DISSOCIATION OF ATOMS

by Prof. George F. Fitzgerald

On Friday evening, April 30th, Prof. J.J. Thomson delivered a very interesting discourse on cathode rays. Anything he brings forward as the result of his mature judgment deserves consideration at the hands of the scientific world. In this discourse he expresses his judgment that atoms are divisible into very much smaller parts, and that they are so divided in cathode rays. The greater part of the discourse is a description and illustration of the work of the pioneers in the investigation of cathode rays and of a series of most interesting observations and experiments by himself. The experiments that bear most closely upon the very important pronouncement with which the discourse closes are:—(1) the production of a magnetic spectrum which is independent of the nature of the residual gas in the vacuum tube; and (2) the apparently great penetration power of the cathode rays.

The first of these observations is explained as follows by his hypothesis of corpuscules into which the atoms are dissociated: "We see, too, on this hypothesis, why the magnetic deflection is the same inside the tube whatever be the nature of the gas, for the carriers of the charge are the corpuscules, and these are the same whatever gas be used." Hence the hypothesis put forward is essentially Prout's hypothesis that all kinds of matter are formed of corpuscules, and that all corpuscules are of the same kind. The magnetic *spectrum* is explained by the suggestion that the corpuscular aggregates are not all reduced to their simplest form, and that two or more corpuscules in combination would be deflected to a difficult extent from single corpuscules. This is a very interesting suggestion, but it naturally suggests the difficulty, why the variety of aggregates into which the atoms are decomposed should be independent of the nature of these atoms. One would, *à priori*, expect that different atoms would decompose into different aggregates, unless, of course, they were all entirely decomposed, which Prof. J.J. Thomson cannot hold, as this would destroy his explanation of a spectrum. Perchance he holds that in the dark space, which he shows reason to think does not conduct electricity, the atoms *are* completely dissociated, and that the aggregation that occurs subsequently depends on the electromagnetic character of the field and possibly on the density of the corpuscular shower. This would certainly get over one difficulty, but it lands one in a most important result, namely, that Prof. J.J. Thomson ought to be able to transmute any substance into any other he desired by passing it through the furnace of the cathode rays. If the reaggregation of the corpuscules depends upon electromagnetic and other such conditions which are under control, and not at all on the nature of the atoms that have been disintegrated, it is evident that we are within measurable distance of the dreams of the alchemists, and are in presence of a method of transmuting one substance into another.

Prof. J.J. Thomson does not seem to have tried, whether the nature of the magnetic spectrum depends on the nature of the cathode itself. The cathodes are generally made of aluminum on account of its superiority over platinum in not being carried to the sides of the tube. It seems very improbable that aluminum is absolutely unaffected when used as a cathode, and a very small number of molecules would suffice to carry the cathode spectrum discharge. The blackening of the tube with platinum electrodes is well known, and, *à priori*, it would be natural to attribute the change of the glass under cathode discharges from aluminum electrodes to some effect produced by small quantities of aluminum being carried over. No doubt other very important actions also take place, but when one comes across an effect which is independent of the gas, and has been observed with only one kind of cathode, one very naturally concludes that it may be connected with the nature of this cathode. It would undoubtedly be very desirable to investigate this before concluding that the corpuscular elements of atoms are all alike.

The other basis for the hypothesis is the difficulty of explaining the great penetration power of cathode rays. Lenard, in his extremely beautiful and careful experiments, had shown that all matter is roughly opaque to cathode rays, in proportion to its density. Prof. J.J. Thomson has himself made some very interesting observations on the apparent transmission of cathode rays by brass 1 mm. thick. He attributes this apparent transmission, however, to an electric impulse transmitted through the brass which generates cathode rays on the other side. He seems somewhat doubtful as to the legitimacy of this suggestion, because it requires the electric action to be discontinuous, and specially notes that thin aluminum transmits cathode rays produced by the discharge of a battery, apparently implying that in this case there can be no discontinuity in the action, and, consequently, some other explanation must hold. He does not discuss this question of the possibility of the discharge of the battery being sufficiently rapidly discontinuous to elude our observation of its discontinuity, and at the same time being sufficiently discontinuous to reproduce cathode rays on the far side of a metal plate. Nor does he discuss the possibility that at one side of the plate cathode rays may produce various forms of Röntgen rays which are transmissible by the plate, and are able to reproduce cathode rays of the same kind as those that produced them.

There are other actions of an electric character that may be transmitted by conductors and non-conductors from particle to particle in the direction of the electric force, and which would differ entirely from ordinary electric conduction, being more of the nature of electric vection, where the rapidity of action was great compared with that of the redistribution of directed actions by the irregular impacts of molecules in matter. This whole question of the transmission of actions through and by a gas, for instance, when the rapidity of action is great compared with that of equalisation of pressure round a point by the irregular impacts, is one that deserves careful investigation. Without some such investigation it is hardly safe to conclude that an action which is certainly a mixed action of matter and ether (in which the ether actions are transmitted with a velocity incomparably greater than that of the matter actions) would or would not be competent to do certain things, such as transmitting the power of generating cathode rays through 1mm. of brass. There is no doubt at all that the molecular bombardment on one side of the brass is essentially discontinuous even when a battery is producing cathode rays, and there is too little known about the inner nature of conduction and the transference of electricity from one atom of matter to another for us to be at all sure that each molecular impact of a charged atom on one side of a brass plate may not produce a corresponding emission of a cathode ray on the other side. There seems anyway no sufficient reason for dividing the transmissibility of cathode rays into two kinds, and considering the transmissibility through a gas as in any way different from that through a solid. There can hardly be any doubt that Lenard is right in his contention that gases are far too transparent for the hypothesis that cathode rays are simply projected molecules to account for the phenomena. At the same time it would require a very full discussion of the effect of increased velocity in diminishing the effective size of atoms to be quite sure of what would happen. If we take two bodies as colliding when they come so close that their paths are deflected, say 10deg., it is quite evident that they must approach more closely in order to in this sense collide when their relative velocity is large than when it is small. The variation is enormous if the law of force be the inverse square of the distance, and charged atoms may act according to this law. If so it seems at least possible that the effective size of these rapidly moving charged atoms, both as regards one another and as regards the residual gas, may be different from that of the ordinary molecules that constitute the gas. It may also be that the laws of impacts of spheres do not apply even approximately to the actions of molecules polarised by an electric force. The action may be transmitted from molecule to molecule, not by any impact, but by the advent of a charged atom enabling one of the constituents of the molecule it is approaching to obey the electric force and dart off in the line or nearly the line of the approaching one. This would account for actions being transmitted long distances in straight lines.

An hypothesis seems also possible on the lines of Grotthus, chains being formed under the action of the cathode rays or under the action of Röntgen rays due to the impacts of cathode rays on the molecules. In fact, there seems an *embarras de richesse* in the way of possible explanations of the transparency of media to cathode rays without supposing that we are in presence of a possible method of transmutation of matter. This latter is by far the most interesting hypothesis, and it is very much to be hoped that Prof. J.J. Thomson's hypothesis is true.

As regards the calculation of the ratio of the numerical measure of the mass of the corpuscule to the electric charge it carries, there are two suggestions that can be made in respect of it. The first is that we are dealing with free electrons in these cathode rays. This is somewhat like Prof. J.J. Thomson's hypothesis, except that it does not assume the electron to be a constituent part of an atom, nor that we are dissociating atoms, nor consequently that we are on the track of the alchemists. There seems every reason to suppose that electrons can be transferred from atom to atom without at all destroying or indeed sensibly changing the characteristic properties of the atom: that in fact there is a considerable analogy between a charged sphere and an atom with an electron charge. If this be so, the question of course arises, how far can an electron jump in going from atom to atom? Why not the length of a cathode, say, or at least from molecule to molecule along it, or anyway in nearly straight lines along it? In this case, the mass calculated may be the effective mass of the electron, and that will depend on its size as an electric charge, and, as Dr. Lodge has pointed out, in the corresponding case of Zeemann's observation the resultant size is quite feasible. If it be so we should have this further interesting result. We can calculate how much nearer the electrons must be in 2HC1 than in HH and ClCl if the heat of combination be due to this approach. This gives a maximum size for an electron if they preserve their individuality. Knowing the size of the electrons, *and assuming it to stay constant*, we could calculate what the change in the effective inertia of the electrons must be, due to their being nearer together in 2HCl than in H_2 + Cl_2. This would give us a possible reason why the mass of matter may change when it changes its chemical constitution. I have not had time to worry out the calculation, but it is evident that the change in effective inertia would be a very small part of the total inertia of the matter: yet it may be within our powers of measurement. If there is no change, then either the size of the electrons changes in such a way as to compensate exactly for their approach, a very likely contingency, or else the inertia we are dealing with is not the effective inertia of electrons.

The other suggestion is that Prof. J.J. Thomson is quite wrong in assuming that nearly all the bombarding molecules give up charges to the cylinder, or what comes to much the same thing, that he is wrong in thinking that all the charges stuck there, and that only a few of them escape into the surrounding gas. Suppose that only a thousandth part of the molecules entering the cylinder gave up charges to it, and that the rest were either uncharged or were driven out by the entering ones, and accumulated near the anode to which they quietly gave up their charges, then the energy of these 999 would be attributed to the few that give up their charges, and this naturally leads to an abnormally small mass and an extraordinarily great velocity for these molecules. The velocity that Prof. J.J. Thomson now attributes to the corpuscules in cathode rays is 1.5×10^9 cm. per second, which is only one-twentieth of that of light, a velocity that would penetrate anything, and is enormously greater than what his own direct observations of cathode rays give. This latter, when introduced into the equation—

$$\frac{m}{e}v = \mathrm{I}.$$

gives values for m corresponding approximately to that usually received for the mass of an atom. Hence this recent investigation coupled with his former one would lead to the conclusion that only a small part of the projected atoms give up their charge to the cylinder, either because they take it out again with themselves, or because only a small proportion of the bombarding atoms are charged. In any case, there does not seem much necessary connection between these experiments and the case Zeemann investigates. In this latter case it would seem *most* improbable that the moving electric charge that originates the light vibrations should carry the whole atom along with it in its incursions. It would seem much more likely that an extremely minute deformation of the atom would accompany the incursions of the charge, so that Zeemann's result is what one would naturally expect, and the only remarkable thing about it seems to me to be that such a large proportion of the matter accompanies the ether incursions. In his case it may quite possibly be that the inertia is that of the electron and not of the matter at all.

In conclusion, I may express a hope that Prof. J.J. Thomson is quite right in his by no means impossible hypothesis. It would be the beginning of great advances in science, and the results it would be likely to lead to in the near future might easily eclipse most of the other great discoveries of the nineteenth century, and be a magnificent scientific contribution to this Jubilee year.