independently of any supposition or condition of shape and density of the shot, provided the spin imparted by the rifling is suitable, and that the trajectory is not curved too much. A. G. GREENHILL.

The Atomic Weight of Nickel.

IN a paper on the absorption of Röntgen rays (*Journal de Physique*, p. 653, 1901) M. Benoist shows the connection between the transparency to X-rays of elementary substances and the atomic weight of those substances by means of a curve, which in general exhibits a fall of transparency with a rise in the atomic weight of the absorbing substance. In continuing investigations on secondary X-rays, Mr. C. A. Sadler and I have found that by replacing Benoist's primary beam by secondary beams from different substances, curves are obtained similar to that got by using a beam direct from an X-ray tube, except in the region of atomic weights near to that of the radiator. In those regions a strongly marked deviation occurs, showing a special transparency to the secondary radiation from a substance, by a sheet of the same substance, and a less strongly marked abnormal transparency of those substances with atomic weights differing little from that of the radiator. Also the nearer on the same side the atomic weight of the absorbing substance is to that of the radiator, the greater is the deviation from the normal transparency. This effect does not indicate that the secondary rays as emitted by the atoms of a substance are specially penetrating, but simply that in emerging from the interior atoms to the surface a selective absorption has occurred, leaving the remainder specially penetrating to further layers of the same substance and to a less extent to substances of neighbouring atomic weights. This is not a property of secondary rays alone, for experiments on primary beams which have passed through thin sheets of metal show the same effect.

In making such experiments on a number of metals it was found that the radiation from nickel was much more abnormally penetrating to copper than to iron, indicating a proximity of atomic weight to that of copper. On the other hand, when cobalt was used as a radiator the rays were much more abnormally penetrating to iron than to copper, indicating that the atomic weight of cobalt is nearer that of iron than of copper.

The two experiments together furnish what seems to us to be the strongest evidence, based, not only on empirical law, but on theory, that the atomic weight of nickel is not slightly less than that of cobalt (the accepted values are Ni 58·7, Cr 59), but is considerably greater.

The evidence, however, does not end here. In a paper on secondary Röntgen radiation I suggested a method of determining atomic weights—based on the fact that the radiation is purely an atomic property—by graphically plotting the absorbability of the secondary radiation proceeding from different elements subject to X-rays and the atomic weight of the radiator. A periodic curve was obtained in many portions of which the slope was so great that atomic weights might be obtained by interpolation with considerable accuracy.

Using a thin plate of aluminium as the absorber, the relation between the absorbability of the radiation and the atomic weight of the radiator was found to be approximately a linear one for a long range of atomic weights on both sides of nickel. Nickel itself, however, can only be brought into line by assigning it an atomic weight a little above 61. Many absorbing substances have been used, and all give approximately the same value, the maximum variation in the values found from these different experiments being about 0·3.

The experiments on fairly good commercial specimens indicated an atomic weight of about 61·4. To make the evidence more conclusive and the numerical values as accurate as possible—though a 2 per cent. or 3 per cent. impurity could not materially affect the result—the purest specimens were used, and the atomic weight found by two separate series of observations did not differ by more than about 0·1 from the value previously obtained. We are thus forced to the conclusion that the atomic weight of nickel is about 61·3. Details of these experiments we hope to publish shortly. CHARLES G. BARKLA.

University of Liverpool, February 6.

ON HOMER LANE'S PROBLEM OF A SPHERICAL GASEOUS NEBULA.

§ 1. A HIGHLY interesting problem of pure mathematics was brought before the world in the *American Journal of Science*, July, 1870, by the late Mr. Homer Lane, who, as we are told by Mr. T. J. J. See,[1] was for many years connected with the U.S. Coast and Geodetic Survey at Washington. Lane's problem is the convective equilibrium, of density, of pressure, and of temperature, in a rotationless spherical mass of gaseous fluid,[2] hot in its central parts, and left to itself in waveless quiescent ether.

§ 2. For the full discussion of this problem we must, according to the evolutionary philosophy of the physics of dead matter, try to solve it for all past and future time. But we may first, after the manner of Fourier, consider the gaseous globe as being at any time given with any arbitrarily assumed distribution of temperature, subject only to the condition that it is uniform throughout every spherical surface concentric with the boundary. And our subject might be the absolutely determinate problem of finding the density and pressure at every point necessary for dynamical equilibrium. But for stability of this equilibrium, Homer Lane assumed, rightly as I believe is now generally admitted, that it must be of the kind which two years later[3] I called convective equilibrium.

§ 3. If the fluid globe were given with any arbitrary distribution of temperature, for example uniform temperature throughout, the cooling, and consequent augmentation of density of the fluid at its boundary, by radiation into space, would immediately give rise to an instability according to which some parts of the outermost portions of the globe would sink, and upward currents would consequently be developed in other portions. In any real fluid, whether gaseous or liquid, or liquid with an atmosphere of vapour around it, this kind of automatic stirring would tend to go on until a condition of approximate equilibrium is reached, in which any portion of the fluid descending or ascending would, by the thermodynamic action involved in change of pressure, always take the temperature corresponding to its level, that is to say, its distance from the centre of the globe.

§ 4. The condition thus reached, when heat is continually being radiated away from the spherical boundary, is not perfect equilibrium. It is only an approximation to equilibrium, in which the temperature and density are each approximately uniform at any one distance from the centre, and vary slowly with time, the variable irregular convective currents being insufficient to cause any considerable deviation of the surfaces of equal density and temperature from sphericity.

§ 5. A very interesting and important theorem was given by Prof. Perry, on p. 252 of NATURE for July, 1899, according to which, for cosmical purposes, it is convenient to divide gases into two species—species P, gases for which the ratio (k) of thermal capacity, pressure constant, to thermal capacity, volume con-

1 "Researches on the Physical Constitution of the Heavenly Bodies" *Astr. Nachr.*, November, 1905.)

2 By a gaseous fluid I here mean what is commonly called a "perfect gas," that is, a gas which fulfils two laws:—(1) Boyle's law. At constant temperature it exerts pressure exactly in proportion to its density, or in inverse proportion to the volume of a given homogeneous mass of it; (2) A given mass of it, kept at constant pressure, has its volume exactly proportional to its temperature, according to the absolute thermodynamic definition of temperature (Preston's "Theory of Heat," Article 290). According to the "Kinetic Theory of Gases," every gas or vapour approximates more and more closely to the fulfilment of these two laws, the smaller is the proportion of the sum of times in collision to the sum of times of moving approximately in straight lines between collisions.

3 "On the Convective Equilibrium of Temperature in the Atmosphere." (Literary and Philosophical Society of Manchester, January 21, 1862; re-published as Appendix E, Math. and Phys. Papers, vol. iii.)