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"To the solid ground
Of Nature trusts the mind which builds for aye."—WORDSWORTH.

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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.)

stant, is greater than $1\frac{1}{3}$; species Q, gases for which k is less than $1\frac{1}{3}$. On looking at the page of NATURE referred to, it will be seen that Perry questioned or even denied the possibility of a gas of species Q. His theorem is:—*A finite spherical globe of gas, given in equilibrium with any arbitrary distribution of temperature having isothermal surfaces spherical, has less heat if the gas is of species P, and more heat if of species Q, than the thermal equivalent of the work which would be done by the mutual gravitational attraction between all its parts, in ideal shrinkage from an infinitely rare distribution of the whole mass to the given condition of density.*

§ 6. From this we see that if a globe of gas Q is given in a state of convective equilibrium, with the requisite heat given to it, no matter how, and left to itself in waveless quiescent ether, it would, through gradual loss of heat, immediately cease to be in equilibrium, and would begin to fall inwards towards its centre, until in the central regions it becomes so dense that it ceases to obey Boyle's law; that is to say, ceases to be a gas. Then, notwithstanding Perry's theorem, it can come to approximate convective equilibrium as a cooling liquid globe surrounded by an atmosphere of its own vapour.

§ 7. But if, after being given as in § 6, heat be properly and sufficiently supplied to the globe of Q-gas at its boundary, and the interior be kept stirred by artificial stirrers, the whole gaseous mass can be brought into the condition of convective equilibrium.

§ 8. In the course of the communication to the Royal Society of Edinburgh, curves were shown representing the distributions of density and temperature in convective equilibrium for four different gases, corresponding to the four values of k:—

Gas (1) $k=1\frac{2}{3}$ (approximately the value of k for the monatomic gases, mercury vapour according to Kundt and Warburg, argon, helium, neon, krypton, and xenon).

Gas (2) $k=1\frac{2}{5}$ (approximately the value of k for seven known diatomic gases, hydrogen, nitrogen, oxygen, carbon monoxide, nitric oxide, hydrochloric acid, hydrogen bromide).

Gas (3) $k=1\frac{1}{3}$ (approximately the value of k for water vapour, chlorine, marsh gas, bromine iodide, chlorine iodide).

Gas (4) $k=1\frac{1}{4}$ (approximately the value of k for sulphur dioxide).

Four of these curves agree practically with curves given by Homer Lane for $k=1\frac{2}{3}$ and $k=1\frac{2}{5}$, in his original paper to the *American Journal of Science*, July, 1870.

§ 9. In a communication to the Edinburgh Royal Society of February, 1887, "On the Equilibrium of a Gas under its own Gravitation only," I indicated a graphical treatment of Lane's problem by successive quadratures, which facilitated the accurate calculation of numerical results, and was worked out fully for the case $k=1\frac{2}{5}$ by Mr. Magnus Maclean, with results shown in a table on p. 117 of the Proceedings of the Royal Society of Edinburgh, vol. xiv., and on p. 292 of the *Phil. Mag.*, March, 1887. The numbers in that table expressing temperature and density are represented by two of the curves now laid before the society. The other curves represent numerical results calculated by Mr. George Green, according to a greatly improved process which he has found, giving the result by step by step calculation without the aid of graphical constructions.

The mathematical interpretation of the solution for Perry's critical case of $k=1\frac{1}{3}$, and for gases of the Q-species, is exceedingly interesting.

The communication included also fully worked out examples of the general solution of Lane's problem for gases of class P of different total quantities and of different specific densities.

§ 10. In my communication to the Royal Society of Edinburgh, of February, 1887, I pointed out that Homer Lane's problem gives no approximation to the present condition of the sun, because of his great average density (1.4). This was emphasised by Prof. Perry in the seventh paragraph, headed "Gaseous Stars," of his letter to Sir Norman Lockyer on "The Life of a Star" (NATURE, July 13, 1899), which contains the following sentence:—

"It seems to me that speculation on this basis of perfectly gaseous stuff ought to cease when the density of the gas at the centre of the star approaches 0.1 or one-tenth of the density of ordinary water in the laboratory."

KELVIN.

THE PROBLEM OF THE RHODESIAN RUINS.[1]

THE recent investigation of some of the famous ruins of Rhodesia, conducted in 1905 by Dr. D. Randall-MacIver on behalf of the British Association and the Rhodes trustees, has resulted in an entirely fresh view of their origin and age. The hitherto generally accepted view, that these buildings were erected in very ancient days by a Semitic people, whose search for gold led them thus far afield, has received a serious check. Dr. MacIver's researches, conducted upon the lines of archæological investigation, point to the buildings in question being of comparatively recent date, not earlier, in fact, than late mediæval times. This result is the more striking when we remember that his previous researches have been mainly archæological, conducted chiefly in Egypt, and that, in consequence, we might expect a certain degree of bias in favour of retaining the ruins within the sphere of archæology. That a trained archæologist has been unable to find evidence of high antiquity upon the sites investigated is at least a strong point in favour of his argument.

Dr. MacIver made excavations on seven sites in various parts of Rhodesia, these being:—(1) Inyanga, on the Cecil Rhodes estate, sixty miles north of Umtali; (2) the Niekerk ruins to the north-west of Inyanga; (3) a site three miles south of Umtali; (4) Dhlo Dhlo, in the Incisa district; (5) Nanatali, sixteen miles east of Dhlo Dhlo; (6) Kami, fourteen miles west of Bulawayo; and (7) Great Zimbabwe, in the Victoria district, the site which hitherto had received the greatest attention. These sites were well selected as being distributed over a wide area, and, moreover, as differing considerably from one another both in general character and in special features, as also in the greater or less degree of elaborateness in their structure. It may be remarked at once that the distinctive features observable in comparing the different buildings are often no less remarkable than are the points of similarity. No two seem to be alike, and the divergences and specialisation render their individuality very striking.

The principal questions to be determined in regard to these remarkable buildings were: By what people and at what period were they erected? The controversy, which is still active, centres mainly upon these two main points, and the older theory of their Semitic origin and great antiquity, urged by Mauch, Bent, Keane, Hall, and others, is being maintained steadfastly and strenuously by several authorities. Dr. MacIver in the title of his book, "Mediæval Rhodesia," has hoisted his fighting flag. His conten-

[1] "Mediæval Rhodesia." By Dr. David Randall-MacIver. Pp. xv+106. (London: Macmillan and Co., Ltd., 1906. Price 20s. net.