markings and the variations of the polar cap with the seasons. —M. Em. Touchet contributes an illustrated account of his successful attempt to photograph the "shadow cast by the planet Venus." This he did on January 11, with an exposure of fifteen minutes, the object casting the shadow being an incandescent bulb-holder placed about 21 cm. from the plate.—Lastly, rather more than nine pages are devoted to a dissertation, by M. Rideau, on "the satellites of Jupiter," dealing with their dimensions, surface, probable variability of brightness, eclipse and other phenomena.

SOLID HYDROGEN.[1]

IN the autumn of 1898, after the production of liquid hydrogen was possible on a scale of one or two hundred c.c., its solidification was attempted under reduced pressure. At this time, to make the isolation of the hydrogen as effective as possible, the hydrogen was placed in a small vacuum test-tube, placed in a larger vessel of the same kind. Excess of the hydrogen partly filled the circular space between the two vacuum vessels. The apparatus is shown in Fig 1. In this way the evaporation was mainly thrown on the liquid hydrogen in the annular space between the tubes. In this arrangement the outside surface of the smaller tube was kept at the same temperature as the inside, so that the liquid hydrogen for the time was effectually guarded from influx of heat. With such a combination the liquid hydrogen was evaporated under some 10 mm. pressure, yet no solidification took place. Seeing experiments of this kind required a large supply of the liquid, other problems were attacked, and any attempts in the direction

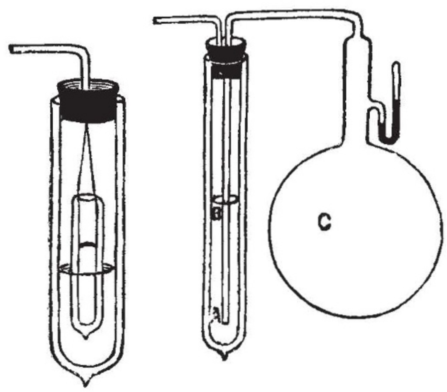

FIG 1. FIG 2.

of producing the solid for the time abandoned. During the course of the present year many varieties of electric resistance thermometers have been under observation, and with some of these the reduction of temperature brought about by exhaustion was investigated. Thermometers constructed of platinum and platinum-rhodium (alloy) were only lowered $1\frac{1}{2}°$ C. by exhaustion of the liquid hydrogen, and they all gave a boiling point of $-245°$ C., whereas the reduction in temperature by evaporation *in vacuo* ought to be $5°$ C., and the true boiling point from $-252°$ to $-253°$ C. In the course of these experiments it was noted that almost invariably there was a slight leak of air, which became apparent by its being frozen into an air snow in the interior of the vessel, where it met the cold vapour of hydrogen coming off. When conducting wires covered with silk have to pass through india-rubber corks it is very difficult at these excessively low temperatures to prevent leaks, when corks get as hard as a stone, and cements crack in all directions. The effect of this slight air leak on the liquid hydrogen when the pressure got reduced below 60 mm. was very remarkable, as it suddenly solidified into a white froth-like mass like frozen foam. My first impressions were that this body was a sponge of solid air containing the liquid hydrogen, just like ordinary air, which is a magma of solid nitrogen containing liquid oxygen. The fact, however, that this white solid froth evaporated completely at the low pressure without leaving any substantial amount of solid air led to the conclusion that the body after all must be solid hydrogen. This surmise was confirmed by observing that if the pressure, and therefore the temperature, of the hydrogen was allowed to rise, the solid melted when the pressure reached about 55 mm. The failure of the early experiment must then have been due to supercooling of the liquid, which is prevented in this case by contact with metallic wires and traces of solid air. To settle the matter definitely, the following experiment was arranged. A flask, C, of about a litre capacity, to which a long glass tube bent twice at right angles was sealed, as shown in Fig. 2, and to which a small mercury manometer can be sealed, was filled with pure dry hydrogen and sealed off. The lower portion, A B, of this tube was calibrated. It was surrounded with liquid hydrogen placed in a vacuum vessel arranged for exhaustion. As soon as the pressure got well reduced below that of the atmosphere, perfectly clear liquid hydrogen began to collect in the tube A B, and could be observed accumulating until, about 30 to 40 mm. pressure, the liquid hydrogen surrounding the outside of the tube suddenly passed into a solid white foam-like mass, almost filling the whole space. As it was not possible to see the condition of the hydrogen in the interior of the tube A B when it was covered with a large quantity of this solid, the whole apparatus was turned upside down in order to see whether any liquid would run down A B into the flask C. Liquid did not flow down the tube, so the liquid hydrogen with which the tube was partly filled must have solidified. By placing a strong light on the side of the vacuum test-tube opposite the eye, and maintaining the exhaustion to about 25 mm., gradually the solid became less opaque, and the material in A B was seen to be a transparent ice in the lower part, but the surface looked frothy. This fact prevented the solid density from being determined, but the maximum fluid density has been approximately ascertained. This was found to be 0·086, the liquid at its boiling point having the density 0·07. The solid hydrogen melts when the pressure of the saturated vapour reaches about 55 mm. In order to determine the temperature, two constant volume hydrogen thermometers were used. One at $0°$ C. contained hydrogen under a pressure of 269·8 mm., and the other under a pressure of 127 mm. The mean temperature of the solid was found to be $16°$ absolute under a pressure of 35 mm. All the attempts made to get an accurate electric resistance thermometer for such low temperature observations have been so far unsatisfactory. Now that pure helium is definitely proved to be more volatile than hydrogen, this body, after passing through a spiral glass tube immersed in liquid hydrogen to separate all other gases, must be compared with the hydrogen thermometer. For the present the boiling point which is $21°$ absolute at 760 mm., compared with the boiling point at 35 mm., or $16°$ absolute, enables the following approximate formula for the vapour tension of liquid hydrogen below one atmosphere pressure to be derived :—

$$\log p - 6{\cdot}7341 - 83{\cdot}28/T \text{ mm.},$$

where T = absolute temperature, and the pressure is in mm. This formula gives us for 55 mm. a temperature of $16{\cdot}7°$ absolute. The melting point of hydrogen must therefore be about $16°$ or $17°$ absolute. It has to be noted that the pressure in the constant volume hydrogen thermometer, used to determine the temperature of solid hydrogen boiling under 35 mm., had been so far reduced that the measurements were made under from one-half to one-fourth the saturation pressure for the temperature. When the same thermometers were used to determine the boiling point of hydrogen at atmospheric pressure, the internal gas pressure was only reduced to one-thirteenth the saturation pressure for the temperatures. The absolute accuracy of the boiling points under diminished pressure must be examined in some future paper. The practical limit of temperature we can command by the evaporation of solid hydrogen is from $14°$ to $15°$ absolute. In passing it may be noted that the critical temperature of hydrogen being $30°$ to $32°$ absolute, the melting point is about half the critical temperature. The melting point of nitrogen is also about half its critical temperature. The foam-like appearance of the solid when produced in an ordinary vacuum is due to the small density of the liquid, and the fact that rapid ebullition is substantially taking place in the whole mass of liquid. The last doubt as to the possibility of solid hydrogen having a metallic character has been removed, and for the future hydrogen must be classed among the non-metallic elements.

[1] Read before the British Association (Section B), Dover Meeting, by Prof. James Dewar, F.R.S.