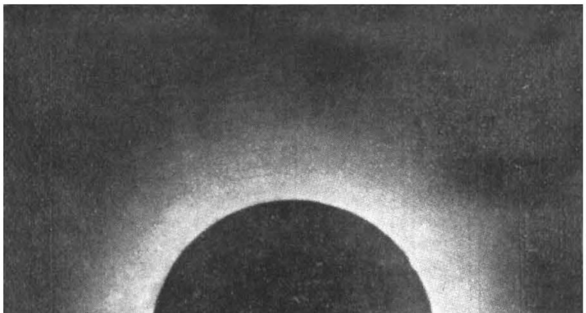
appeal is made for their general adoption. Rowland's scale of wave-lengths, as represented by the tables in course of publication in the journal above named, is to be employed, and the unit of wave-length is to be the ten-millionth of a millimetre, or "tenth-metre." For measurements of velocity in the line of sight, the kilometre is to be taken as the unit. To distinguish the lines of hydrogen, the nomenclature starting with H_α in the red and continuing in alphabetical order through the entire series is agreed upon. Maps of spectra are to be drawn with the red end to the right, and tables of wave-length are to be printed with the shorter wave-lengths at the top.

Although some of the leading workers in astrophysics have not been consulted, it is probable that these arrangements, so far as they go, will meet with general approbation. It is to be regretted, however, that the representation of intensities of spectrum lines was not considered, as a scale which every one might be willing to adopt is, perhaps, even more urgently required than any general agreement on the points to which reference is made above.

REPRODUCTION OF ASTRONOMICAL PHOTOGRAPHS.—The Council of the Royal Astronomical Society has lately undertaken the reproduction (by paper prints and lantern slides) of a selection of the instructive astronomical photographs in the possession of the Society. The prints and lantern slides are sold to Fellows of the Society at approximately cost-price, and full details as regard subject, instrumental data, exposure, &c., are given upon each. Among the celestial pictures which have been thus rendered available to a wider circle of astronomers, are photographs of total solar eclipses of 1886, 1889, and 1893, Dr. Roberts' photographs of the Pleiades and the Great Nebula in Orion, Prof. Barnard's photographs of the Milky Way, and of Brooks' and Swift's comets, Dr. Gill's photograph of the nebula about η Argûs, and MM. Loewy and Puiseux's lunar photographs. The accompanying illustration of the eclipse of April 16, 1893, has been reduced by one-third from a print sold by the Society. The original was taken by Sergt.-Major Kearney, R.E., at Fiundium, West Africa, with a Dallmeyer photoheliograph, the exposure being twenty seconds.



HOLMES' COMET.—Prof. Barnard has just published an account of his observations and photographs of this comet, made during its appearance in 1892 and 1893 (*Astrophysical Journal*, vol. iii. No. 1). Some of the telescopic features appear to have been quite unique. On January 4, 1893, only a feeble glow was visible; twelve days later it seemed like a hazy star, and the nucleus was actually seen to brighten in the few hours of observation, while the body itself expanded; six days afterwards, the nucleus had almost disappeared again. A photograph taken on November 10, 1892, is chiefly remarkable as showing a large irregular mass of nebulosity covering an area of at least a square degree, and connected with the comet by a short hazy tail. This curious appendage, which certainly belonged to the comet, seems to have been overlooked by most observers, but its recognition may possibly at some time or other prove to be of importance. The facts seem to be in favour of the comet having suddenly become bright just before the time of its discovery. It differed from the average comet in having a nearly circular orbit, and unless there had been some great change in its path, or some internal change, it should have been discovered long before. As the comet could not be seen with the Lick telescope during the succeeding opposition, Prof. Barnard thinks that it no longer exists in the cometary form, and will never be seen again.

THE LIQUEFACTION OF AIR AND RESEARCH AT LOW TEMPERATURES.[1]

THE best and most economical plant for the production of liquid air or oxygen is one based on the general principle of that used by Pictet in 1878, for liquefying oxygen; instead, however, of using Pictet's combined circuits of liquid sulphur dioxide and carbon dioxide kept in circulation by compression, liquefaction and exhaustion, it is better to employ ethylene in one circuit, as Cailletet and Wroblewski did, and to use nitrous oxide, or preferably carbon dioxide, in another. Further, instead of causing the oxygen to compress itself during its formation from potassium chlorate heated in an iron bomb connected with the refrigerator, it is found convenient to use gas previously compressed in steel cylinders.

A very convenient laboratory apparatus, the arrangements of the circuits of which will be easily understood from the sectional view shown in Fig. 1, has been devised for the liquefaction of small quantities of oxygen or other gases; with this simple arrangement, 100 c.c. of liquid oxygen can readily be obtained, using liquid carbon dioxide at – 79° C. for cooling and employing no exhaustion. The gaseous oxygen, cooled before expansion by passing through a spiral of copper tube immersed in solid carbon dioxide, passes through a fine screw stopcock under a pressure of 100 atmos., and thence backwards over the coils of pipe. The liquid oxygen begins to drop in about a quarter of an hour from starting. The pressure in the oxygen cylinders at starting is generally about 150 atmos., and the best results are got by working down to about 100. This little apparatus will enable liquid oxygen to be used for demonstration and research in all laboratories.

By employing jacketed glass vessels, of which the annular space is highly exhausted, for storing liquefied gases, the influx of heat is reduced to one-fifth of that which occurs when the jacket contains air; if the interior walls are silvered, or excess of mercury vapour is left in the jacket, the influx of heat is again reduced to one-sixth, so that the total effect of the high vacuum and the silvering is to reduce the ingoing heat to about $3\frac{1}{2}$ per cent. of that which enters when these precautions are neglected. The suggestion that the metallic coating is useless, because Pictet has found that all kinds of matter are transparent to heat at low temperatures, is thus disposed of; further, no increase in the transparency of glass to thermal radiation occurs on cooling to the boiling point of air.

In order to test Olszewski's statement that air cannot be solidified at the lowest pressures (*Phil. Mag.*, February 1895), the author's former experiments have been repeated on a larger scale. If a litre of liquid air be exhausted in a silvered vacuum vessel, half a litre of solid air may be obtained and kept solid for half an hour. The solid is at first a stiff transparent jelly, which, when placed in a magnetic field, has the still liquid oxygen drawn out to the poles, showing that solid air is a nitrogen-jelly containing liquid oxygen. Solid air can only be examined in a vacuum or an atmosphere of hydrogen, because it instantly melts on exposure to the air, causing an additional quantity of air to liquefy; it is strange to see a mass of solid air melting in contact with the atmosphere, and all the time welling up like a fountain.

On causing dry air, contained in sealed flasks, to solidify by

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[1] A paper read before the Chemical Society on December 19, 1895, by Prof. J. Dewar, F.R.S. (Abridged from the *Proceedings* of the Society issued January 14.)

immersing the side arms attached to the flasks in liquid air boiling under a low pressure, and subsequently hermetically sealing off the side arms containing the solid, the residual air left in the flasks may be preserved for analysis; it is then ascertained that the residual air still contains oxygen and nitrogen in the usual proportion. In the earlier experiments, the argon solidified before the nitrogen, but chemical nitrogen and air nitrogen with its 1·1 per cent. of argon behaved in substantially the same way on liquefaction.

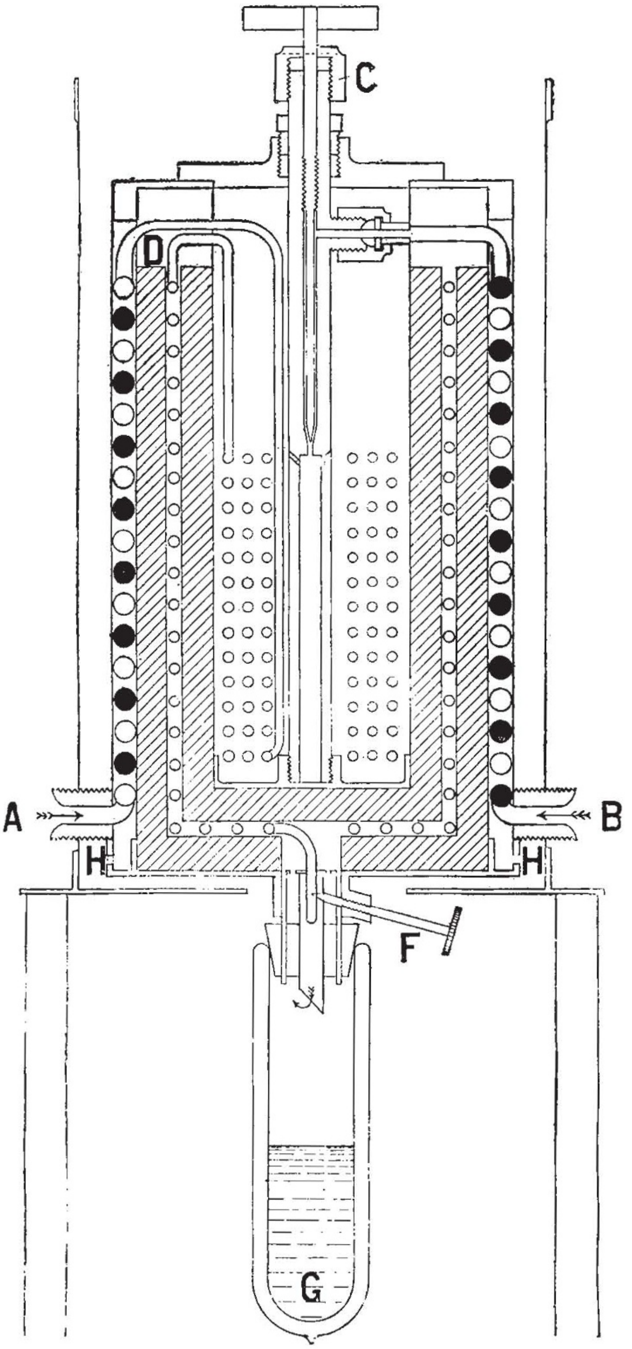

Fig. 1.—A, air or oxygen inlet. B, carbon dioxide valve. D, regenerator coils. F, air or oxygen expansion valve. G, vacuum vessel with liquid oxygen. H, carbon dioxide and air outlet. ○, air coil. ● carbon dioxide coil.

Olszewski has examined liquid nitric oxide, and describes it as colourless, but on strongly cooling several carefully purified samples of this gas, which had been prepared by different methods, the author obtained in each case a nearly white solid melting to a blue liquid. The colour is more marked at the melting than at the boiling point, and the liquid is not magnetic. Solid nitric oxide is not phosphorescent, nor does it show any chemical action in liquid oxygen, provided the tube containing it is completely immersed; but if the tube full of liquid oxygen be lifted into the air, a violent explosion almost instantly occurs.

In a good vacuum vessel, specific gravities may be taken in liquid oxygen as easily as in water. Some twenty substances were weighed in liquid oxygen, and the apparent density of the liquid calculated; the results were then corrected, using Fizeau's values for the variation of the coefficients of expansion of the solids employed, and the real density of liquid oxygen was thus calculated as 1·1375 under a pressure of 766·5 m.m. The variation of density is about ± 0·0012 for 20 m.m. pressure. Wroblewski found the density of liquid oxygen at the boiling point to be 1·168, whilst Olszewski found 1·124. Fizeau's parabolic law for the variation of the coefficient of expansion holds down to −183°; the solid which contracted least during cooling was a compressed cylinder of silver iodide, that which contracted most a block of compressed iodine.

Similarly the density of liquid air was found to be 0·910 and that of nitrogen at its boiling point 0·850. No great accuracy attaches to the density of liquid air as thus determined, for liquid air kept in a silvered vacuum vessel rises 1° in boiling point every ten minutes during the first hour; the density of liquid air, however, does not reach that of pure oxygen even after thirty hours' storage.

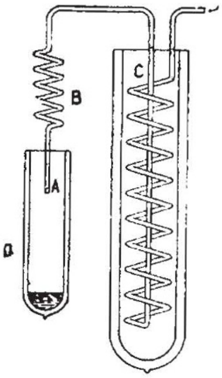

Fig. 2.

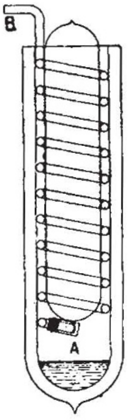

Fig. 3.

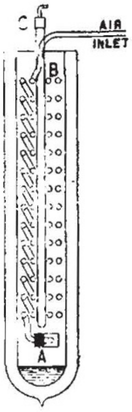

Fig. 4.

A small ignited jet of hydrogen burns continuously below the surface of liquid oxygen, all the water produced being carried away as snow. There is a considerable amount of ozone formed, which concentrates as the liquid oxygen evaporates. In the same way graphite, or diamond, when properly ignited, burns continuously on the surface of liquid oxygen, producing solid carbonic acid and generating ozone. If liquid oxygen is absorbed in wood charcoal, or cotton wool, and a part of the body heated to redness, combustion can start with explosive violence.

The experiments of Joule and Thomson and Regnault on the temperature of gas jets issuing under low pressures are well known; the following observations refer to the pressure required to produce a lowering of temperature sufficient to yield liquid in the gas jet. The apparatus used in the study of highly compressed gas jets is sketched in Fig. 2; C is a vacuum tube holding a coil of pipe about 5 mm. in diameter along with carbon dioxide or liquid air for cooling the gas before expansion, and A is a small hole in the silver or copper tube about $\frac{1}{6}$ mm. in diameter, which takes the place of a stopcock. When carbon dioxide gas, at a pressure of 30 or 40 atmos., is expanded through such an aperture, liquid can be seen where the jet impinges on the wall of the vacuum tube along with a considerable amount of solid. If oxygen gas escapes from the small hole at the pressure of 100 atmos., having been cooled previously to −79° in the vessel C, a liquid jet is just visible. It is interesting to note in passing that Pictet could get no liquid oxygen just below 270 atmos., owing to his stopcock being massive and outside the refrigerator. If the oxygen is replaced by air, no liquid jet can be seen unless the pressure is raised to 180 atmos. If the carbon dioxide is cooled by exhaustion (to about 1 in. pressure) or –115°, liquid air can easily be collected in the small vacuum vessel D, or if the air pressure is raised above 200 atmos., keeping the cooling at –79° as before. The chief difficulty is in collecting the liquid, owing to the rapid current of gas. The amount of liquid in the gas jet is small, and its collection is greatly facilitated by directing the spray on to a part of the metallic tube above the little hole, or by increasing resistance to the escaping gas by placing some few turns of the tube, like B in the figure, in the upper part of the vacuum tube, or generally by pushing in more tube in any form. For better isolation, the pipe can be rolled between two vacuum tubes, the outer one being about nine inches long and one and a half inches diameter, as shown in Fig. 3; the aperture in the metal pipe has a small piece of glass tube over it, to help the collection of the liquid. Using this apparatus and an air supply at 200 atmos. with no previous cooling, liquid air begins to collect in about five minutes, but the liquid jet can be seen in two to three minutes. In Fig. 4 the metallic tube in the vacuum vessel is placed in horizontal rings, leaving a central tube for the passage of the glass tube C, which is used to cool bodies or examine gases under compression; the inner tube can be filled for an inch with liquid air at 60 atmos. pressure, in about three minutes. A double coil of pipe may be advantageously used in some experiments; the efficiency is low, but it affords a quick method of reaching low temperatures and collecting a few hundred cubic centimetres of liquid air. By the use of this apparatus air at the ordinary temperature can be simply converted into liquid air at the boiling point, –194°, in less than ten minutes; a fall of 200° is effected in this short period of time.

The author, after giving a sketch of the results up to the present achieved in connection with the liquefaction of hydrogen, remarks that hydrogen, cooled to –194° (80° abs. *t*), the boiling point of air, is still at a temperature which is two and a half times its critical temperature, and its direct liquefaction at this point would be comparable to that of air taken at 60°, and liquefied by the apparatus just described. Now, air supplied at such a high temperature greatly increases the difficulty and the time required for liquefaction. Still, it can be done, even with the air supply at 100°, in the course of seven minutes; and this is the best proof that hydrogen, if placed under really analogous conditions, at –194° must also liquefy with the same form of apparatus. Hydrogen, cooled to –200°, was forced through a fine nozzle under 140 atmos. pressure, and yet no liquid jet could be seen. If the hydrogen contained a few per cent. of oxygen the gas jet was visible, and the liquid collected, which was chiefly oxygen, contained hydrogen in solution, the gas given off for some time being explosive.

If, however, hydrogen, previously cooled by a bath of boiling air, is allowed to expand at 200 atmos. over a regenerative coil similar to that shown in Fig. 2, but longer, a liquid jet can be seen after the circulation has continued for a few minutes along with a liquid which is in rapid rotation in the lower part of the vacuum vessel. The liquid did not accumulate, owing to its low specific gravity and the rapid current of gas. These difficulties will doubtless be overcome by the use of a differently shaped vacuum vessel and by better isolation. The liquid jet can, however, be used as a cooling agent, like the spray of liquid air obtained under similar circumstances, and, this being practicable, the only difficulty is one of expense. In order to test in the first instance what the hydrogen jet could do in the production of lower temperatures, liquid air and oxygen were placed in the lower part of the vacuum tube just covering the jet. The result was that in a few minutes about 50 c.c. of the respective liquids were transformed into hard white solids resembling avalanche snow, quite different in appearance from the jelly-like mass of solid air got by the use of the air pump. The solid oxygen had a pale, bluish colour, showing by reflection all the absorption bands of the liquid. There is no reason, apart from that of cost, why a spray of liquid hydrogen, at its boiling point in an open vacuum vessel, should not be used as a cooling agent in order to study the properties of matter at some 20° or 30° above the absolute zero.

The only widely distributed element which has not yet been liquefied is fluorine; and it would seem that, although the atomic weight of fluorine is nineteen times that of hydrogen, it must in the free state approach hydrogen in volatility. If the chemical energy of fluorine is abolished at low temperatures, like that of other active substances, some kind of glass or transparent substance, less brittle than calcium fluoride, could be employed in the form of a tube, and the liquefaction of fluorine achieved by the use of hydrogen as a cooling agent.

SCIENCE IN THE MAGAZINES.

POLITICS saturates the February magazines, but science is not altogether drowned in this plethora of diplomatic diatribes. There are four articles in the *Contemporary* of interest to scientific readers. Mr. Herbert Spencer traces the development of the sculptor, and shows how, in its primitive character, sculpture was an auxiliary to ancestor-worship. "The tomb and the temple are," he shows, "developed out of the shelter for the grave—rude and transitory at first, but eventually becoming refined and permanent; while the statue, which is the nucleus of the temple, is an elaborated and finished form of the original effigy placed on the grave. The implication is that, as with the temple so with the statue, the priest, when not himself the executant, as he is among savages, remains always the director of the executant—the man whose injunctions the sculptor carries out." Mr. W. H. Hudson writes pleasantly, if somewhat aimlessly, about the village of Selborne and of the simple naturalist whose observations have made it famous. Mr. W. H. Mallock continues his study of "Physics and Sociology." The argument of the two articles which preceded the present one may be thus summarised: Great men are analogous to atoms of superior size, on whose presence the aggregation of all the other atoms depend, therefore they should form the first study of the sociologist. Two propositions (among others) which follow from this conclusion are now stated by Mr. Mallock; the first of them being more or less of a heresy, so far as scientific opinion is concerned. The propositions are as follows. (1) Other things being equal, communities progress and become civilised not in proportion to the talents of the mass of the individuals who compose them, but in proportion to the percentage which occurs in each of the individuals whose talents are superior to those of the mass. (2) Other things being equal, communities progress and become civilised in proportion to the desirability of the rewards which are practically attainable in each by the exercise of superior talents, and which thus stimulate the possessors of these talents to develop them, and make them actual instead of merely potential. Mr. D. C. Boulger having suffered from diphtheria, and been made a victim of the anti-toxin treatment, survived, and now records his experience of the disagreeable character of the disease and its sequelæ, all of which unpleasantness was aggravated, in his opinion, by the employment of antitoxic serum. From his particular case, he passes to a general discussion of diphtheria and antitoxin, which he condemns. So few are the gifts to science and education in England, that we rejoice to find Mr. Bernard Shaw commending in the *Contemporary* such benefactions to the attention of millionaires. The questions which a millionaire, moved by a generous spirit to benefit any locality, should ask himself are: "Has it a school, with scholarships for the endowment of research, and the attraction of rising talent at the universities? Has it a library, or a museum? If not, then he has an opening at once for his ten thousand or hundred thousand pounds."

"Reflex Action, Instinct, and Reason" are discussed from the point of view of their development in the *Fortnightly* by Mr. G. A. Reid. It suffices here to call attention to the article, which is a chapter from a forthcoming book on "The Present Evolution of Man," and to state the definitions of instinct and reason given in it. Instinct is defined as "the faculty which is concerned in the conscious adaptation of means to ends," by virtue of inborn inherited knowledge and ways of thinking and acting. Reason is defined as "the faculty which is concerned in the conscious adaptation of means to ends" by virtue of acquired non-inherited knowledge and ways of thinking and acting. An admirable article on "Plant Names" appears in the *Quarterly Review* (January), being a review of the "Index Kewensis" and of four other recent publications upon the names of plants. In the *National*, Mr. Walter B. Harris describes Tiflis, the capital of Transcaucasia, and in *Scribner* an interesting account is given of an ascent of Mount Ararat, the paper being illustrated by several of the finest specimens of process-work we have ever seen.