of agitation is found to be such that the mean square of velocity of the meteorites is almost exactly $\frac{5}{8}$ of the square of the velocity of a satellite grazing the surface of the sphere in a circular orbit.

As indicated above, it is supposed that in the meteor-swarm the rigid envelope, bounding the isothermal sphere, is replaced by a layer or atmosphere in convective equilibrium. The law of density in the adiabatic layer is determined in the paper, and it appears that when the isothermal sphere has minimum temperature the mass of the adiabatic atmosphere is a minimum relatively to that of the isothermal sphere. Numerical calculation shows, in fact, that the isothermal sphere cannot amount in mass to more than 46 per cent. of the mass of the whole isothermal-adiabatic sphere, and that the limit of the adiabatic atmosphere is at a distance equal to 2·786 times the radius of the isothermal sphere.[1]

It is also proved that the total energy, existing in the form of energy of agitation, is exactly one-half of the potential energy lost in the concentration of the matter from a condition of infinite dispersion. This result is brought about by a continual transfer of energy from a molar to a molecular form, for a portion of the kinetic energy of a meteorite is constantly being transferred into the form of thermal energy in the volatilized gases generated on collision. The thermal energy is then lost by radiation.

It is impossible as yet to sum up all the considerations which go to justify the assumption of the isothermal-adiabatic arrangement, but it is clear that uniformity of kinetic energy must be principally brought about by a process of diffusion. It is therefore interesting to consider what amount of inequality in the kinetic energy would have to be smoothed away.

The arrangement of density in the isothermal-adiabatic sphere being given, it is easy to compute what the kinetic energy would be at any part of the swarm, if each meteorite fell from infinity to the neighbourhood where we find it, and there retained all the velocity due to such fall. The variation of the square of this velocity gives an indication of the amount of kinetic energy which has to be degraded by conversion into heat and distributed by diffusion, in the attainment of uniformity. This may be called "the theoretical value of the kinetic energy." It appears that in the swarm, this square of velocity rises from zero at the centre of the swarm to a maximum which is attained nearly half-way through the adiabatic layer, and then diminishes. It is found that the variations of this theoretical value are inconsiderable throughout the greater part of the range. From this it follows that there must be diffusion of kinetic energy from without inwards, and considerations of the same kind show that when a planet consolidates there must be a cooling of the middle strata both outwards and inwards.

We must now consider the nature of the criterion which determines whether the hydrostatic treatment of a meteor-swarm is permissible.

The hydrodynamical treatment of an ideal plenum of gas leads to the same result as the kinetic theory with regard to any phenomenon involving purely a mass, when that mass is a large multiple of the mass of a molecule; to any phenomenon involving purely a length, when the cube of that length contains a large number of molecules; and to any phenomenon involving purely a time, when that time is a large multiple of the mean interval between collisions. Again, any velocity to be justly deduced from hydrodynamical principles must be expressible as the edge of a cube containing many molecules passed over in a time containing many collisions of a single molecule; and a similar statement must hold of any other function of mass, length, and time.

Beyond these limits we must go back to the kinetic theory itself, and in using it care must be taken that enough molecules are considered at once to impart statistical constancy to their properties.

There are limits, then, to the hydrodynamical treatment of gases, and the like must hold of the parallel treatment of meteorites.

The principal question involved in the nebular hypothesis seems to be the stability of a rotating mass of gas; but unfortunately this has remained up to now an untouched field of mathematical research. We can only judge of probable results from the investigations which have been made concerning the stability of a rotating mass of liquid. Now it appears that the instability of a rotating mass of liquid first enters through the graver modes of gravitational oscillation. In the case of a rotating spheroid of revolution the gravest mode of oscillation is an elliptic deformation, and its period does not differ much from that of a satellite which revolves round the spheroid so as to graze its surface. Hence, assuming for the moment that a kinetic theory of liquids had been formulated, we should not be justified in applying the hydrodynamical method to this discussion of stability, unless the periodic time of such a satellite were a large multiple of the analogue of the mean free time of a molecule of liquid.

Carrying, then, this conclusion on to the kinetic theory of meteorites, it seems probable that hydrodynamical treatment must be inapplicable for the discussion of such a theory as the meteoric-nebular hypothesis, unless a similar relation holds good.

These considerations, although of a vague character, will afford a criterion of the applicability of hydrodynamics to the kind of problem suggested by the nebular hypothesis. And certain criteria suggested by this line of thought are found in the paper; they give a measure of the degree of curvature of the average path pursued by a meteorite between two collisions.

After these preliminary investigations, we have to consider what kind of meeting of two meteorites will amount to an "encounter" within the meaning of the kinetic theory.

Is it possible, in fact, that two meteorites can considerably bend their paths under the influence of gravitation, when they pass near one another? This question is considered in the paper, and it is shown that unless the bodies have the dimensions of small planets, the mutual gravitational influence is insensible. Hence, nothing short of absolute impact is to be considered an encounter in the kinetic theory, and what is called the radius of "the sphere of action" is simply the distance between the centres of a pair when they graze, and is therefore the sum of the radii of a pair, or, if of uniform size, the diameter of one of them.

(*To be continued.*)

[1] This is one of the results established by M. Ritter in a series of papers in the *Annalen der Physik und Chemie* from 1878 onwards.

SOME CURIOUS PROPERTIES OF METALS AND ALLOYS.[1]

THE lecture consisted mainly of experimental demonstrations of the changes induced in metals, either by slight variations in the treatment to which they are subjected or by rendering them impure by the addition of small quantities of metals or metalloids.

Prof. Austen began by pointing out that for centuries the early metallurgists investigated the action of exceedingly small quantities of matter upon masses of metal; and he said that, strange as it may seem, the promulgation, in 1803, of Dalton's atomic theory threw a flood of light upon chemical phenomena, but cast into the shade such investigations as those of Bergman, which dealt with influences

[1] Abstract of a Lecture delivered by Prof. W. Chandler Roberts-Austen, F.R.S., at the Royal Institution, on May 11, 1888.

of "traces" upon masses, and the authority of Berthollet was not sufficient to save them from neglect. In this eventful year for science, 1803, the latter published his essay on chemical statics, in which he stated, as a fundamental proposition, that in comparing the action of bodies on each other, which depends "upon their affinities and mutual proportions, the mass of each has to be considered" (English edition, by M Farrell, M.D., 1804, p. 5). His views were successfully contested by Proust, but, as Lothar Meyer says, the influence on chemistry of the rejection of Berthollet's views was remarkable:—"All phenomena which could not be attributed to fixed atomic proportions were set aside as not truly chemical, and were neglected. Thus chemists forsook the bridge by which Berthollet had sought to unite the sister sciences, physics and chemistry." Fortunately, however, in this country there was one chemist who had followed up the line of work indicated by the early metallurgists, for in 1803, the same year as that in which both Berthollet's essay and Dalton's atomic theory were published, Charles Hatchett (Phil. Trans., vol. xciii. p. 43, 1803) communicated to the Royal Society the results of a research which he had conducted, with the assistance of Cavendish, in order to ascertain "the chemical effects produced on gold by different metallic substances when employed in certain" (often very small) "proportions as alloys."

Allusion was then made to the evidence of the passage of metals into allotropic states, and it was shown that, although the importance of the isomeric and allotropic states was abundantly recognized in organic chemistry, it had been much neglected in the case of metals. Special attention was then devoted to the works of Joule and Lyon Playfair, who showed, in 1846, that metals in different allotropic states possessed different atomic volumes, and the lecturer then proceeded to the consideration of the work of Matthiessen, who, in 1860, was led to the view that in certain cases when metals were alloyed they passed into allotropic states, probably the most important generalization which has as yet been made in connection with the molecular constitution of alloys

Instances of allotropy in pure metals were then shown to the audience, such, for example, as Bolley's lead, which oxidizes readily in air; Schützenberger's copper; Fritsche's tin, which fell to powder when exposed to an exceptionally cold winter; Gore's antimony; Graham's palladium; and allotropic nickel. It was further shown that metals could be obtained in chemically active states under the following conditions:—Joule proved that when iron is released from its amalgam by distilling away the mercury the metallic iron takes fire on exposure to air, and is therefore clearly different from ordinary iron, and is, in fact, an allotropic form of iron. Moissan (*Comptes rendus*, vol. lxxxviii. p. 180, 1879) has shown that similar effects are produced in the case of chromium and manganese, cobalt, and nickel, when released from their amalgams with mercury.

Evidence is not wanting of allotropy in metals released from solid alloys, as well as from fluid amalgams with mercury. Certain alloys may be viewed as solidified solutions, and when such bodies are treated with a suitable solvent, usually an acid, it often happens that one constituent metal is dissolved, and the other released in an insoluble form. Reference was then made to a new alloy of potassium and gold, containing about 10 per cent. of the precious metal. If a fragment of this alloy be thrown upon water, the potassium takes fire, decomposes the water, and the gold is released as a black powder: there is a form of this black or dark-brown gold which appears to be an allotropic modification of gold, as it combines with water to form auric hydride. If this dark gold be heated to dull redness, it readily assumes the ordinary golden colour. The Japanese use this gold, released from gold-copper alloys, in a remarkable way, for they produce, by the aid of certain pickling solutions, a beautiful patina on copper which contains only 2 per cent. of gold, while even a trace of the latter metal is sufficient to alter the tint of the patina.

With regard to theoretical views as to molecular change in metals, special care was given to a description of the work of Prof. W. Spring, of Liége, who had furnished much evidence in support of the view that polymerization of metals—that is, the rearrangement of atoms in their molecules—could take place even in *solid* alloys of lead and tin.

With reference to the passage of metals into allotropic states under slight external influences, it was stated that Debray (*Comptes rendus*, vol. xc p. 1195, 1880) has given a case of an alloy in which a simple elevation of temperature induces allotropic change in the constituent metals. It is prepared as follows: 95 parts of zinc are alloyed by fusion with 5 parts of rhodium, and the alloy is treated with hydrochloric acid, which dissolves away the bulk of the zinc, leaving a rich rhodium-zinc alloy, containing about 80 per cent. of rhodium. When this alloy is heated *in vacuo* to a temperature of 400° C., a slight explosion takes place, but no gas is evolved, and the alloy is then insoluble in *aqua regia*, which dissolved it readily before the elevation of temperature caused it to change its state. We are thus presented (as the experiment shown to the audience proved) with another undoubted case of isomerism in alloys, the unstable, soluble modification of the alloy being capable of passing into the insoluble form by a comparatively slight elevation of temperature.

The industrial importance of the passage of metals and alloys into allotropic states, and the possibility of changing the mechanical properties of metals by apparently slight influences, were fully dealt with; and the lecture concluded with a detailed description of Prof. Austen's own experiments, which have since been printed in the Philosophical Transactions of the Royal Society, the results showing that very small amounts of metallic impurities exert an extraordinary effect on the tenacity and extensibility of gold, and that small as the amounts of these impurities are, their influence is rigidly controlled by the periodic law of Newlands and Mendelejeff, the deleterious action of a metallic impurity being in direct relation to its atomic volume. The audience was asked "to remember that the knowledge of the kind of facts which had been considered comes to us from very early times, for the influence produced on metals by small quantities of added matter had a remarkable effect on the development of chemistry, mainly by sustaining the belief of the early chemists in the possibility of ennobling a base metal so as to transmute it into gold. This was the object to which they devoted life and health, and laboured with fast and vigil. We inherit the results of their labours, and their prayers have been answered in a way they little anticipated, for, from an industrial point of view, if not from a scientific one, metals are 'transmuted' by traces of impurity. Possibly we are nearing an explanation of the causes which are at work, but the fact remains that iron may be changed from a plastic material, which in ornament can be fashioned into the most dainty lines of flow, into one of great endurance, to which, for the present at least, the defence of the country may be trusted, apparently because armour-plates and missiles owe their respective qualities to the fact that carbon, manganese, and chromium have small atomic volumes."

THE LEONID METEOR-SHOWER, 1888.

AT Bristol rain fell heavily between midday on November 12 and the same time on November 13, a 5-inch gauge registering an inch and eight-tenths, which is by far the greatest downpour of the year within twenty-four hours. In the afternoon of November 13 the clouds broke, and the weather showed a disposition to become more favourable. At night the sky was moderately clear