SOLID HYDROGEN.*

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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 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 1½° 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.

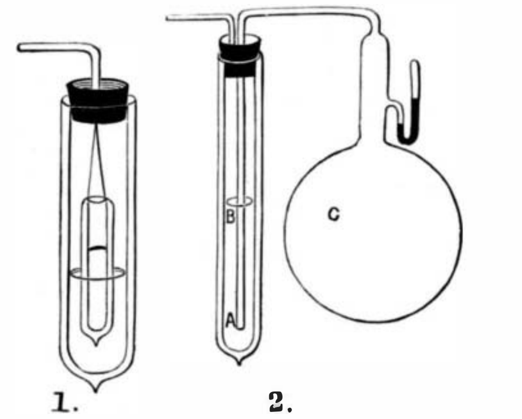
In the course of these experiments it was noted that almost invariably there was a slight leak of air, which became apparent by its being frozen into an air snow in the interior of the vessel, where it met the cold vapor of hydrogen coming off. Where conducting wires covered with silk have to pass through 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 liter capacity, to which a long glass tube bent twice at right angles was sealed, as shown in Fig. 2, to which a small mercury manometer can be sealed, was filled with pure dry hydrogen and sealed off. The lower portion, *AB*, 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, *AB*, 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, *AB*, 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 *AB* 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 *AB* 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 vapor 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 vapor tension of liquid hydrogen below one atmosphere pressure to be derived:

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

where T = absolute temperature, and the pressure is in mm. This formula gives us for 55 mm. a temperature of 16·7° 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.

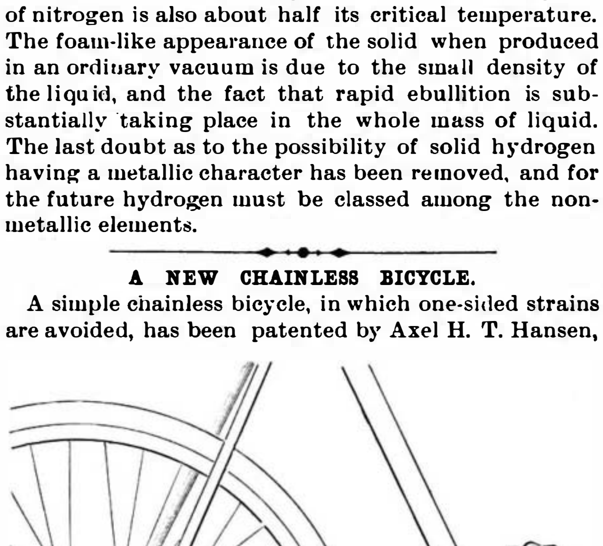


APPARATUS FOR PRODUCING SOLID HYDROGEN.

*Read before the British Association (Section B), Dover meeting, 1899.—From The Chemical News.

A NEW CHAINLESS BICYCLE.

A simple chainless bicycle, in which one-sided strains are avoided, has been patented by Axel H. T. Hansen, Avenida de Mayo 748, Buenos Aires, Argentina, which is noteworthy for its strong construction and for the novelty of its driving mechanism. This mechanism consists of a bevel-gear which takes the place of the usual sprocket-wheel on the pedal-shaft and meshes with a wheel beveled on both front and rear faces and mounted in ball-bearings on the rear stay, which is made single instead of double as usual. The rear face of the doubly-beveled wheel on the side opposite the first-mentioned bevel-gear engages a bevel-pinion secured upon a transverse shaft journaled in the rear stay. The pinion is provided with a crank-pin; and at the opposite side of the pinion the shaft carries a crank. The crank and crank-pin are set at ninety degrees to each other. Similarly located crank-pins are mounted on the hub of the rear bicycle-wheel. Rods connect the two sets of crank-pins on each side.



HANSEN'S CHAINLESS BICYCLE.

The rear wheel, it will be observed, is driven from both sides. By reason of the central position of the doubly-beveled transmission-wheel, lateral strains are minimized, particularly as the main driving-wheel and the bevel-pinion mesh with the transmission-wheel on opposite sides of the longitudinal central plane of the bicycle.

If desired, the rear stays can be enlarged so as to receive and cover the connecting-rods.

Automobile News.

A company is being formed in Italy for the purpose of placing a public service of automobiles in various parts of the country.

Several owners of large cotton fields in the South are investigating the possibility of successfully introducing a steam wagon for the transportation of the cotton crop from the field to the market.

An automobile is being experimented with in Boston for city work. The carriage is used by the Chief of the Public Building Department. The Mayor has ridden in it several times, and it was regarded as very successful.

According to The Horseless Age, Mr. and Mrs. John D. Davis, who were stalled at Toledo, O., have resumed their journey westward. All value to the industry of a trip of this kind is taken out of it by the long delays and the many breakdowns.

An international exhibition of automobiles at Berlin was opened on September 3. There were 140 vehicles shown by 120 exhibitors. An experimental line of electrical omnibuses is being operated in connection with the exhibition by the General Omnibus Company, of Berlin.

The Siemens & Halske Company, of Chicago, Ill., announce they will introduce the Berlin system of automobile omnibuses in Chicago. These cars carry twenty-five passengers and can run on either tracks or paved roadway. They will be operated by storage batteries and can be charged from a trolley line.

The Columbia Company, of Hartford, Conn., who have devoted great attention to electrical vehicles, as our readers are aware, have now turned to gasoline as a source of energy and are experimenting on the same with a view to putting gasoline carriages upon the market. There is an ample field for both gas and electrical carriages.

An automobile exhibition is being arranged in connection with the cycle show which is being held at Chicago, September 25 to October 9. It is the intention of the club to devote an hour during each evening's entertainment to an exhibition of automobiles on the track. One Chicago manufacturer will show twelve of them. A number of private owners of automobiles will show the working of their carriages. It is planned to have a road race between Chicago and Milwaukee at the close of the exhibition, and it is expected that there will be three charging stations on the road.

The University of California Plans.

Last year the regents of the University of California sent out invitations to the architects of Europe and the United States to participate in a competition whose object was to secure the best possible plans for new buildings for the university. A careful programme was outlined, and in deference to European architects, Antwerp was selected as the city where the first competition should be held, and one hundred and one plans were received from architects in every country in Europe and from the United States as well. A representative international jury passed on the plans.

Eleven plans were selected as entitling their makers to enter into the final competition, and a cash payment of $1,200 was made to each, and in addition an appropriation was made sufficient to cover the expenses of a trip to California for the purpose of studying the site which the new building will occupy. Most of those who were successful in the first competition have already made the trip to the Pacific coast. The date for the final competition was set for September 1, and prior to that time all the plans had been received. They were all so elaborate as regards detail that the jury required a week to make its decision. Finally, on September 8, they announced that the plan of M. E. Benard, of Paris, was successful and would receive the $10,000 prize. The choice was unanimous and is indorsed by the local profession as a just award. Messrs. Howells, Stokes & Hornbostel, of New York, received the second priz of $4,000, the third went to a Boston firm, the fourth to Howard & Cauldwell, and the fifth to Lord, Hewlett & Hull, of New York. Mrs. Phoebe A. Hearst gave $100,000 for defraying the necessary expense of the competition; she has also promised to bear the cost of some of the buildings. The whole scheme calls for $20,000,000.

GERMANY maintains schools in foreign countries, and a fund is freely voted for this purpose.