	4 He	1–6 Li	2–7 Gl	3–8 B	4–8 C	5–9 N	1–5–10 O	1–6–12 F			
3	1–7–12 Ne	1–8–14, 2–8–13 Na	2–8–14 Mg	3–8–16 Al	4–10–14 Si	5–10–16 P	1–5–10–16 S	1–6–12–16 Cl			
4	1–7–12–16, 1–7–13–17 ? A	1–8–12–18 K	2–8–12–18 Ca	3–9–14–18, 3–10–14–18 ? Sc	4–10–16–18 Ti	5–10–16–20 V	1–5–10–16–20 Cr	1–6–12–16–20 Mn	1–7–12–16–20 Fe	1–7–12–18–20 Ni	2–7–12–18–20 Co
5		1–8–12–18–24, 2–7–12–18–24 Cu	2–8–14–19–22, 2–8–14–18–22 ? Zn	3–10–14–20–22 Ga	4–10–16–20–24 Ce	5–10–16–20–24 As	?	?			

Fig. 5.
Mendeléeff's Table with Group Substitutions.

It will at once be noticed that the above are only a chosen few out of all the groups indicated in the experimental list. Let the reader compare the above groups with those which have no corresponding atoms and he will observe that, in the majority of cases, the latter groups are unsymmetrical, and have odd-numbered rings; while a majority of the former groups are symmetrical, and have even numbers of magnets in every ring, except the center group, which we do not consider in either case. For example, there is 5–10–16, which should have a maximum valency of five, and a weight of thirty-one. Every ring, except that of the valency determining center group, is an even number. The element phosphorus, corresponds. A group, 5–10–15, should have a valency of five, and weight thirty. Fifteen is an odd number, and no element corresponds. However, there are several exceptions.

The group which we prefer for argon is 1–7–12–16. This would give an atomic weight of thirty-six, instead of thirty-nine. It is possible that the thirty-eight group, 1–7–13–17, may stand for argon. These

[1] Groups so marked are of weak stability and formed with difficulty in the experiment.

experiments therefore suggest that the atomic weight of argon may be less than thirty-nine.

A further point of interest is, that the group for chlorine, 1–6–12–16, simply adds a ring of 16 to the group of fluorine, which is 1–6–12. This is very suggestive in view of the strong family resemblance of these elements, and seems to experimentally confirm a suggestion first made by Sir J. J. Thomson. The reader may find for himself other such instances by comparing the groups given in the Mendeléeff's table.

In carrying out these experiments, a small jar of eight or ten inches diameter will be found most suitable for the small groups, one to twenty; while the large tank, described, is most suitable for the larger groups. The field strength should be made such that the average distance between needles is nearly equal to their lengths, which may be one and one half to two inches. Care should be taken to avoid drafts of air on the surface, or currents within the body of the liquid. Much patience is required with some of the larger groups. The author has waited as long as three hours for a single group to establish its permanent equilibrium.

These experiments were done in the physical laboratory of Phillip's University (Enid, Oklahoma), through the permission of Professor A. F. Reiter, of that institution. For this and for other assistance and inspiration which he has rendered to me I wish to thank him. I am now engaged, in the physical laboratory of the Rice Institute (Houston, Texas), in the continuation of this work towards the clearance of some exceptional cases, and the investigation of larger groups.