It must be emphasised at this point that the designs for the new telescope with a wide field of good definition, and for the new cellular type of mirror do not merely exist on paper. Prof. Ritchey has constructed in the optical laboratory of the Paris Observatory the mirrors for a model of this kind. Such instruments are to be known as Ritchey-Chrétien reflectors. In the model which has been constructed the aperture is 19·9 inches and the focal length of the combination 136 inches. The two mirrors are 41·73 inches apart, the convex being of 4·9 inches aperture. The focus is situated at a point 6·3 inches behind the vertex of the optical surface of the large mirror. The mirrors are of the cellular type described above, and are figured according to Prof. Chrétien's designs. The field is spherical and is concave towards the incident light, with a radius of 23·62 inches. Spherically-concave photographic plates have been constructed for use with the model. These are easily moulded to the required curvature. But it may be remarked here that, so far as astronomy of position is concerned, the precise measurement of images on a curved plate will present a difficulty to be overcome.

Optical tests with an artificial star have been carried out with this model, and also with a Newtonian model of the same aperture and focal length. These tests make interesting reading. Even at a distance of 2½ minutes of arc from the centre of the field the images of the Newtonian reflector are distorted by appreciable coma. It is otherwise with the Ritchey-Chrétien model. Up to 20 minutes of arc from the centre of the field, the image is a diffraction disc of about 0·28 seconds of arc in diameter. Beyond this and up to 60 minutes from the centre they are approximately circular, the diameter of the image at 60 minutes being eight seconds of arc.

This much has been accomplished, and it is clear that the accomplishment represents something of the nature of a revolution in the design and construction of reflectors. There seems no reason why instruments of moderate size of the Ritchey-Chrétien type should not be constructed, and astronomers would welcome their obvious advantages. No doubt the constructional technique would develop in a normal manner and larger instruments would appear in the course of time.

Prof. Ritchey has, however, determined to go immediately to instruments of the largest kind, and he has already designed telescopes up to ten metres aperture. Space forbids a detailed description of his plans, but one such design provides for a fixed vertical telescope with cœlostat. The aperture is to be 10 metres and there are to be interchangeable mirrors, so that five combinations of focal ratios ranging from 2·75 to 20 will be available.

Prof. Ritchey has announced his intention of constructing such an instrument. Whilst sympathising with his desire for rapid progress, many astronomers will feel that it would perhaps be more desirable to consolidate the ground already occupied and to erect an instrument of moderate dimensions under practical working conditions in an observatory. At the same time, if Prof. Ritchey's great adventure is successful, they will be the first to rejoice with him : in the meanwhile they will wish him good luck.

W. M. H. G.

The States of Aggregation of Condensed Helium.[1]

By Prof. W. H. KEESOM, University of Leyden

IN virtue of the very low value of its interatomic forces, helium—discovered in the solar chromosphere in 1868 and obtained from terrestrial sources by Ramsay in 1895—represents the ideal gas more nearly than any other known substance, and is the thermometric gas *par excellence*, while its extremely low critical temperature and boiling-point furnish the means of descending the scale of temperature to the immediate neighbourhood of the absolute zero.

The first experimenters to attempt the liquefaction of helium were Dewar and Olszewski. The method they used—cooling the gas in liquid hydrogen and then allowing it to expand—proved ineffectual, but success attended the efforts of Kamerlingh Onnes, who, in 1908, resorted to the procedure employed ten years earlier by Dewar for the liquefaction of hydrogen. Fig. 1 shows diagrammatically the arrangement of the apparatus. The helium from the storage cylinders was compressed into the liquefying vessel, in which it was cooled, by means first of hydrogen vapour and afterwards of liquid hydrogen boiling under reduced pressure, to −258° C. The cooled helium then passed into the spiral regenerator and through the expansion valve, part undergoing liquefaction in virtue of the Joule-Kelvin phenomenon. The lower part of the liquefaction vessel has been since modified to allow of the transference of the liquid to a cryostat, in which it can be subjected to physical measurement. In a later experiment for obtaining the lowest possible temperature, Onnes made use of a battery of Langmuir mercury condensation pumps in conjunction with a preliminary series of powerful mechanical pumps. To judge whether helium at those extremely low temperatures would solidify, he introduced into the Dewar vessel containing the liquid helium a small metallic cylinder suspended from a rod and capable of being moved upwards or downwards.

The results of these experiments showed that, whereas hydrogen boils at 20° abs. and the temperature 10° is attainable by bringing the solid hydrogen under diminished pressure, a temperature little above 0·8° is brought within reach by the similar use of liquid helium, with boiling-point 4·2° abs. At this temperature, however, the helium, under its own very low saturated vapour pressure, retained its liquid state.

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[1] From a lecture before the Fifth International Congress on Refrigeration, at Rome, delivered on April 13.

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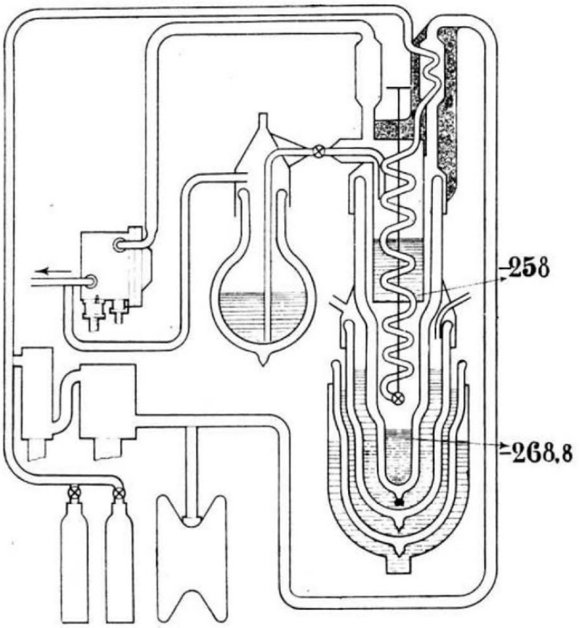
My experiments, which resulted in the solidification of helium, demonstrate clearly that such solidification requires not only a temperature at which the interatomic forces overcome the thermal motion to such an extent that the atoms may be fixed in a crystalline lattice, but also the application of an external pressure sufficiently high to permit of free play for the interatomic forces. In the absence of such pressure the helium remains liquid at the lowest temperature yet realised, although at a certain temperature it may pass suddenly into a new liquid state of aggregation.



The apparatus used is shown diagrammatically in Fig. 2. The lower parts of two metallic tubes, B_1 and B_3, connected by a narrower tube, are immersed in liquid helium, and into these tubes helium is compressed by means of a small hydraulic pump charged with glycerine. When the plunger P of the pump is withdrawn, the mercury which half fills the two steel cylinders C, rises in the right-hand cylinder and draws helium from the supply vessel through the tap K_1 into the left-hand cylinder. The tap K_1 being then closed and K_3 opened, forward movement of the plunger P forces the helium into the system of tubes. In order to detect solidification of the helium, these tubes communicate with the branches of a differential manometer, consisting of a steel tube D passing into a steel chamber E partially filled with mercury. If a block of solid helium forms in the lower portion of the tubes and the tap K_2 is opened for an instant, a certain amount of gaseous helium escapes, and, the tap K_4 connecting the tubes being closed, the pressure in the right-hand tube becomes lower than that in the left and the mercury in the steel tube of the differential manometer rises. This tube contains a thin platinum wire forming part of one of the arms of a Wheatstone bridge; the mercury rising causes deflection of the galvanometer needle.

Another device, introduced later, and due originally to Kuenen, consists of a stirrer of soft iron H—capable of being raised and lowered magnetically—enclosed in the glass tube F communicating with the helium tubes through a metal tube; this glass tube is actually placed within the helium cryostat, although shown outside for the sake of clearness.

By adjusting the temperature of the helium bath by variation of the pressure exerted thereon, and ascertaining the corresponding pressure in the helium tubes necessary to produce blocking, the fusion curve of helium was followed for pressures ranging from 25 to about 140 atmospheres, the corresponding range of melting-point being about 1·2°–4·2° abs. At its lower end the fusion curve becomes more and more nearly parallel to the temperature axis and exhibits no tendency to meet the vapour pressure curve in a triple point, so that co-existence of gas and solid, and hence sublimation, appear impossible (below the critical temperature of helium).

Experiments made with the glass tube revealed neither change of volume nor change of state, nor a surface of demarcation between either gas and liquid or solid and liquid. Nevertheless, the solidification of helium was demonstrated in this experiment also, for a block of solid helium could be hammered. It is evident that, at the pressures used (about 90 atmospheres), the densities and the refractive indices are nearly identical for the three phases.

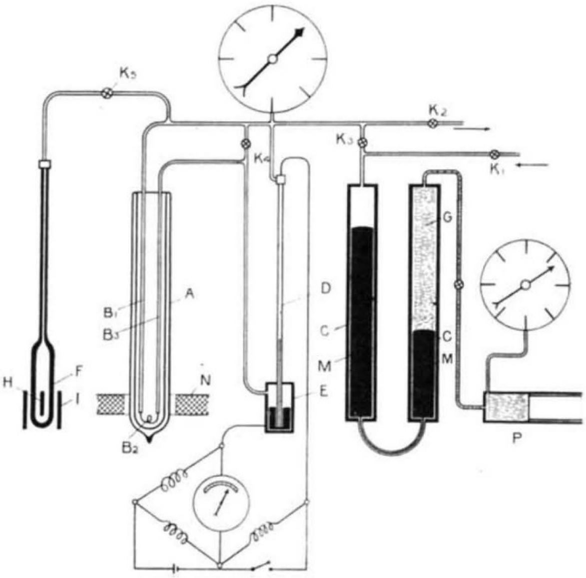


FIG. 2.

In the course of a series of measurements of the dielectric constant of liquid helium, carried out with the collaboration of Prof. Wolfke of Warsaw, it was noticed that this constant undergoes a sudden or, at any rate, a very rapid change in magnitude at about 2·3° abs., which coincides sensibly with the temperature at which Onnes and Boks observed a maximum value for the density of the liquid. It appears that helium exists in

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two liquid modifications, liquid helium I being stable above 2·3° and liquid helium II at lower temperatures; the density of the former is about 0·1 per cent higher than that of the latter.

Measurements of the specific heat of liquid helium were made by Dana and Onnes, who did not, however, publish the relatively high values obtained at temperatures near 2·3°, as these were not considered to be in accord with the other results. The apparent discordance is evidently due to the heat of transformation of helium I into helium II, which is calculated to be −0·13 cal. per gram. The heat of evaporation of helium appears to show a sudden variation, the value for helium II being the greater, while the surface tension of helium I exceeds that of helium II by about 3 per cent. It is remarkable that this transformation occurs at a temperature which corresponds, in the sense of the van der Waals' law of corresponding states, with the temperatures at which other substances melt.

Helium has, then, a triple point: liquid helium I—liquid helium II—vapour. Up to the present, such a point has been observed only for certain substances of complicated composition exhibiting a mesomorphic state (crystalline liquid), but further investigation is necessary before it can be ascertained if this is the case with helium. Fig. 3 is the characteristic diagram of the different states of helium, and shows the curve of saturated vapour pressure, the triple point, and the melting-point curve. Between liquid helium I and liquid helium II there must be a transformation curve, but it is not yet known if this curve meets the melting-point curve, as shown in the diagram, or if it bends towards the axis of pressure.

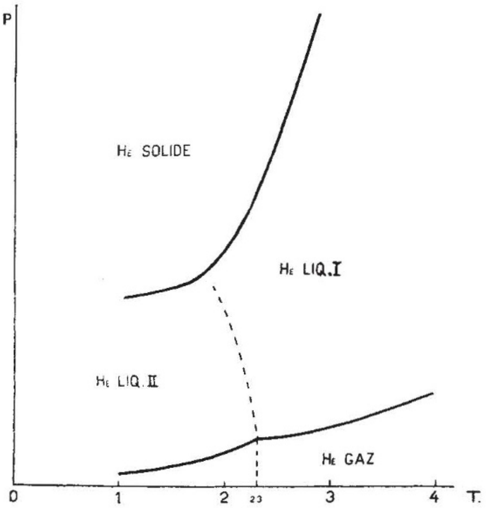

FIG. 3.

Obituary.

PROF. G. H. BRYAN, F.R.S.

THE death of Prof. George Hartley Bryan on Oct. 13 removed one of the most interesting personalities among British mathematicians. His influence was felt in several directions, but it is in the mathematical theory of aeroplane flight that his work has made the greatest and most lasting impression.

Bryan was born at Cambridge on Mar. 1, 1864, the only child of Robert Purdie Bryan of Clare College. He lost his father at a very early age. His mother lived to a good old age, and Bryan always spoke of her with the greatest affection. He was brought up by his mother and his grandparents. He was the idol of the household, and being supposed to be delicate he was never allowed to go to school. Even when he went to Peterhouse as an undergraduate he was not given the opportunity of becoming self-reliant, for he still lived at home. The result of such an upbringing, in which discipline was totally absent, was a rather noticeable eccentricity, which did not, however, cover up a remarkable simplicity, honesty, and kindliness of character. Much of Bryan's early life was spent in Italy, France, and Germany. His excellent knowledge of the languages of these countries influenced both his scientific work and his literary style.

Bryan was fifth wrangler in the Mathematical Tripos of 1886 and second Smith's prizeman. He was a fellow of Peterhouse from 1889 until 1895. He succeeded the late Dr. G. B. Mathews as professor of pure and applied mathematics in the University College of North Wales, Bangor, in 1896, and held the chair until his retirement in 1926.

Hydrodynamical problems occupied Bryan's attention during the whole of his mathematical career. Inspired by the work of G. H. Darwin, he wrote important papers on the waves on, and the stability of, a rotating liquid spheroid, in 1888 and 1890. He soon became interested in the motion of solids through liquids, and in 1900 he produced a mathematical theory of the action of bilge keels in extinguishing the oscillations of a ship. This work was recognised by the award of the gold medal of the Institution of Naval Architects in 1901. He returned to the theory of discontinuous fluid motion as applied to a bent plate, in collaboration with Mr. R. Jones, in 1914, but meanwhile the fundamental work of Levi-Cività had introduced new methods for dealing with curved barriers, and the work of Lanchester, Joukowski, and Kutta was leading to the development of the powerful Prandtl theory. Later on Bryan wrote on the motion of an elastic fluid past a barrier.

The Cardiff meeting of the British Association in 1891 was the occasion of Bryan's important report on thermodynamics. He also wrote several independent researches based on kinetic theory, and when the "Encyklopädie der mathematischen Wissenschaften" was planned, Bryan was invited to contribute the section on thermodynamics. This appeared in 1903.

Bryan became interested in aviation very early,

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