forces acting on an electron due to a beta particle at this close range will greatly exceed the restoring forces due to the other electrons in the atom which for weaker fields may make the atom diamagnetic. In fact, there is no reason for supposing that the effective susceptibility of the medium when subjected to such highly intense magnetic pulses of very short duration has any intimate relation to its susceptibility in steady and comparatively weak fields. It seems rather that the problem must be treated as a statistical one of encounters of a rapidly moving, electrically charged, magnetic doublet with a random distribution of similar doublets at rest. A preliminary investigation of this problem indicates, however, that the average motion of the beta ray should be rather similar to its motion when passing through a medium of uniform susceptibility. The above numerical discussion is therefore of value as showing that it is not unreasonable to expect a magnetic particle to induce in the surrounding medium a magnetization of the magnitude required to account for the observed helical paths.

If the obvious explanation of these spiral tracks is the correct one, their interpretation yields very valuable results. We have seen that the beta ray seems to act as a tiny gyroscope with a magnetic moment, which is capable of giving rise to torques on other electrons of a duration corresponding to the frequency of X-rays. The reaction, according to classical dynamics, must result in mutational oscillations of the spinning beta particle. This obviously supplies a mechanism for the production of high frequency radiation by a free electron, which has been suggested by Webster to account for Doppler effects at the target of an X-ray tube. The possibility that the electrons are magnetic doublets is also of great importance in connexion with our ideas of the structure of the atom and the nature of chemical combination.

Cavendish Laboratory,
Cambridge University.
August 16, 1920.

XXIV. *The Constitution of Atoms.* By Professor Orme Masson, *F.R.S., University of Melbourne* *.

Professor Orme Masson, F.R.S., University of Melbourne

SINCE it must now be conceded that all material atoms are compounded of positive and negative electrical atoms, it is surely time that each of these fundamental and universal constituents were known by some distinctive name. This compliment has been paid to the one, but not,

* Communicated by Professor Sir E. Rutherford, F.R.S.

as yet, to the other. For convenience of reference and notation, if for nothing else, it is just as necessary to have a name for positive electrical atoms as for the electrons.

Though the hydrogen nucleus has been identified with the positive particle, it would not be well to adopt a name specially indicative of the fact; for hydrogen has no monopoly in these particles, which are also present in the nucleus of every other atom. Moreover, the electron is just as essential a constituent of hydrogen itself, though not of its nucleus, as is the positive particle.

The outstanding characteristic of the electrons is that they mainly determine the electro-chemical characters of the atom; so they are well named. The outstanding characteristic of the positive particles is that they mainly determine the mass of the atom. I therefore suggest that they should be called *barons* (βάρος, weight)*.

If this name be adopted, we can conveniently symbolize the baron as b, using e for the electron. We thus have, in what follows,

$$b = \text{one baron} \quad (\text{charge} +1, \text{mass } 1),$$
$$e = \text{one electron} \quad (\text{charge} -1, \text{mass negligible}).$$

A may stand for the mass of any elementary atom with the atomic number N.

* *Footnote by Professor Rutherford*:—

At the time of writing this paper in Australia, Professor Orme Masson was not aware that the name "proton" had already been suggested as a suitable name for the unit of mass nearly 1, in terms of oxygen 16, that appears to enter into the nuclear structure of atoms. The question of a suitable name for this unit was discussed at an informal meeting of a number of members of Section A of the British Association at Cardiff this year. The name "baron" suggested by Professor Masson was mentioned, but was considered unsuitable on account of the existing variety of meanings. Finally the name "proton" met with general approval, particularly as it suggests the original term "protyle" given by Prout in his well-known hypothesis that all atoms are built up of hydrogen. The need of a special name for the nuclear unit of mass 1 was drawn attention to by Sir Oliver Lodge at the Sectional meeting, and the writer then suggested the name "proton."

Professor Orme Masson sent the present paper for publication through the writer, and in order to avoid the long delay involved in correspondence, his paper is printed in its original form. If the name "proton" is generally approved, it is merely necessary to change the symbol "b" into "p" in the chemical equations given in the paper.

It should be pointed out that a somewhat similar type of nomenclature for the constituents of atoms has been suggested in the interesting paper of Professor W. D. Harkins, entitled "The Nuclei of Atoms and the New Periodic System" (Phys. Review, xv. p. 73, 1920).

The inference from radioactivity work, that most of our elements are not "pure" but consist of mixtures of isotopes, and that the A value of any pure element, or single isotope, is appreciably integral (O = 16 being taken as standard) has been splendidly confirmed by Aston's recent work. Of the eighteen elements already examined by his mass-spectrum method, only hydrogen gives an atomic weight (1·008), which is not integral to within one in a thousand. The cause of this exception requires further investigation, but in the meantime it may be set aside as related in some way (as suggested by Aston) to the fact that hydrogen is unique in containing no electrons in its nucleus.

It is unique also in other ways, and especially in the value of the ratio A/N, which in H is 1 and in no other atom is less than 2 (nor more than 2·6).

If we write $A-2N=n$, we find from Aston's work that $n=0$ in pure elements, He, C, N, O, S, and also in the lower isotopes of B, Ne, Si, and Ar. There can be no doubt that this also holds for the lower isotopes of Li, Mg, Ca, and, perhaps, some of the other light atoms. It follows, therefore, that the group (b_2e) may be regarded as a secondary unit of positive charge, with mass 2, and that $(b_2e)_N$ expresses the composition of the nucleus of any of those atoms.

In the higher isotopes of B, Ne, Si and Ar, in the pure elements F and P, and in both the isotopes of Cl, n has small values, ranging from 1 to 4; in As it is 9, in the two Br isotopes it is 9 and 11, and in the six isotopes of Kr it ranges between 6 and 14. The values are higher still in Xe (20 to 27); and in Hg it apparently ranges between 37 and 44. The numerous isotopes of elements with N values from 81 to 92, contained in the three radioactive series, have all n values from 42 to 54. There is thus a general tendency for n to increase with N, modified by the fact that it may vary considerably among isotopes with the same N.

If the b_2e group be still taken as the unit of positive charge, there must be added to it in most cases n electrically neutral couplets (be), each having unit mass. We thus can express the nuclei of all atoms from He to U by the general formula $(b_2e)_N(be)_n$, n having any integral value from 0 to 54; and even the unique case of H is included if n be given the special value of -1.

If we distinguish the nucleus from the shell electrons by enclosing the former within square brackets, $[(b_2e)_N(be)_n]e_N$ becomes the perfectly general formula for any electrically neutral atom, while positively or negatively charged ions are similarly indicated with the appropriate decrease in the number of electrons in the shell.

We can now express in general terms (which, of course, may be made specific by substitution of the proper numbers for N and n) any action that occurs within the nucleus. Thus an α-ray change depends on the intranuclear action $2(b_2e) = (b_2e)_2^{\nearrow}$ and is expressed by the sub-chemical equation

$$[(b_2e)_N(be)_n]e_N = [(b_2e)_{N-2}(be)_n]e_N + (b_2e)_2^{\nearrow}$$

where $(b_2e)_2$ is the expelled He nucleus and the other product is the ion of the new element, carrying a double negative charge till, by discharge, it becomes the atom $[(b_2e)_{N-2}(be)_n]e_{N-2}$. This clearly expresses the characteristics of α-ray action—that the atomic number is lowered by 2 and the mass by 4, to which may be added the statement that there is no change in the number of neutral couplets (n). A β-ray change, on the other hand, depends on another intranuclear action, $2(be) = (b_2e) + e^{\nearrow}$, thus subtracting 2 from n and adding 1 to N, while the mass is unchanged and the main product is the single charged positive ion of an isobare. In full, the equation is

$$[(b_2e)_N(be)_n]e_N = [(b_2e)_{N+1}(be)_{n-2}]e_N + e^{\nearrow},$$

The results obtained by Sir E. Rutherford by the bombardment of light atoms with swift α-particles can be expressed similarly. Thus the expulsion of a particle with the mass 3 and a charge of $+2$ (the nucleus of a lower isotope of helium) can obviously be attributed to the change $2(b_2e) = (b_3e)^{\nearrow} + (be)$, while the expulsion of a hydrogen nucleus (a single baron) results from the action $(b_2e) = b^{\nearrow} + (be)$. Sir E. Rutherford has shown that the nitrogen atom gives both these particles, apparently by actions which occur independently. The equations for them are

$$[(b_2e)_7]e_7 = [(b_2e)_5(be)]e_7 + (b_3e)^{\nearrow},$$

and

$$[(b_2e)_7]e_7 = [b_2e)_6(be)]e_7 + b\,.$$

In the first case the main product is the double charged negative ion of Aston's higher isotope of boron. In the second case it is the single charged negative ion of a previously unknown isotope of carbon.

The suggested notation * does not indicate any reason why nitrogen atoms should emit both b_3e and b ions under α-ray bombardment, while oxygen atoms emit b_3e but no b ions. Sir E. Rutherford seems inclined to infer that barons exist, as such, in the nitrogen nucleus and not in that of oxygen, just as it has been usual to take the emission of α-rays as evidence that the radioactive atoms contain helium nuclei as such. Of course it may be so, but the inference may not be justified. A similar inference, long ago proved incorrect, is embalmed in the term carbohydrate. The sugar molecules do not contain water molecules as such, though they do, under certain conditions, emit water molecules and leave a residue of carbon.

It need hardly be said that no claim is made that the formulæ suggested in this paper express the atomic constitutions in the full sense of the term. There are really as yet no data to justify such an attempt, so far at least as the nuclear part of the atom is concerned. They do, however, express correctly the nuclear charge (N) and mass $(2N+n)$ and the shell charge, whether of atoms or of ions; they locate the difference between isotopes in the numerical value of n (and there is no other difference); and they serve to correlate the whole system of atoms and their proved processes of disintegration by means of a comparatively simple notation, which may be employed to illustrate either general rules or special instances.

If the chart of radioactive transformations, as given by Soddy (J. C. S. Jan. 1919, p. 16) be re-drawn, making the N scale horizontal and the A scale vertical and one unit of the former equal in length to two units of the latter, the n values of all the atoms can be read off on a scale drawn diagonally from N.E. to S.W. across the centre of the chart. A succession of α-ray changes is thus marked by arrows running along a line of equal n, pointing from S.E. to N.W., and such lines of equal n may pass through the symbols of atoms belonging to the same or different series, just as do the vertical isotopic lines or the horizontal isobaric lines.

The Universitv of Melbourne,
8th October, 1920.

* It may be pointed out here that the (b_3e) particle, isotopic with the He nucleus, may be formulated as $[b_2e)_2(be)_{-1}]$, just as the baron may be writen $[(b_2e)(be)_{-1}]$. These formulæ are, of course, merely a repetition of the equations already given for intranuclear changes by which the particles are generated; but the negative value of n serves to classify them together and apart from other ions. H is no longer quite unique in this respect.