THE LIQUEFACTION OF OXYGEN.

BY M. RAOUL PICTET.

The object I have had in view for more than three years is to demonstrate experimentally that molecular cohesion is a general property of bodies to which there is no exception. If the permanent gases are not capable of liquefying, we must conclude that their constituent particles do not attract each other, and thus do not conform to this law. Thus, to cause experimentally the molecules of a gas to approach each other as much as possible certain indispensable conditions are necessary, which may be expressed thus: 1. To have the gas absolutely pure, with no trace of foreign gas. 2. To be able to obtain extremely energetic pressures. 3. To obtain intense cold and to subtract heat at these low temperatures. 4. To utilize a large surface for condensation at these low temperatures. 5. To be able to utilize the rapid expansion of the gas from extreme intense condensation to the atmosphere pressure, an expansion which, added to the preceding means, will compel liquefaction. Having fulfilled these five conditions, we may formulate the following alternative: When a gas is compressed to 500 or 600 atmospheres and kept at a temperature of —100° or —140°, and it is allowed to expand to the atmospheric pressure, one of two things takes place: either the gas, obeying the force of cohesion, liquefies and yields its heat of condensation to the portion of gas which expands or loses itself in the gaseous form, or, on the hypothesis that cohesion is not a general law, the gas must pass to the absolute zero and be come inert—that is to say, an impalpable powder.

The work done by expansion will not be possible, and the loss of heat will be absolute.

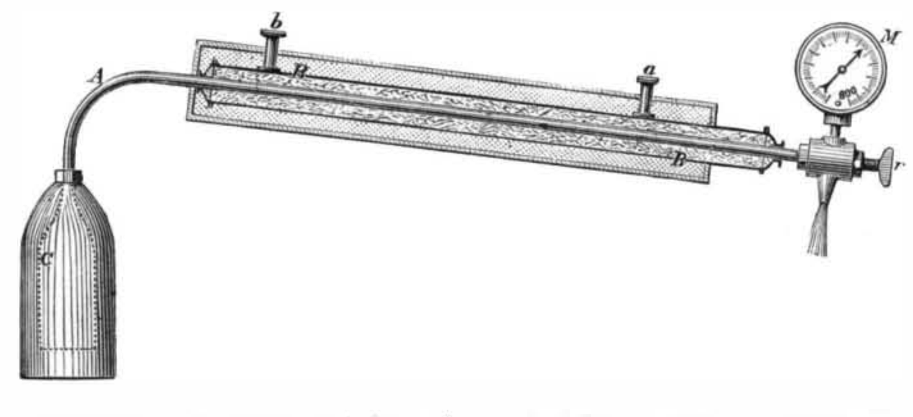
Struck with the truth of this alternative, which is rendered certain by thermo-dynamic equations based on accurate data, I have sought to produce a mechanical arrangement which should entirely satisfy these different conditions, and I have chosen the complicated apparatus of which the following is a brief description:

I take two pumps, P_3 and P_4, for exhaustion and compression such as are used industrially in my ice-making apparatus. I couple these pumps in such a way that the exhaustion of one corresponds to the compression of the other. The exhaustion of the first communicates with a tube, R, of 1·1 meter long and 12·5 centimeters in diameter, and filled with liquid sulphurous acid. Under the influence of a good vacuum the temperature of this liquid rapidly sinks to —65° and even to —73°, the extreme limit attained. Through this tube of sulphurous acid passes a second smaller tube, S, of 6 centimeters in diameter and the same length as the envelope. These two tubes are closed by a common base. In the central tube is retained compressed carbonic acid produced by the reaction of hydrochloric acid on Carrara marble. This gas being dried is stored in an oil gasometer, G, of 1 cubic meter capacity. At a pressure of from 4 to 6 atmospheres the carbonic acid easily liquefies under these circumstances. The resulting liquid is led into a long copper tube, B, 4 meters in length and 4 centimeters in diameter. Two pumps, P_1 and P_2, coupled together like the first, exhaust carbonic acid either from the gasometer, G, or from the long tube, B, full of liquid carbonic acid. The ingress to these pumps is governed by a three-way tap, H. A screw valve cuts off at will the ingress of the liquid carbonic acid in the long tube; it is situated between the condenser of carbonic acid and this long tube. When this screw valve is closed and the two pumps draw the vapor from the liquid carbonic acid contained in the tube 4 meters long, and the greatest possible lowering of temperature is produced, the carbonic acid solidifies and descends to about —140°. The subtraction of heat is maintained by the working of the pumps, the cylinders of which take out 3 liters per stroke and the speed is 100 revolutions per minute.

Both the sulphurous acid tube and the carbonic acid tube are covered with a casing of wood and non-conducting stuff to intercept radiation.

In the interior of the carbonic acid tube, B, passes a fourth tube, A, intended for the compression of oxygen; it is 5 meters long and 14 millimeters in external diameter. Its internal diameter is 4 millimeters. This long tube is consequently immersed in solid carbonic acid, and its whole sur face is brought to the lowest obtainable temperature. These two long tubes are connected by the ends of the carbonic acid tube, consequently the small tube extends about 1 meter beyond the other. I have curved this portion downward and given the two long tubes a slightly inclined position, but still very near the horizontal, as I have shown in the accompanying drawing.

The engravings given herewith, which we take from the *Chemical News*, will be more clearly understood from the following references: A. A tube 14 millimeters external diameter and 4 millimeters internal diameter, in which the oxygen condenses. It is furnished with a screw tap, 2, from which the liquid oxygen jets out. A pressure gauge, M, measures the pressure up to 800 atmospheres. B. A tube 4 meters long, in which is solid carbonic acid. The stock of carbonic acid is contained in a gasometer, G, of 1 cubic meter capacity. A three-way tap, H, puts it when desired into communication with the apparatus. C. A howitzer shell containing 700 grammes of chlorate of potash mixed with chloride of potassium. It is heated with gas.

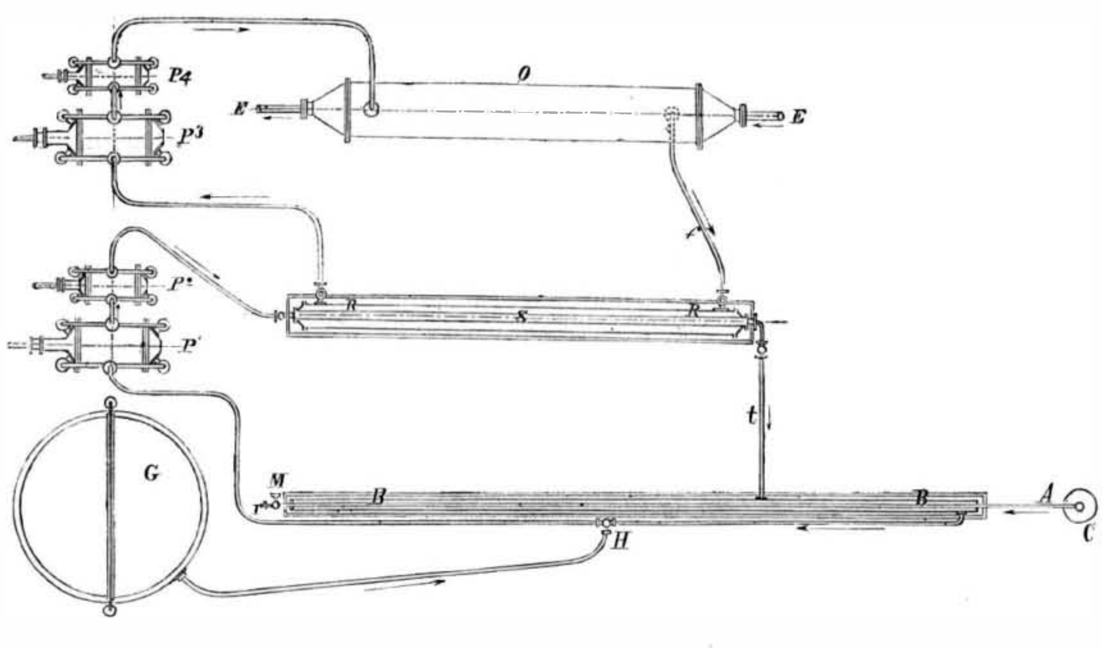


PICTET'S APPARATUS FOR THE LIQUEFACTION OF OXYGEN.

P_1 P_2. Double-action exhaustion and force pumps, drawing carbonic acid from the tube, B, or the gasometer, G, according to the position of the tap, H. S. A tube 60 millimeters in diameter and 1·1 meter long, in which is condensed the liquid carbonic acid compressed by the pumps. This liquefied gas returns by the small tube, *t*, to the tube B. R. A tube 125 millimeters in diameter and 1·1 meter long, containing liquid sulphurous acid. P_3 P_4. Double-action exhaustion and force pumps, exhausting sulphurous acid gas from the tube R. Q. A tubular condenser of sulphurous acid compressed by the pumps. This body when liquefied returns by the small tube, *f*, to the tube R. The cold water for condensing the sulphurous acid passes through the apertures, E E. *a*. Entry for liquid carbonic acid. *b*. Exit for the vaporized carbonic acid caused by the suction of the pumps.

The small central tube is curved at A, and screws into the neck of a large howizer shell, C, the sides of which are 35 millimeters thick; the height is 28 centimeters, and the diameter 17 centimeters.

This shell contains 700 grammes of chlorate of potash and 256 grammes of chloride of potassium mixed together, fused, then broken up, and introduced into the shell perfectly dry.



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When the double circulation of the sulphurous and carbonic acids has lowered the temperature to the required degree, I heat the shell over a series of gas burners. The decomposition of the chlorate of potash takes place at first gradually, then rather suddenly toward the end of the operation. A pressure gauge, M, at the extremity of the long tube, lets me constantly observe the pressure and the progress of the reaction. This gauge is graduated to 800 atmospheres, and was made for me expressly by Bourdon, of Paris.

When the reaction is terminated the pressure exceeds 500 atmospheres; but it almost immediately sinks a little, and stops at 320 atmospheres. If at this moment I open the screw tap, *r*, which terminates the tube, a jet of liquid is distinctly seen to spurt out with extreme violence. I close the tap, and in the course of a few moments a second jet—less abundant, however—can be obtained. Pieces of charcoal, slightly incandescent, put in this jet inflame spontaneously with inconceivable violence. I have not yet succeeded in collecting the liquid, on account of the considerable projectile force with which it escapes, but I am trying to arrange a pipette, previously cooled, which possibly may be able to retain a little of this liquid.

Yesterday I repeated this experiment before the majority of the members of our Physical Society, and we had three successive jets, well characterized. I cannot yet determine the minimum pressure necessary, for it is evident that I have a surplus pressure produced by the excess of gas accumulated in the shell, and which could not condense in the small space represented by the interior tube.

I hope to utilize a similar arrangement in attempting the condensation of hydrogen and nitrogen, and I am especially occupied with the possibility of maintaining low temperatures very easily, thanks to four large industrial pumps which I have at my disposal, worked by a steam engine.

GENEVA, December 25, 1877.

Since receiving the above we have been favored with further particulars of an experiment which was performed for the fourth time on Thursday, December 27th, in the presence of ten scientific men—among others, Professor Hagenbach, of Basle, who came expressly to assist at this important experiment.

At 10 o'clock in the evening the manometer, which had risen to 560 atmospheres, sank in a few minutes to 505, and remained stationary at this figure for more than half an hour, showing by this diminution in the pressure that part of the gas had assumed the liquid form under the influence of the 140 degrees of cold to which it was exposed. The tap closing the orifice of the tube was then opened, and a jet of oxygen spurted out with extraordinary violence.

A ray of electric light being thrown on the escaping jet showed that it was chiefly composed of two parts—one central, and some centimeters long, the whiteness of which showed that the element was liquid, or even solid; the other exterior, the blue tint of which indicated the presence of oxygen compressed and frozen in the gaseous state.

The success of this remarkable and conclusive experiment called forth the applause of all present.

We understand that Messrs. Pictet and Co., of 22 Rue de Grammont, Paris, are fitting up apparatus with the intention of having these experiments repeated at their Freezing-Machine Works, at Clichy, Paris. We read in the *Times* that on the morning of Monday, December 31st, 1877, in the presence of three members of the Institute, M. Cailletet effected the liquefaction of hydrogen, nitrogen, and atmospheric air, thus proving that all gases can be liquefied.

A New Chimera.

The discovery of a new fish in American waters has been announced by Professor Gill to the Philosophical Society of Washington, D. C. It is of a uniform lead color, and has been named *Chimera plumbea*. It was caught near the La Have Bank, about 250 miles southeast of Halifax. Its form is said to be quite distinct from the European *Chimera monstrosa*, which is fortunate, since that appropriately named fish is one of the ugliest in existence.

DEATH OF THE DISCOVERER OF FŒTAL AUSCULTATION.—The Count de Kergaredec, the first to apply auscultation to the detection of the fœtal heart in pregnancy, died lately in Paris at an advanced age. His son in announcing his death to the French Academy said: "Among his children who stood around his death bed was that beloved daughter, the beating of whose heart her father heard while she was still in her mother's womb."

A TOLLING machine has been erected at Ealing cemetery at the cost of £80, and seems to give universal satisfaction. It was calculated that this method of doing things would (at 300 funerals a year) be in the long run cheaper than paying a man threepence an hour to ring the bell. Thus we mourn for the departed.

OUR public schools should embrace the science of man, the science of agriculture, the science of mechanics, the science of housewifery, and the moment we enter the domain of nature our range is unlimited.—*William Crandle.*