THE STRUCTURE OF THE ATOM.

THE earliest developments of the electronic theory led necessarily to the conclusion that in every atom in its normal condition there were contained electrons which could be detached from it by suitable agencies; these electrons were the same in respect of the only two properties attributed to them, charge and mass, whatever the atom in which they were contained. This conception of a constituent common to all atoms indicated for the first time the possibility of explaining the relationships described by the periodic law between the properties of different atoms; if similar atomic properties represent similar numbers or arrangements of electrons, any theory which would make these numbers or arrangements periodic functions of the atomic mass would explain in some measure those relationships.

The first attempt to frame such a theory was made by Sir J. J. Thomson; the structure which he proposed for the atom is so generally known that it may be described here with great brevity. Since an atom in its normal condition is electrically neutral, it is necessary, if the principles of electrostatics be accepted, that it should contain a positively charged portion, the total charge on which is equal and opposite to that of the electrons contained in the atom. Until recently there was no evidence whatsoever as to the form of this positively charged portion; accordingly, Thomson adopted provisionally the form most convenient for his purpose; he supposed that the positive charge was distributed uniformly over throughout a sphere, the radius of which was taken to be the same for all atoms. In addition, he assumed that the number of electrons in an atom increases regularly with the atomic mass.

The mathematical problem of determining the distribution of N electrons within such a uniformly charged positive sphere is capable of partial solution whatever the magnitude of N. It can be shown that certain distributions are in equilibrium, but it cannot generally be shown that it is only these distributions that are in equilibrium, nor can it be shown generally that the equilibrium is stable. The problem of calculating from Thomson's assumption the structure of an atom is therefore not completely determinate; but if it be assumed that the distributions which can be calculated are unique and that they are stable, certain conclusions can be reached. If almost any other assumption concerning the distribution of the positive charge on the atom is made, even this small amount of progress is impossible. Thomson showed that the distributions which could be calculated were those in which the elecrons were arranged in circular rings, and that the number of electrons in any ring (*e.g.*, the outermost or the innermost) was a periodic function of N, and therefore of the atomic mass.

Before any theory of this kind can be regarded as complete, it must be shown that certain distributions of electrons are connected with certain properties of the atoms containing them, and it must be shown that the same distribution of electrons is connected with the many different properties which are found to be associated in similar elements. It must be shown, for example, that a certain distribution (which is to be identified with an atom of the alkali metals) is necessarily connected with electro-positive chemical characteristics, metallic conductivity, a special type of spectral series, and so on. It is necessary that the theory should explain the relation between different properties of the same element as well as that between the same property of different elements. Thomson endeavoured to correlate certain chemical properties with certain electronic distributions by showing that some of these would be likely to lose electrons, leaving the atom positively charged, while others would be likely to gain them; a difference in the tendency to lose electrons would probably lead to a difference in respect of metallic conductivity. But in no case could any observed atomic property be calculated with quantitative agreement from one of the supposed electronic distributions. The failure was especially important in the case of spectra, for the frequency of the vibration of the electrons could be definitely calculated in some cases, and it appeared that the relation between the frequencies of different vibrations in the same atom was not at all of the same form as that indicated by the known spectral series.

However, there was no definite evidence for disbelieving the assumptions underlying Thomson's theory until investigations were made on the scattering of α and β rays. These rays consist of charged particles which can certainly pass through atoms, and it is to be expected that in their passage they should be deflected by forces exerted between them and the electrons or the positive charge in the atom; by examining these deflections some indications as to the number of the electrons and the nature of the positive charge may be obtained. Rutherford and Geiger showed that the experimental results were quite irreconcilable with Thomson's theory, but that they were reconcilable with the view that the positive charge in the atom is concentrated on a single particle, like the electron of dimensions infinitesimal compared with the "radius of the atom"; the number of electrons in an atom must be taken as about half the number representing the atomic weight, the total charge on the "positive nucleus" being, of course, equal and opposite to that on all the electrons.[1]

The assumption that the whole positive charge on an atom is concentrated on a single positive particle had previously been suggested by Nagaoka, but it presents very great difficulties; for it is quite certain that, if the principles of mechanics and electrostatics are true, no collection of electrons round a positive nucleus can possibly be stable, unless all the electrons fall into the nucleus forming a single infinitesimal neutral particle. It has recently been proposed to

[1] Thomson had already advanced several lines of argument indicating that the number of electrons in an atom was not very different from its atomic weight, referred to that of hydrogen as unity.

solve this difficulty by denying that the principles of mechanics are true in their application to systems of atomic dimensions. Such a solution may appear heroic rather than practical to those who have not followed the trend of modern physics; those who have know that it is completely in accordance with the recent development of our ideas. The new conceptions which were first introduced by Planck's theory of radiation, and have been applied with such striking results to the theory of specific heats and elasticity, are directly contradictory of those of the older mechanics. They involve the recognition of a new "universal constant" (usually denoted by the symbol h), which, like the charge and the mass of the electron, is characteristic of all forms of matter. The source of many of the difficulties connected with the theory of a "positive nucleus" is that such a theory does not introduce sufficient quantities to determine an atomic structure; it introduces only the charge and mass of an electron, and from such quantities neither a length (such as the distance apart of the electrons) or an energy can be deduced. Thomson's theory rejects the "positive nucleus" and introduces another quantity, the radius of the atom, but there is no reason to believe that it is a "universal constant." The newer theories accept the "positive nucleus" and introduce the "universal constant" h in place of the radius of the atom.

Of these theories, that of Bohr is the most definite. This is not the place to describe the precise assumptions made by this theory; it is sufficient to say that they are simple, plausible, and easily amenable to mathematical treatment; from them all the properties of any atomic system which does not contain more than one electron can be deduced uniquely.[2] There are probably only two such atomic systems experimentally realisable, the neutral hydrogen atom and the helium atom, bearing a single positive charge. Bohr has calculated the spectra of these systems and obtained results which are in exact quantitative agreement with observation; in respect of other properties, the agreement between calculation and experiment is as close as can be expected in view of the doubts connected with the exact connection between these properties and a distribution of electrons. The properties of more complex atoms cannot be calculated with certainty, owing to the mathematical difficulties involved. Indeed, theories of atomic structure will probably never be very interesting to chemists, for our powers of explaining in detail the properties of systems so complex as the heavier atoms must be are closely limited by the powers of mathematical analysis.

Bohr's theory explains more than any previous or rival theory, but it does not explain everything. It introduces many novel assumptions, of which some are quite dubitable, and may have to be abandoned. Its great interest lies rather in the nature of the ideas which it introduces than in the exact explanation of atomic properties to which it leads. It not only rejects the principles of mechanics, which the most conservative are being slowly driven to abandon, but it indicates that fundamental propositions are to take their place. To attempt to explain Bohr's theory in terms of those principles is useless: it is impossible to explain why certain propositions are not true by assuming that they are true. There are only two alternatives open to the modern theoretical physicist: he may either suppose that the principles of the older mechanics are true, and that all the brilliant results which have followed from the application of the conceptions of Planck and Einstein to the most diverse phenomena are illusory and devoid of evidential value; or he may suppose that they are not true. Bohr's theory offers him the choice in its most striking form. NORMAN CAMPBELL.

[2] One of the assumptions originally proposed by Van den Broek is especially interesting. It is that the number of electrons in an atom in its uncharged state is equal to that representing its position in the series of elements arranged in order of their atomic weights. Thus hydrogen has 1 electron, helium 2, lithium 3, and so on. This simple assumption leads to the result that the number of electrons is about half the atomic weight, and, of course, it gives a simple reason for that relation.

THE AUSTRALIAN MEETING OF THE BRITISH ASSOCIATION.

THE eighty-fourth meeting of the British Association will be opened in Adelaide on August 8, 1914, under the presidency of Prof. W. Bateson, F.R.S. On four previous occasions the association has met outside the British Isles; three times in Canada, and once in South Africa. Now, for the first time, a visit is to be made to the most distant portion of the Empire.

The invitation was conveyed at the Sheffield meeting in 1910 by the Australian High Commissioner and Prof. Orme Masson, F.R.S., acting on behalf of the Commonwealth Government. Since then arrangements have been proceeding for the fitting reception in the various Australian States of a considerable body of visitors from Britain. The sum of 15,000*l.* has been set aside by the Federal Parliament to defray the ocean passages of at least 150 members; in addition, the Government has undertaken the issue of a large handbook of permanent scientific value which will contain contributions by Mr. G. H. Knibbs, C.M.G., Hon. T. Pearce, M.P., Profs. Baldwin Spencer, F.R.S., Edgeworth David, F.R.S., Harrison Moore, and many others. The State Governments are giving active support in granting railway facilities, issuing handbooks supplementary to the larger Federal work, and in making direct contributions to the local expenses of the meeting; whilst, of course, every university is most heartily adding its full assistance.

Official meetings will be held in Adelaide (for four days), Melbourne (seven days), Sydney (seven days), and Brisbane (four days), extending from August 8 until September 1, but the ordinary proceedings of sections will take place in Sydney and Melbourne only, three sessions being held in each city. Western Australia is not included in the itinerary of the main body of visiting members, but special arrangements are being made for an advance party of seventy to visit that State between July 28 and August 4. This party will be