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LIQUEFACTION OF GASES—CAILLETET'S EXPERIMENTS.

We recently laid before our readers full details of the very important experiments made by M. Raoul Pictet, which resulted in the liquefaction of oxygen, air, and other gases hitherto supposed to be permanent. We also noted that simultaneously with M. Pictet, who carried on his investigations in Geneva, M. Cailletet, of Paris, had experimented in the same direction, though by different means, and had obtained similarly successful results.

M. Cailletet is engaged in iron manufacturing, and his researches were conducted at his foundery at Châtillon-sur-Seine. The apparatus used by him is represented in the annexed engravings, for which we are indebted to *La Nature*. A hollow steel cylinder, A, Fig. 1, is solidly fixed on a cast iron frame by the straps, B. This is filled with water, and entering it is a soft steel plunger, to the extremity of which is attached a heavily-threaded screw, which enters the bronze nut, F, of the large hand wheel, M. The nut is prevented from horizontal motion and is held in a heavy strap, as shown, so that when it is rotated by turning the hand wheel it causes the screw to move forward or back, and so moves the plunger into or out of the cylinder. A leather washer inside the latter prevents any escape of the liquid within. In order to introduce the water or other fluid to be compressed into the cylinder, it is poured into the receiver, G, which communicates with the interior, the passage being closed at will by a conical steel screw, operated by the hand wheel, O. By this means compressed gases may be suddenly allowed to expand and to produce an intense fog in the capillary tube inclosed in the glass cylinder, *m*. This fog is formed under the influence of the exterior cold produced by the sudden expansion, and is a sure sign of the liquefaction or even congelation of the gases hitherto regarded as permanent. The other portions of the apparatus may briefly be described as follows: *a* is a hollow steel reservoir capable of supporting a pressure of 900 or even 1,000 atmospheres. It is connected to the compression apparatus by a metallic capillary tube. Water, under the action of the plunger, enters this reser-

Fig. 2.

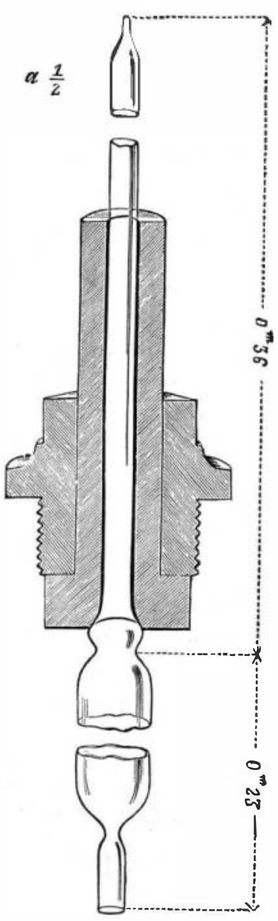
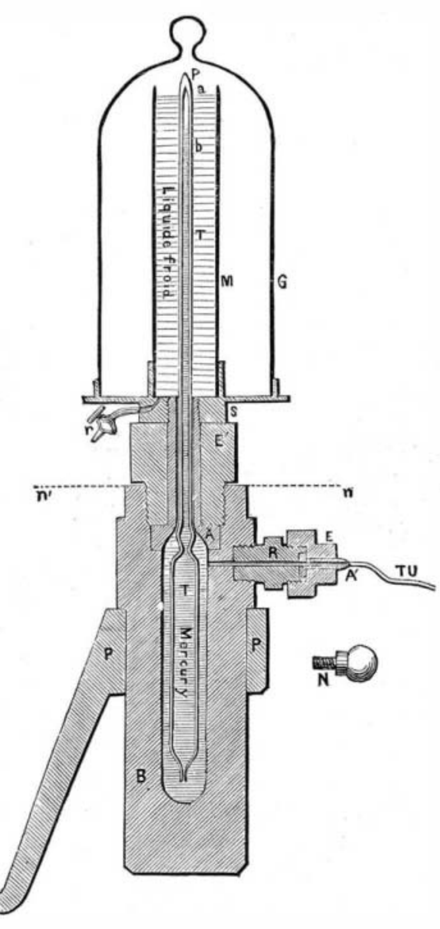


Fig. 3.



voir and acts on mercury, which compresses the gas. *b* is the adjutage which receives the glass vessel which contains the gas experimented upon. A screw serves to fix this piece to the upper part of the reservoir. Fig. 2 shows this arrangement half its natural size. *m* is a glass cylinder containing another cylinder in which is the fine tube in which the gas is liquefied. This capillary tube may thus be surrounded by liquid protoxide of nitrogen and other refrigerating liquids. The exterior cylinder contains moisture-absorbing material so as to prevent a deposit of ice or vapor on the cooled tube, which would hinder observation. *p* is a cast iron tablet which supports the reservoir, *a*. Screws, *d d*, allow of lifting or lowering the reservoir for spectroscopic examination. An adjutage, S, unites the metallic capillary tubes and transmits the pressure to the different parts of the apparatus. N is a Thomasset manometer modified and verified by means of a free air manometer established on a hillside near the laboratory. N' represents a glass manometer which serves to control the indications of the first mercury apparatus.

No danger attends the use of this machine, as the glass tube in which the gas is compressed presents but a very small surface and would do no harm if it broke.

In discussing these experiments in our former issue we referred to Dr. Andrews' experiments. One of the chief deductions made by him was that there existed for permanent gases a "critical point" of pressure and temperature above which they could not be brought to a liquid state. M. Cailletet's experiments have confirmed this, and proved that for every gas a certain pressure must be combined with a certain lowering of temperature. Neither influence alone is sufficient to produce the desired result, no matter what the intensity may be. M. Cailletet first liquefied nitric oxide. This gas remained gaseous at the pressure of 270 atmospheres and at a temperature of 46·4° Fah. Marsh gas, on the other hand, liquefied at 180 atmospheres and 44·6° Fah.

"If oxygen or pure carbonic oxide be inclosed in the compression apparatus," says M. Cailletet, "if these gases be brought to the temperature of —20·2° Fah. by means of sulphurous acid and under a pressure of about 300 atmospheres,

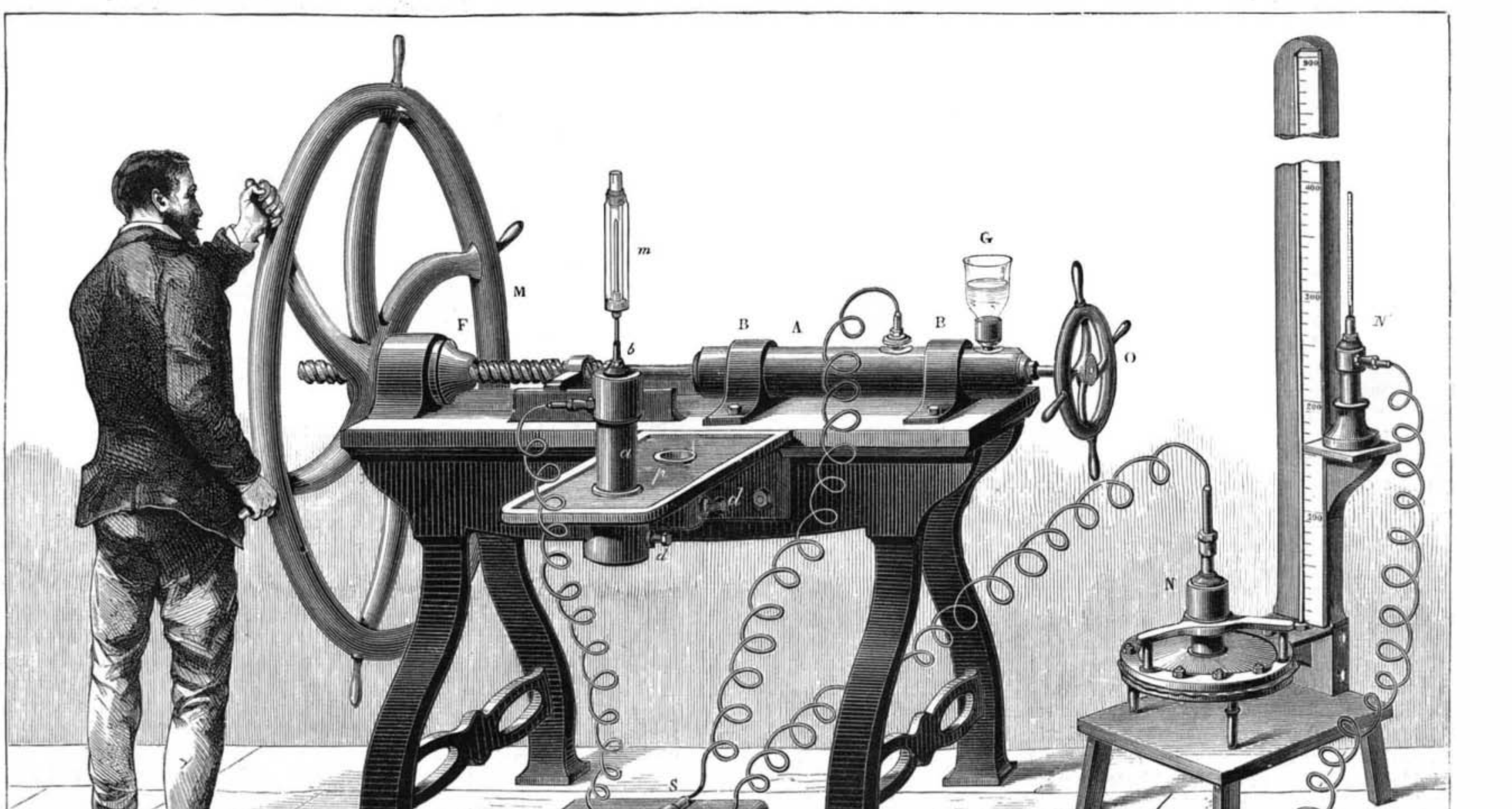


Fig. 1.—CAILLETET'S APPARATUS FOR LIQUEFYING GASES.

both will retain their gaseous state. But if they be subjected to sudden expansion, which according to Poisson's formula should produce a temperature of at least 392° Fah. below that existing, an intense fog is at once seen, due to their liquefaction and possibly to their solidification. The same phenomenon is observed on the expansion of carbonic acid, and nitrous and nitric oxides when strongly compressed." Shortly after having obtained this result, M. Cailletet announced to the French Academy of Sciences his success in liquefying nitrogen, atmospheric air, and even hydrogen itself, hitherto found the most refractory of all gases. M. Cailletet furnishes the following details to the *Comptes Rendus* of the French Academy:

Nitrogen.—Pure or dry nitrogen compressed to about 200 atmospheres at a temperature of 55·4° Fah., then expanded suddenly, condenses and appears first in the form of spray, in drops of appreciable volume. This liquid disappears gradually, its vanishing beginning at the exterior and extending toward the center, until finally a single vertical column remains in the axis of the tube for a few seconds.

Hydrogen.—This gas compressed to 280 atmospheres and expanded gives a thick fog throughout the entire tube, which however suddenly disappears.

Air.—Atmospheric air was first dried and deprived of all traces of carbonic acid, and then treated as above described. The data of temperature, etc., we have already given in our previous article.

In Fig. 3 is illustrated a small and simple apparatus designed by M. Cailletet, which may be used for exhibiting the liquefaction of gases before a class. It is an exact copy of the parts, *a* and *m*, of the large apparatus shown in Fig. 1. The glass cover is modified and the screw press is replaced by a pump. T T is a glass tube filled with the gas to be compressed, it being previously traversed by a gaseous current until all air is expelled. To this end it is first placed in a horizontal position; when it is full of gas, the end, P, is sealed up hermetically by heat, and the other end is held closed by the finger until it is introduced in the wrought iron device below and enters a cylindrical hollow containing mercury. The upper part of the tube is enveloped in a glass cylinder, M, which is filled with a refrigerating mixture, and over all is placed the bell glass, G. The tube, T U, is connected with the hand compressing pump, which is provided with a suitable manometer. The water compressed by the pump acts on the upper part of the mercury, as shown by the horizontal lines in our figure. The mercury is thus driven into the tube, T T, and reduces the space occupied by the gas. It soons becomes covered with little drops of the compressed vapor, which unite in a liquid mass, *b*.

B is a block of very resistant forged iron; E′ and E are screws which allow of the apparatus being taken apart; A′ is an adjutage; P P, three legged strong support for the apparatus; S, support for the bell, G, and cylinder, M; N, supplementary screw designed to close the aperture, R, when mercury is placed in the apparatus. The large lower portion of the tube, T, being subjected to equal pressure within and without, cannot break, and the only portion open to rupture is the small upper part of the tube, which may be made exceedingly strong. The experiment may, by the electric or oxyhydrogen light, be projected on a screen, when all the phenomena may be followed by the eye without incurring any danger through breakage.

Improved Cow Stables.

Mr. J. Wilkinson, of Harvard, Ill., commenting on the article in SCIENTIFIC AMERICAN SUPPLEMENT, No. 105, p. 1674, entitled "Labor Saving Cows," protests against the use of any such device, as well as against all the other methods in general use for keeping stables clean. He styles them all barbarous, and claims that his plan, which he has advocated for twenty years in various journals (and which we remember having read), is the only perfect one.

His method is to construct an open or latticed floor, through which the solid and liquid excrements fall, the former into a concealed gutter and the latter into a receptacle from which it immediately flows out of the building into a cistern constructed for the purpose. By a system of sub-earth ventilation the excrement lying in the gutter beneath the flow is soon cooled and its surface dried so that all fetid exhalations soon cease. The open floor being always dry and comparatively clean, he dispenses with bedding entirely.

Honors to American Scientists.

Although it has not hitherto been the policy of the Committee on Foreign Affairs to encourage the receiving of decorations and medals by officers of the United States, it recently reported back, with a recommendation that it pass, the bill authorizing Spencer F. Baird, Assistant Secretary of the Smithsonian Institution, to receive from the King of Sweden a diploma and medal, constituting him a member of the Norwegian Order of Saint Olaf, as a testimonial of distinguished scientific service. In the opinion of the committee of Congress, Professor Baird is not an officer of the United States in any such sense that there could be any serious objection to permitting him to accept a diploma as member of a literary organization of a foreign country. The bill was therefore passed.

Professor Hall, of the Naval Observatory, the discoverer of the two satellites of Mars, has bestowed on them the names of "Deimus" and "Phobus," and the Bureau of Navigation of the Navy Department has approved of them. They were suggested, it is said, by Mr. Madan, of Eaton, England, and will probably be accepted by astronomers.

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(Illustrated articles are marked with an asterisk.)

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THE SCIENTIFIC AMERICAN SUPPLEMENT
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PARADOXES IN STEAM.

It has been stated by some observers that if a watery solution of any salt is heated to its boiling point, the temperature of the vapor or steam of the same will not be equal to that of the solution, but equal to that of pure boiling water. For instance, if a concentrated solution of common salt, which boils at 260° Fah., is evaporated at that temperature, the vapor has a temperature of only 212°, while pure water has only to be heated to 212° to produce the same result.

This statement has been denied by others, claiming that it could not be so, and that the vapor must always have the temperature of the liquid from which it proceeds; but this is a false conclusion, as, contrary to this opinion, it is well established that steam of 260° cannot exist under ordinary atmospheric pressure, but only at a pressure of 3 to 4 atmospheres; under ordinary pressure it must at once expand, and thus by this expansion have its temperature reduced to the corresponding pressure, 15 lbs. to the square inch, and a temperature of 212° Fah.

It follows from this that the steam of salt water is equal to that of fresh water, and the only difference is that in order to raise steam from salt water, its temperature has to be higher than to raise steam of the same pressure from fresh water. The disadvantage of this fact in the production of steam is, however, more apparent than real, because, after once the proper temperature is reached and maintained, the consumption of heat made latent in the steam evolved is 960 units for every pound of water evaporated, whether this water be salt or fresh.

If we invert the experiment and condense steam in saline solutions we find results perfectly in accordance with the above, but quite surprising and even paradoxical at first sight. If, for instance, we send steam of 212° into a concentrated solution of common salt, its temperature will at last be raised far above 212°; if the solution is concentrated so much as to have a boiling point of 260°, it may be heated in this way to 258° or thereabout. It is indeed paradoxical that steam of 212° would be able to raise the temperature of a solution in which it condenses 45° above its own temperature, but such is the fact, and any one can easily convince himself of the reality of these apparently strange results, and it is only the latent heat of the condensed steam which is set free, and part of which shows itself as sensible heat under the circumstances explained.

Soluble salts have strong affinity for water, and will promote the condensation of its vapor, absorb the water, and change the latent heat of the vapor into sensible heat, which latter means a rise of temperature. This action is analogous to that of water absorbing hydrochloric acid gas or ammoniacal gas. In both cases the water becomes very hot, much hotter than the temperature of the gas it is absorbing, and the strong affinity of water for these gases is, as well as the affinity of salt for water, the key to the understanding of all these apparently strange phenomena.

ARCTIC EXPLORATIONS.

There is a fascination about explorations in unknown lands that makes men count as nothing the extremes of heat and cold, hunger, thirst, fatigue, and danger. The mystery which surrounds the polar regions, and the success with which its barriers of ice have guarded its secrets in the past, are maddening to the explorer and geographer. The pole attracts those who yearn to know the hitherto unknown, in the same manner as it attracts the magnetic needle that always points toward it; and notwithstanding the large amount of money spent and the number of lives heretofore lost in Arctic explorations, there are now so many expeditions either organized or organizing for further effort in this direction that it would seem as if the secrets of the polar regions would soon be secret no longer.

In addition to the Howgate expedition, which has already made a start from our shores, other nations are hurrying forward exploring expeditions on a somewhat similar plan. England is about to fit two vessels under Captain Nares, who will operate by way of the east coast of Greenland. Sweden, during the present year, will explore the polar regions by way of Behring's Strait, under the auspices of Professor Nordenskjöld. Holland has determined upon one also. Germany, under the direction of the Arctic Exploration Society, has an Obi expedition, commanded by Captain Wiggins, now on duty. Russia, during the coming spring, will push forward an ethnological expedition, under the Helsingfors professor, to the Vogels and Ostyacs, of the Obi and Irtysh. Besides these expeditions many eminent explorers and scientific societies in different countries are busying themselves in an endeavor to establish stations at different points in the Arctic regions, with a view to those systematic synchronous observations so necessary in making proper progress in the discoveries in meteorological and other kindred sciences.

There is little doubt but that many of the natural sciences might be much enriched by observations directed especially in their directions. Geographical discovery has hitherto been the main point of the expeditions sent out, and while this is no doubt a very important feature, yet there are many others which should receive attention. Usually the expeditions have been so conducted as to preclude anything beyond mere locomotion, all appliances for discoveries in other directions than that of geographical science being left behind.

Under the colony system, or what is now known as the Howgate plan, there is no doubt that many interesting discoveries in various sciences can be made that have hitherto escaped observation under the systems which made locomo-