

“Preliminary Note on the Liquefaction of Hydrogen and Helium.” By JAMES DEWAR, M.A., LL.D., F.R.S., Ful-
lerian Professor of Chemistry in the Royal Institution.
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In a paper entitled “The Liquefaction of Air and Research at Low Temperatures,” read before the Chemical Society, and published in their ‘Proceedings,’ No. 158, an account is given of the history of the hydrogen problem and the result of my own experiments up to the end of the year 1895. The subject is again discussed in a Friday Evening Lecture on “New Researches on Liquid Air,”* which contains a drawing of the apparatus employed for the production of a jet of hydrogen containing liquid. It was shown that such a jet could be used to cool bodies below the temperature that could be reached by the use of liquid air, but all attempts to collect the liquid in vacuum vessels failed. No other investigator has so far improved on the results described in 1895. The type of apparatus used in these experiments worked well, so it was resolved to construct a much larger liquid air plant, and to combine with it circuits and arrangements for the liquefaction of hydrogen, which will be described in a subsequent paper. This apparatus, admirably constructed by the engineers, Messrs. Lennox, Reynolds, and Fyfe, took a year to build up, and many months have been occupied in testing and making preliminary trials. The many failures and defeats need not be detailed.

On May 10, starting with hydrogen cooled to -205° C., and under a pressure of 180 atmospheres, escaping continuously from the nozzle of a coil of pipe at the rate of about 10 cubic feet to 15 cubic feet per minute, in a vacuum vessel double silvered and of special construction, all surrounded with a space kept below -200° C., liquid hydrogen commenced to drop from this vacuum vessel into another doubly isolated by being surrounded with a third vacuum vessel. In about five minutes, 20 c.c. of liquid hydrogen were collected, when the hydrogen jet froze up from the solidification of air in the pipes. The yield of liquid was about 1 per cent. of the gas. The hydrogen in the liquid condition is clear and colourless, showing no absorption spectrum and the meniscus is as well defined as in the case of liquid air. The liquid has a relatively high refractive index and dispersion, and the density appears to be in excess of the theoretical density, viz., 0.18 to 0.12, which we deduce respectively from the atomic volume of organic compounds and the limiting density found by Amagat for hydrogen gas under infinite

* ‘Roy. Inst. Proc.,’ 1896.

compression. My old experiments on the density of hydrogen in palladium gave a value for the combined body of 0.62, and it will be interesting to find the real density of the liquid substance at its boiling point. Not having arrangements at hand to determine the boiling point, two experiments were made to prove the excessively low temperature of the boiling fluid. In the first place, if a long piece of glass tubing, sealed at one end and open to the air at the other, is cooled by immersing the closed end in the liquid hydrogen, the tube immediately fills, where it is cooled, with solid air. The second experiment was made with a tube containing helium.

The 'Cracow Academy Bulletin' for 1896 contains a paper by Professor Olszewski, entitled "A Research on the Liquefaction of Helium," in which he states "as far as my experiments go, helium remains a permanent gas and apparently is much more difficult to liquefy than hydrogen." In a paper of my own in the 'Proceedings of the Chemical Society,' No. 183 (1896-7), in which the separation of helium from Bath gas was effected by a liquefaction method, the suggestion was made that the volatility of hydrogen and helium would probably be found close together just like those of fluorine and oxygen. Having a specimen of helium which had been extracted from Bath gas, sealed up in a bulb with a narrow tube attached, the latter was placed in liquid hydrogen, when a distinct liquid was seen to condense. A similar experiment made with the use of liquid air under exhaustion in the same helium tube (instead of liquid hydrogen) gave no visible condensation. From this result it would appear that there cannot be any great difference in the boiling points of helium and hydrogen.

All known gases have now been condensed into liquids which can be manipulated at their boiling points under atmospheric pressure in suitably arranged vacuum vessels. With hydrogen as a cooling agent, we shall get within 20° or 30° of the zero of absolute temperature, and its use will open up an entirely new field of scientific inquiry. Even as great a man as James Clerk Maxwell had doubts as to the possibility of ever liquefying hydrogen.* No one can predict the properties of matter near the zero of temperature. Faraday liquefied chlorine in the year 1823. Sixty years afterwards Wroblewski and Olszewski produced liquid air, and now, after a fifteen years' interval, the remaining gases, hydrogen and helium, appear as static liquids. Considering that the step from the liquefaction of air to that of hydrogen is relatively as great in the thermo-dynamic sense as that from liquid chlorine to liquid air, the fact that the former result has been achieved in one-fourth the time needed to accomplish the latter, proves the greatly accelerated rate of scientific progress in our time.

* See 'Scientific Papers,' vol. 2, p. 412.

The efficient cultivation of this field of research depends upon combination and assistance of an exceptional kind; but in the first instance money must be available, and the members of the Royal Institution deserve my especial gratitude for their handsome donations to the conduct of this research. Unfortunately its prosecution will demand a further large expenditure. The handsome contribution made by the Goldsmiths Company ought also to be mentioned as very materially helping the progress of the work.

During the whole course of the low temperature work carried out at the Royal Institution, the invaluable aid of Mr. Robert Lennox has been at my disposal; and it is not too much to say that but for his engineering skill, manipulative ability, and loyal perseverance, the present successful issue might have been indefinitely delayed. My thanks are also due to Mr. J. W. Heath for valuable assistance in the conduct of these experiments.

“Effects of Prolonged Heating on the Magnetic Properties of Iron.” By S. R. ROGET, B.A. Communicated by Professor EWING, F.R.S. Received April 4,—Read May 12, 1898.

It has been known for some years that when transformers are kept in use, their open-circuit loss is liable to increase considerably with the lapse of time. This implies a deterioration of the iron core in regard to magnetic hysteresis. The subject began to receive attention in 1894-5, when some curves showing this increase in hysteresis were published by Mr. G. W. Partridge.* The effect was first thought to be due to a species of magnetic fatigue, resulting from repeated reversals of magnetism in the iron, but it was proved by Professor Ewing early in 1895 not to be due to this cause;† and was further shown by the experiments of Mr. Bláthy and Mr. Mordey to be a direct effect of heat and to occur in transformers as a consequence of the iron being maintained for long periods at a comparatively high temperature. Continued baking of iron was found to produce a similar augmentation of hysteresis. The published results of Mr. Mordey,‡ and, later, those of Mr. Parshall,§ deal with prolonged heating at temperatures which do not exceed 140° C. At the suggestion of Professor Ewing, the author has been carrying out, in the laboratory of the Engineering Department of Cambridge University, some investigations which deal with a more extended range of temperature. The experiments are still in progress, but

* ‘The Electrician,’ vol. 34, p. 160, December, 1894.

† *Ibid.*, p. 297, January, 1895.

‡ ‘Proc. Roy. Soc.,’ vol. 57, p. 224, June, 1895.

§ ‘Min. Proc. Inst. C.E.,’ vol. 126, p. 244.