of the cylinder and its contents. An infinitesimal proportion of the radiation will be condensed, and the pressure will fall to the equilibrium value, $p-dp$, corresponding to the temperature $T-dT$. There is no change of frequency since the volume is not altered. Complete the cycle by condensing the volume v at $T-dT$, and heating the cylinder to its original temperature. The cycle is reversible, and the infinitesimal CdT may be made as small as we please in comparison with $E+pv$. The external work done in the cycle is $v(dp/dT)dT$, and is equal to the fraction dT/T of the heat absorbed, $E+pv$. Whence $E/v=T(dp/dT)-p$.

I cannot see any escape from this conclusion so long as Carnot's principle is accepted for the definition of the absolute scale of temperature. Still less is there any escape from the conclusion, depending only on the first law, that the quantity measured experimentally is $E/v+p$, and not E/v, as generally assumed. Both conclusions are inconsistent with much of Wien's reasoning, but I have shown that they are not inconsistent with his displacement law. My formula satisfies all three conditions, makes the entropy of the distribution a maximum, and the thermodynamic potential the same for each frequency.

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Atomic Models and X-Ray Spectra.

I AM unable to agree with Sir Oliver Lodge (NATURE, January 29, p. 609) that the impossibility of the existence of two coplanar rings of electrons with the same angular velocity is self-evident, though it is proved very simply. For the mutual repulsions of the electrons in different rings are complicated, and their effect on any ring varies very much with the number of electrons. I think the amount of proof given in my letter is necessary, especially since, in discussions of two rings, inequality of angular velocity has not often been mentioned.

Although my illustrative case concerns rings with the same angular velocity, the greater part of the letter relates to rings with different angular velocities, as, of course, in Bohr's theory, the angular momenta of the electrons are equal, thus precluding identity of angular velocity in any two coplanar rings. It must be borne in mind that the portion of Bohr's theory which deals with coplanar rings is admittedly more tentative than that relating to spectra. The point of my letter was that this part of the theory needs modification; and, of course, it is not essential to the other. The variations from circular orbits may be shown to be cumulative, when the orbits are coplanar, and, in fact, it is possible to prove the non-existence of approximately circular orbits from considerations of angular momentum alone, and as this investigation will be published in detail shortly, there is no necessity to enter further upon it now. But, in particular, the nearest possible approximation to a circular orbit for the two inner electrons of Bohr's lithium atom makes their distances from the nucleus in the ratio 12 to 1 for certain positions.

In fact, the only possible arrangement of three electrons with equal angular momenta, in which the orbits are circular, requires all to be in the same circle, and such an atom can be shown by Bohr's method to be as inert as helium. Lithium therefore cannot have a nucleus of strength $3e$, and we cannot retain both Bohr's theory and van den Broek's hypothesis. One at least must be abandoned, and the latter must certainly, for lithium, beryllium, and boron, all of which can be treated very simply on theoretical grounds.

An important argument can be derived from astrophysics. These three elements are, so far as can be judged, practically unknown in celestial spectra, where hydrogen and helium are strong. This seems to imply no great similarity in constitution.

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IN the recent discussion in NATURE on the constitution of the atom, attention has been directed mainly to the electrostatic forces exerted by the positively charged portion of the atom. Prof. Nicholson has been successful in calculating the frequencies of the lines in the nebular and coronal spectra on this basis by employing Rutherford's model atom consisting of a central nucleus surrounded by a ring (or rings) of electrons. Bohr's theory, though not dependent on the usual dynamical laws, involves the calculation by ordinary mechanics of the steady motion of the electron in the electrostatic field of the positive nucleus. In the case of a *simple* nucleus this procedure leads to results as to the frequencies that agree with observation. It may, however, be necessary to suppose, at least in the case of the heavier atoms, that the nucleus produces not only an electrostatic but also a magnetic field. Such a view has recently been developed by Prof. Conway using the atomic model of Sir J. J. Thomson. If we adopt Rutherford's model the expulsion of α and β particles from radio-active substances with large velocities may indicate that the particles possess these velocities *within the nucleus*. If they are in orbital motion a magnetic field would exist outside the nucleus.[1] This hypothesis may be associated with the theory of the Zeeman effect put forward by Ritz, and also with the theories of magnetic action developed by Langevin and by Weiss. According to the latter, there exists an elementary magnet, the *magneton*, which is common to the atom of a large number of different substances.

Prof. Nicholson regards Planck's universal constant h as an angular momentum. According to Bohr's theory the angular momentum of an electron is constant and is $h/2\pi$. Prof. Conway, using a different model, obtains the value h/π. Prof. McLaren identifies the natural unit of angular momentum with the angular momentum of the magneton. It has been pointed out (*Phys. Zeitsch.*, vol. xii., p. 952, 1911) that Planck's constant may be connected with the magnetic moment of the magneton. Suppose that an electron (charge e, mass m) is moving in a circular orbit (radius a) with angular velocity ω. Then its angular momentum is $ma^2\omega$, and the magnetic moment of the equivalent simple magnet is $\frac{1}{2}ea^2\omega$. Thus the magnetic moment is equal to some constant multiplied by he/m. Taking (for illustration only) Bohr's value for the angular momentum, we obtain as the magnetic moment 92×10^{-22} E.M.U. The magnetic moment of the magneton, as given by Weiss, is a quantity of about the same order of magnitude, viz. $15{\cdot}94\times10^{-22}$.

My chief object is to direct attention to the work of Prof. Carl Størmer, of Christiania, on the path of an electron in the magnetic field of an elementary magnet. It would be of great interest if it should prove that his results, originally obtained in connection with cosmical problems, are applicable within the atom. In addition to computing the trajectories corresponding to different circumstances of projection in the field of an elementary magnet, he has investigated the corresponding problem when the electron is also under the action of a central force varying inversely as the square of the distance from the centre of the magnet (*Videnskabs-Selskabets Skrifter*, 1907, Chris-

[1] This view necessitates a larger estimate for the diameter of a complex nucleus than that at present accepted.