A Kinetic Model of the Electron Atom.

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Modern theories of the structure of an atom assumes one or more electrons in motion in or about a central body or positive nucleus. Probably the experiment which has been the most helpful in giving an idea as to the structure of an atom is the Mayer experiment of the floating needles. (Experiments with Floating and Suspended Magnets, Illustrating the Action of Atomic Forces, the Molecular Structure of Matter, Allotropy, Isomerism, and the Kinetic Theory of Gases. Alfred M. Mayer, Scientific American Supplement, Vol. 5, p. 2045, June 22, 1872.) This, together with the work of J. J. Thomson, has become almost classic. (Phil. Mag., Vol. 7, p. 237, 1904.) The experiment gives an idea of the possible structure of atoms and may account for the periodic variations of the properties of the atoms. Thus one by assuming that an atom of large atomic weight has more electrons than one of small atomic weight, may account for the periodic table. The

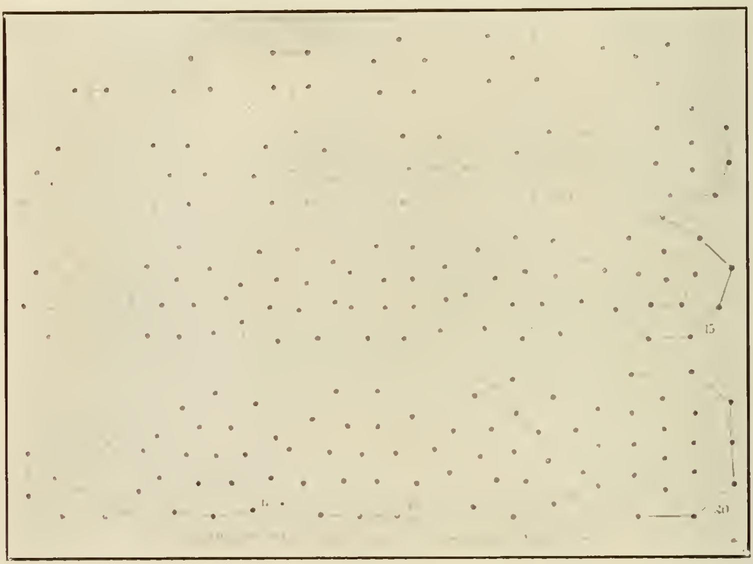

Fig. 1.

periodic variations of the properties of the atoms may be illustrated by the periodic variation of the number of needles in any of the rings, the inside ring, say. This has been done by Lyon. (Phys. Rev., Vol. 3, p. 232, 1914.) Figure 1 is a reproduction of the groupings of the needles taken from Mayer's original article. The following table taken from Thomson's work gives the theoretical groupings of the magnets from one to one hundred. The lower row of figures gives the number of magnets in the inside ring, and the upper row of figures gives the number in the outside ring. The intervening rows give the number in the intervening rings.

TABLE.

Number of Corpuscles in Order.

1	2	3	4	5

5	6	7	8	8	8	9	10	10	10	11
1	1	1	1	2	3	3	3	4	5	5

11	11	11	12	12	12	13	13	13	13	13	14	14	15	15
5	6	7	7	8	8	8	8	9	10	10	10	10	10	11
1	1	1	1	1	2	3	3	3	3	4	4	5	5	5

15	15	15	16	16	16	16	16	16	16	17	17	17	17	17	17	17
11	11	11	11	12	12	12	13	13	13	13	13	13	14	14	15	15
5	6	7	7	7	8	8	8	8	9	9	10	10	10	10	10	11
1	1	1	1	1	1	2	2	3	3	3	3	4	4	5	5	5

17	18	18	18	18	18	19	19	19	19	20	20	20	20	20	20	20	20	20	21	21
15	15	15	15	16	16	16	16	16	16	16	16	16	17	17	17	17	17	17	17	17
11	11	11	11	11	12	12	12	12	13	13	13	13	13	13	13	14	14	15	15	15
5	5	6	7	7	7	7	8	8	8	8	8	9	9	10	10	10	10	10	10	11
1	1	1	1	1	1	1	1	2	2	2	3	3	3	3	4	4	5	5	5	5

21	21	21	21	21	21	21	21	22	22	22	22	22	22	22	22	23	23	23	23	23	23	23	24
17	18	18	18	18	18	19	19	19	19	19	20	20	20	20	20	20	20	20	20	20	21	21	21
15	15	15	15	16	16	16	16	16	16	16	16	16	16	17	17	17	17	17	17	17	17	17	17
11	11	11	11	11	12	12	12	12	12	13	13	13	13	13	13	13	13	14	14	15	15	15	15
5	5	6	7	7	7	7	8	8	8	8	8	8	9	9	10	10	10	10	10	10	10	11	11
1	1	1	1	1	1	1	1	1	2	2	2	3	3	3	3	3	4	4	5	5	5	5	5

24	24	24	24	24	24	24
21	21	21	21	21	21	21
17	18	18	18	18	18	19
15	15	15	15	16	16	16
11	11	11	11	11	12	12
5	5	6	7	7	7	7
1	1	1	1	1	1	1

The object of the present paper is to describe an extension of the Mayer experiment in which the magnets or needles are rotated. In order to understand how the experiment illustrates the structure of an atom it will be well to point out some of the properties of atoms. All atoms have mass and all the atoms of the same element have the same mass. We find that the elements have different atomic weights. Hydrogen has the atomic weight, one; and uranium, the heaviest, has the atomic weight, 238. Thus the mass of the uranium atom is 238 times that of the hydrogen atom.

The atoms of certain elements have the ability to unite with certain other elements to form compounds. Certain elements form the bases and certain others the acid radicals of the compounds. Or certain are said to be electropositive and others are said to be electronegative. If we examine the elements, starting with the lightest, hydrogen, and taking them one by one in order of their atomic weight or mass, we find that this property of combining varies periodically. In this manner we can form the periodic table.

All elements have a definite spectrum. That is, they give off light of a certain wave length. Light is a vibratory motion of the ether. The wave length or frequency depends upon the source. Thus the atoms or something in the atoms must vibrate with certain frequencies. The same as in music, when one hears the note middle C one knows that there is a string, reed, or something vibrating so as to make 261 vibrations per second. In the same manner when one sees the D line of sodium one knows that there must be something in the sodium atom which makes $5. \times 10^{11}$ vibrations per second.

The X-rays are known to be due to a wave disturbance whose wave length is one thousandth that of sodium light. Thus when a swiftly moving electron or cathode ray strikes an atom of platinum there must be a disturbance set up in the atom whose frequency of vibration is one thousand times that which produces the disturbance which we call light.

Besides the radiations or wave disturbances of the ether which are set up by the atom, there are the corpuscular radiations which are given off by the atom, such as in the photo-electric effect, ionization by hot objects and flames, and the cathode rays, in all of which electrons are shot off from the atom.

A theory of atomic structure must account for all of these phenomena. Several theories and modifications have been suggested, all of which involve electrons rotating about or in a central body or region of force which has been called the positive nucleus.

The Mayer experiment with the extension which I propose can be used as an analogy or as an illustration of what happens in an atom. The various phenomena of wave motion and corpuscular radiations can be explained by assuming them to be due to certain motions and disturbances which are seen in the experiment. The experiment lends itself to any or all of the theories as the fundamental assumptions may be changed to fit the particular theory in question.

The classical method of performing the experiment is by floating magnetized needles by means of corks in water. I have found that small bicycle balls floated on mercury are much more convenient. (Professor Merritt used this method at Cornell University in 1900.) The mercury surface lends itself admirably for projection with reflected light. In projection it is well to focus not on the balls but on a plane a short distance above the balls or on the focal point of the concave mirror made by the depression caused by the balls. The position of the ball is then shown on the screen as a point of light. Fig. 5a is a photograph of three balls; the time of exposure is one-fifth of a second. Fig. 5b is a photograph of some thirty balls; the time of exposure is one-hundredth of a second. In this the balls are shown as points so fine that one can scarcely see them in the photograph.

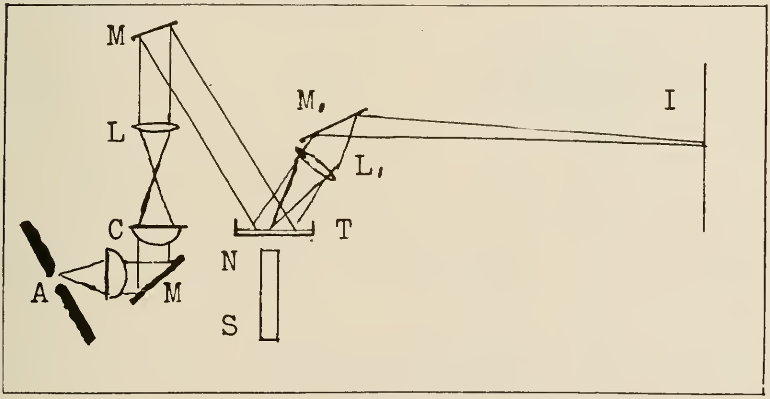

Fig. 2.

Fig. 2 shows diagrammatically the arrangement of the apparatus for projection. A, C, and L are the arc, the condensing lenses, and the objective lense of a vertical projection lantern. M is a mirror with which the light is thrown down on the mercury in the tray, T. L' is a lense with which an image of the balls floating on T is focused on the screen, I. M' is a mirror. N & S is an electro magnet which serves as the positive nucleus.

In the classical Mayer experiment the balls are fixed. There is no motion. There is nothing to suggest how the atom may radiate. The atom is dead. The motion of the atom must be imagined. It is usual to imagine the needles to rotate about the center with a constant angular velocity. This is contrary to the laws of planetary motion as illustrated in the Solar system.

While working with this experiment the thought came to me to rotate the mercury and thus rotate the balls. A wooden tray was made with an electrode at the center and four electrodes, one at each corner which are connected in multiple. By sending a current in at the center electrode and out at the corners one has an approximately radial current flowing at right angles to the magnetic field of the magnet which plays the part of the positive nucleus in the experiment. This causes the mercury to rotate and carry the balls with it. The apparatus consists of a wooden tray as shown in Fig. 3. The dimensions are 15 x 15 cm.

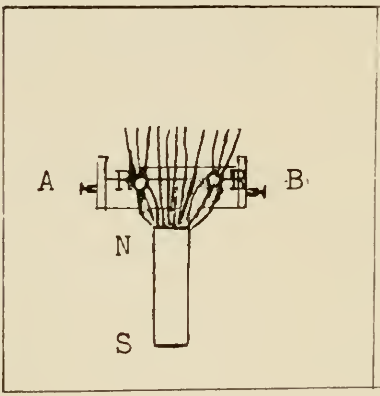

Fig. 4.

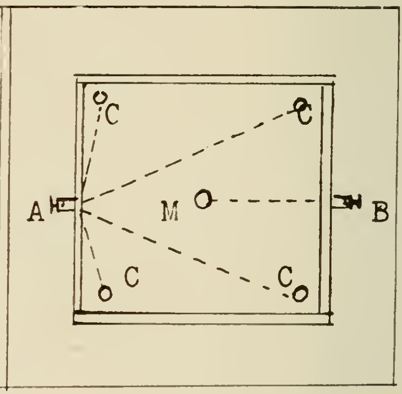

Fig. 3.

and 2 cm. in depth. The electrodes C and M are made of platinum. It has been found later that the electrodes C can be made of iron without appreciably distorting the magnetic field. A and B are binding posts which are connected to the electrodes by wires, shown by dotted lines, which are in grooves on the under side of the box. The apparatus can be centered up by placing one ball on the mercury surface after the current has been turned on through both the magnet and the tray and then shifting the tray until the ball remains practically still at the center of the rotating mercury.

When two balls are placed on the rotating surface they do not rotate about the center on the same circle as one would expect from the Mayer experiment. No. 1 first rotates about No. 2, and then No. 2 rotates about No. 1, their paths resembling rotating elipses. Figs. 5d, 5e, and 5f are photographs showing various phases of the motion. The time of exposure is about one-half a second.

With three balls the motion is more complicated, the three balls taking turns in the center. Figs. 5g, 5h, and 5i give photographs of the motion of three balls. The motion reminds one of a complicated game of leap frog.

With a number of balls the motion becomes very complicated. The mercury at the edges of the tray is stationary while the central portion is rotating. The angular velocity increases as we go from the edge to the center; the balls floating on the surface tend to take up the same angular velocity as the mercury on which they float. Thus there is a tendency for the balls to take up a motion which may approximate to planetary motion. Thus we may assume that they obey Kepler's law. This is shown in Fig. 5j. This photograph also shows two balls exchanging rings.

In the Mayer experiment, balls stationary, when there are a number of rings any one ball is held in its place by the central force and the mutual repulsion of the neighboring balls. The balls of one ring fit into the crotches of the neighboring rings. When the balls are rotating and the angular velocity of the outer ring is less than that of the inner ring there is a slipping of one ring with respect to the one next to it. This slipping produces a perturbation or a vibratory motion which is superimposed on the regular circular motion. This perturbation may be said to be the source of some sort of radiation, light perhaps.

When a ball is allowed to come in from the outside there is a great disturbance of the whole system. This is shown in Fig. 5c, where a ball has been caught coming from the bottom of the photograph into the system. In this case the balls were not rotating. If the balls represent electrons this disturbance may be said to be the source of X-rays as when a cathode ray hits an atom of platinum, say. With a large number of balls the motion is very much more complicated than one would expect. At times a ball will start out from the outer ring and apparently seem to try to escape from the system. Due to the friction of the mercury and the nature of the field the ball always returns. If a ball were to escape it would cause a rearrangement of the others or a disturbance similar to that caused by an added ball. This tendency of the balls to fly off is especially great if the current through the mercury is increased, or if the system is absorbing energy. This may be an illustration of what takes place in the photo-electric effect or in the case of ionization produced by hot bodies.

In the case when a ball flies out when rotating at normal or constant velocity we have an explanation of gamma rays caused by beta rays. Or we may let the balls represent alpha rays, helium atoms, or that

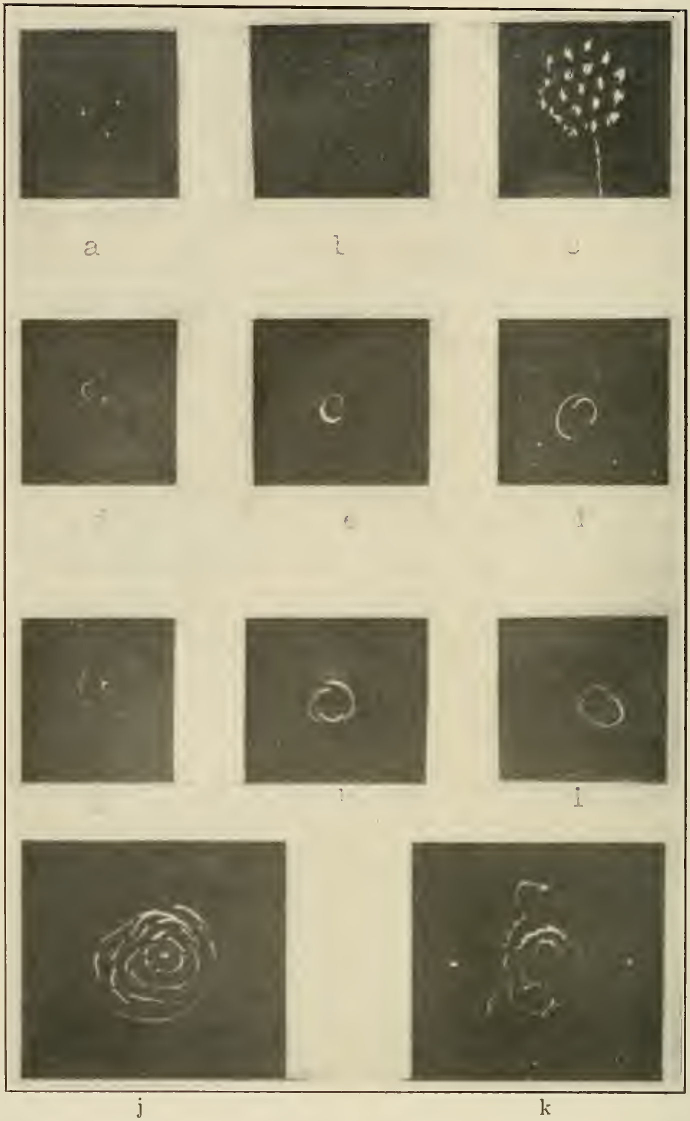

Fig. 5.

which in the atom makes alpha rays or helium atoms after they have escaped, and we have an illustration of a radioactive substance. To illustrate the disintegration of an atom of radium through its several disintegration products I made a tray in which I imbedded a ring of iron so as to make a magnetic field which is strong at the center and diminishes as we go along a radius passing through a minimum and then through a maximum over the ring of iron. Fig. 4 is a cross-section of the tray and central magnet. N, S, is the central magnet. R, R, is a cross-section of the iron ring. A and B are binding posts by which the current is led in and out. The variations of the field is represented by lines of force.

To use this the current is turned on the magnet and a number of balls are placed in the center of the tray, forming the characteristic figure due to the particular number as in the Mayer experiment. The current is then turned through the tray, causing the balls to rotate. When a ball at irregular intervals starts out on a tangent it will be caught and held by the intense field over the iron ring at R. Thus if the ball represents an alpha particle, the escape of beta rays and the gamma radiation may be explained as being due to the disturbance in the atom due to the rearrangement of the electrons in the atom. As many as eight or ten balls may escape from the system, each rearrangement of the system representing one of the products in the radioactive series. Fig. 5k is a photograph of this. The four white spots, one at the top and one at the bottom and one on either side, are balls which have been thrown out and caught and held stationary over the staples which hold the iron ring in place. At the top of the photograph is shown the path of a ball which is being thrown out and caught by the ring.

Getting the conditions right is a matter of trial. Some three or four trays were made before one was satisfactory. The dimensions of this tray are as follows: Length, 10 cm.; breadth, 10 cm.; depth, 2 cm. The iron ring is made of a 2½-millimeter rod bent into a ring of 6 cm. diameter.

No doubt many analogies will occur to the operator which have not been mentioned in this paper. The worst difficulty with the experiment is with the mercury. The mercury must be clean. Any film of dirt or dross on the surface of the mercury prevents the free motion of the balls.

The magnet and tray may be connected in series, but it is more convenient to have two circuits which may be manipulated independently.

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