

permanently about 0.3000 gramme of turpentine. On these principles the following process was devised:

Estimation of Turpentine.—Twenty-five grammes of varnish are weighed into a flask of 400 c. c. capacity, in which has been placed a piece of granulated tin, or its equivalent, to prevent bumping, and about ten c. c. of water. The flask is in this way prevented from becoming greasy, which would cause violent bumping. The contents of the flask are now submitted to distillation, the distillate being caught in a tapped separator. When ninety or ninety-five c. c. of water have come over, the distillation is stopped and the turpentine and water allowed to separate. If the contents of the flask still retain any odor of turpentine, more water should be added and the distillation resumed. After settling for a sufficient length of time, the water is carefully drawn off and the turpentine poured into a tared flask and weighed. A correction is made for the amount of turpentine retained by the water, amounting to 0.300 gramme for ninety c. c. of water. In some experiments salt was added to the water to raise its boiling point, but no apparent advantage was gained, except when the non-volatile residue was heavier than water; in this case the salt prevented the residue from sinking to the bottom and causing bumping by greasing the flask. If it is desired to examine the residue, the remaining water is poured off from it and alcohol added. On distilling off the alcohol, and if necessary removing the last of it by the addition of a little ether, which is also evaporated off, the residue is obtained pure.

The following results were obtained by this process:

Varnish.	Per cent. found.	Per cent. present.
B	41.2	41.4
C	57.1	56.9
D	56.3	56.8

The sample D was made by dissolving common resin in turpentine, and it was therefore more difficult to remove the last trace of turpentine from the non-volatile residue than it ever is in an oil varnish, but even in this case the result is fairly accurate.

The method requires no unusual apparatus, and can be carried out in about half an hour. The residue is not heated above the boiling point of water, and the turpentine is actually weighed and may be itself analyzed.

For the determination of benzene in turpentine, the method of Burton gives the best results. It depends upon the conversion of turpentine into acids soluble in water by the action of nitric acid, while benzene remains unaffected and is separated and measured or weighed.

The Non-Volatile Portion.—The analysis of the residue, consisting of linseed oil and resin, both more or less altered by heat, presents an extremely difficult problem in proximate analysis, and one which yet remains unsolved.

LIQUID AIR.

By J. J. STEWART, B.A. Cantab., B.Sc. Lond.

It is a familiar fact to all that some substances can be obtained in the varying forms of solid, liquid, and gas; but many substances come under our notice only when occupying one of these states. When granite is mentioned we at once think of a hard, solid rock; few people have seen granite in a liquid state. Again, the name *mercury* calls to our mind the well known liquid metal. So there are numerous gases and vapors which are known to us only under this somewhat impalpable and less tangible form. Among the substances familiarly known to us, however, there are a large number which, through the action of heat upon them, can be readily changed into a fluid and then into a vaporous state. Perhaps the best known of all is water, though even this in hot climates is rarely seen in the there uncommon solid form; so that the African chief, who had accepted many statements from his European visitor, utterly refused to believe him when he was told that, owing to the intense cold in some countries, rivers got hard enough to be walked over.

Lately, in many text books of science, gases were divided into two classes—those which could be liquefied by the application of cold, or pressure, or both, and those which were *permanent*, or were known to us only in the form of gases. It was suspected by scientific men, especially after the extensive experiments by Faraday, who succeeded in liquefying many of the "permanent" gases, that all gases without exception could be changed into the liquid form if they were exposed to a sufficiently great pressure and at the same time cooled down far enough. This surmise has been proved correct only within comparatively late years, and now all gases, including the air we breathe, must be considered as differing from vapors, such as steam, only because at the usual temperatures at which we generally deal with them they are in a condition similar to that which other substances attain when heated to a very high temperature.

I propose to give a short account of the work hitherto done in the liquefaction of gases, commencing with that so ably carried out by that unsurpassed experimenter, Michael Faraday, and going on to refer to the researches commenced by Raoul Pictet and by Cailletet, in France, who, about the same time (1877), succeeded in liquefying oxygen and even hydrogen. These researches were pursued by Wroblewski and Olzewski, in Russia, and have been continued lately in our own country by Professor Dewar, who, with such striking success, has liquefied air in large quantities, and has even handed it about in pint bottles for inspection by a large audience.

There are two means open to us of liquefying a vapor. Let us increase the pressure upon it, or lower its temperature, and if we proceed far enough in these operations the vapor will become liquid. A further condition is necessary with the "permanent" gases—we must cool them down below their *critical temperature*. This critical temperature is that above which no amount of pressure applied to the gas will be capable of changing its state into that of a liquid.

Faraday, in his series of experiments, applied the simple but effective means of generating the gas in a strong glass tube, from those compounds which evolved the required gas on heating. In this way the gas, being produced in a limited space, produced a great pressure, under which pressure of its own vapor the gas became a liquid. On breaking the tube the gas, compelled by pressure to exist as a liquid, would revert

to the form natural to it at the temperature of the experiment, and would do this with explosive violence. There was thus always a tendency for the gas to burst the tube, and this sometimes occurred during Faraday's experiments. Hence he was careful to wear a mask made from wire gauze or thick glass, but even thus he did not entirely escape injury. Faraday immersed one end of his tube in a freezing mixture while the other was exposed to heat. In this way he succeeded in liquefying a large number of gases, and examined their properties while in this unusual state. Among the gases so treated were the following: Carbonic acid, hydrochloric acid, sulphur dioxide, cyanogen, ammonia, and chlorine. He carried out his first set of experiments on this subject in the year 1823. Later, in the year 1845, after Thilorier had shown how carbonic acid gas could be obtained in the liquid form on a large scale, and also as a solid, Faraday used the solid carbonic acid mixed with ether, and by means of the cold produced by the evaporation of the mixture he reduced the temperature to about -100° Cent., and obtained most of the above mentioned gases, and also nitrous oxide, not only in a liquid but also in a solid state. Hydrochloric acid, hydrogen arsenide, ethylene, silicon fluoride, boron fluoride and chlorine heat at this time managed to get in the liquid form, but was unable to solidify these substances. The gases hydrogen, oxygen, nitrogen, nitric acid, carbon monoxide, and marsh gas resisted all Faraday's attempts to liquefy them, and it was not until more than thirty years later that these substances were condensed.

Andrews, by his classical researches on the critical point of gases and vapors, and especially by his thorough investigation of the behavior of carbon dioxide when exposed to great pressure at varying temperatures, paved the way for future work on the liquefaction of gases, and showed that great pressure of itself was not sufficient to cause a gas to turn into a liquid, but that a certain limiting temperature must be passed in cooling down the gas before it can by any amount of pressure be liquefied. Thus above this limiting or critical temperature, which is different for each gas, it may be called truly permanent, while below this temperature the gas is liquefiable if only enough pressure is applied to it, and the gas may then be described as a vapor.

When substances evaporate or change from the liquid to the gaseous state, a large amount of heat disappears or becomes latent, and is used up in separating the molecules of the liquid farther apart and giving them increased energy of motion. On account of this disappearance of heat during evaporation great degrees of cold may be produced, and it was by this means that Pictet, in 1877, obtained a temperature of -140° Cent., and obtained oxygen in the liquid state. He cooled liquid carbon dioxide by surrounding it with liquid sulphurous acid, kept boiling in a vacuum, and got a still greater degree of cold by then allowing the liquid carbonic acid to evaporate rapidly in an exhausted space. The oxygen was generated in the usual way from potassium chlorate, a salt which splits up and gives off oxygen gas when it is heated; but the gas was produced in a strong iron retort, so that by means of its own pressure alone the gas was compressed by a force several hundred times greater than that of the ordinary pressure of the atmosphere.

The method adopted by M. Pictet is the same in principle as that employed by Faraday. The gas is generated in a closed vessel capable of standing a great pressure, and it is condensed by being simultaneously exposed to great cold and to the pressure of the gas itself, forced to occupy a very small space. In Pictet's original experiment he obtained a temperature of -130° Cent., at which temperature oxygen is liquefied, when the pressure is raised to 273 atmospheres.

While Pictet was continuing his experiments and endeavoring to liquefy the hitherto permanent gases, the same subject was being investigated by Cailletet, and it was on the same day, the 24th December, 1877, that the French Academy was informed of the success of both these experimenters in liquefying oxygen. Cailletet attained his object by exposing the gas to enormous pressure, produced by means of a hydraulic press, while at the same time the temperature was lowered by suddenly allowing the gas to expand. In this way a sudden disappearance of heat takes place, the heat energy becoming transformed into mechanical motion of the particles of the expanding gas. In Cailletet's apparatus the pressure was produced by a steel piston working in a cylinder, the hydraulic cylinder being filled with water. The gas was contained in a capillary glass tube with small bore and thick walls which could support the strong pressure required. The glass tube containing the gas was connected to the hydraulic pump by means of a flexible metallic tube. Cailletet worked with small quantities of gas, while Pictet, by means of his machinery, was able to obtain relatively large quantities of the various liquefied gases.

The results got were only obtained after years of preparation and endeavor by both experimenters, working quite separately and independently. Cailletet made use of the skill and knowledge obtained by him in the prosecution of his business as an ironmaster at his works at Chatillon-sur-Seine; while Raoul Pictet carried on his experiments at Geneva, where he was engaged as a manufacturer of ice-making machinery.

Cailletet's apparatus is singularly simple and effective, and by it he also obtained liquid hydrogen, which appeared as a mist on the inside of his tube when the great pressure to which the gas was subjected was suddenly relieved, and heat thus suddenly absorbed. Hydrogen was thus liquefied into globules of mist on the glass when the pressure of three hundred atmospheres was suddenly removed, while air previously carefully dried changed into a liquid under a pressure two hundred times that of the atmosphere after it was cooled by means of liquid nitrous oxide. This is what happens in Cailletet's experiment: the gas, first of all cooled on account of its quick expansion, descends in temperature below its critical point, and then becomes liquid under the moderate pressure to which it is then exposed. But as expansion and relief of pressure continues, the liquid is soon under too little pressure to remain in this condition, and besides by conduction from surrounding objects heating occurs, so that the liquefied gas soon evaporates and

the mist produced is fugitive; this is especially so in the case of hydrogen.

MM. Wroblewski and Olzewski have carried out many experiments using an apparatus similar to Cailletet's. At -136° Cent. a pressure of twenty atmospheres sufficed to liquefy oxygen, and the critical temperature of this gas is placed at -112° Cent., that is, it must be cooled at least as far as this before liquefaction can take place. The critical temperature of nitrogen is found to be still lower than this, being -147° Cent., or -223° Fah.

On Friday evening, June 26, 1891, at the Royal Institution, the audience saw liquid oxygen in large quantities freely drawn off from the refrigerating apparatus, and having all the appearance of hot water, with a vaporous cloud above it. In reality the oxygen was boiling at a temperature of -296° Fah., i. e., 328° below freezing point, and the apparent vapor consisted of ice particles produced from the moisture of the surrounding air, cooled from the contact of the chilled gas. On filtering the liquid oxygen, to get rid of the minute particles of solid carbonic acid scattered through it, it was seen to consist of a blue limpid liquid not unlike water. It would naturally be expected that the liquefied gas when placed in an open vessel in a room at the ordinary pressure and temperature would with great rapidity, and even violence, hasten to take the gaseous form. But this was not the case; the liquid oxygen evaporated but slowly, and retained its liquid form for a considerable time, although it was only under the usual atmospheric pressure. When a few drops of the liquid were thrown into water, the effect was like that of plunging red hot iron into a liquid; a fizzling noise was produced, and soon the globules of liquid oxygen were seen each floating about in a little cup of ice formed from the surrounding water. By means of the remarkably cold fluid, alcohol, which remains liquid in even the severest Arctic climate, was quickly frozen into solid lumps; the solidifying temperature for alcohol being -130° Cent.

The effect of cold in rendering sluggish and inert substances which are usually chemically active is strikingly seen in the case of cooled oxygen. At ordinary temperatures oxygen gas has a great affinity for phosphorus, and combines readily with it, producing vigorous combustion with much heat, and light clouds of the solid phosphorous oxide being formed. But a piece of phosphorus when placed in liquid oxygen remains undisturbed; no combination takes place.

By means of liquid oxygen, nitrogen may be liquefied. Advantage is taken of the fact that liquid oxygen when placed in vacuo boils at a lower temperature than when under the ordinary pressure. A temperature of -328° Fah. can thus be obtained, at which both nitrogen and atmospheric air can be liquefied. During the process of liquefaction of air the two gases of which it is made up become liquid together, but when the temperature is allowed to rise they evaporate separately. The nitrogen, though more difficult to liquefy, comes off as a gas first, leaving almost pure oxygen behind.

Prof. Dewar has also solidified air as well as nitrogen by employing powerful pneumatic apparatus. Pure oxygen has itself never been obtained in the solid form. In order to obtain a succession of lower and lower temperatures, the various liquefied gases are caused to boil in a vacuum. Thus the more easily liquefiable gases are made use of to abstract heat on their evaporation from those more difficult to liquefy. When these latter are made to boil in vacuo a still lower temperature is attained, and by successive steps a reading on the thermometer as low as -211° Cent. (or -346° Fah.) has been reached. At these low temperatures experiments of an interesting character have been made on the electrical behavior of metals, and their electrical resistance has been determined.

On boiling successively in vacuo carbonic acid, nitrous oxide and ethylene, using the first to take away by their evaporation heat from the gases which are more difficult to liquefy, a temperature of -229° Fah. is reached, at which oxygen can be liquefied under a pressure of fifteen hundred pounds per square inch. The rapid evaporation of oxygen in vacuo so quickly removes heat from surrounding substances that air and nitrogen are soon liquefied, and these, when treated under powerful air pumps, abstract sufficient heat to allow the production of solid nitrogen. This last experiment was successfully carried out for the first time in public on January 19, 1894.—*Knowledge*.

LEAD WATER PIPES.

THE tests described in this paper were made upon the new water supply of the city of Belgrade (a full analysis of the water is given). This water contains iron, calcium and magnesium salts, is of 24.8° total hardness (German scale), and holds in solution more than 0.5 grm. CO₂ per liter.

Lead was tested for, in water which had stood overnight in the pipes, as follows: One liter of water acidified with acetic acid was evaporated down to 100—200 c. c., filtered, and a drop of dilute sulphureted hydrogen water added. If lead is present, even in the most minute quantity, a darkened coloration of the water is observed. As this reaction might be partially obscured by the precipitation of the iron present in the water, it is necessary to make a test at the same time with a sample known to be free from lead.

An estimation of the amount of lead may be carried out with great accuracy in the following way: One liter of the water is acidified with 5 c. c. glacial acetic acid, concentrated to 100 c. c., filtered, and one or two drops of dilute H₂S water added (one part saturated H₂S water with two parts distilled water). At the same time the sample known to be free from lead is treated in an exactly similar manner. If lead is detected in the first sample, add to the second such an amount of a solution containing 0.1 mg. lead in 1 c. c. that the two solutions have exactly the same color. The amount of lead added to the second sample is the amount present in the first. By this means 0.05 mg. lead per liter may be estimated.

In carrying out the tests here described, a piece of lead pipe 7 meters in length and 22 mm. in diameter was employed. The solvent effect of the water on the lead was greater at first than after the tube had been some time in use. But even after three months about 0.3 mg. lead per liter was found in water which had