degrees of cold, under a pressure of from four to six atmospheres. The liquefied carbonic acid is conducted in a tube four meters long; two combined pumps produce barometric vacuum over that acid, which solidifies in consequence of the difference of pressure. Inside the first tube, containing, as aforesaid, solidified carbonic acid, passes a tube of smaller diameter, in which a current of oxygen is caused by a generator containing chlorate of potash, and in the form of a large-sized thick-walled shell. Pressure may be brought up to 800 atmospheres. Yesterday morning, the 22d of December, under a pressure of 300 atmospheres, a liquid jet of oxygen gushed out of the extremity of the tube at the very moment when the compressed and cooled-down gas was passing from its high pressure to atmospheric pressure. To the beholder the gushing liquid oxygen is very much like a great rush of hot water from the hot-water cock of a bath."

By a singular coincidence, M. Cailletet, of Paris, succeeded in vaporizing oxygen the same day as I liquefied it, and a few days later M. Cailletet vaporized hydrogen and nitrogen. The experiments were made in the laboratory of the Ecole Normale, in the presence of MM. Boussingault, Henri Sainte-Claire Deville, Berthelot, Mascart, etc. These eminent men, says the *Journal des Debats*, declared themselves satisfied that the nitrogen was reduced to the condition of little drops, while the hydrogen became visible in the form of a vapory cloud.

The method employed by M. Cailletet is that of a sudden reducing of a great pressure on the oxygen to that of atmospheric pressure. This sudden slackening of pressure produces a great external work, and is thus the cause of a great lowering of temperature. The refrigeration consequent on the slackened pressure may easily reach -200° C. below the initial temperature of the gas. The sudden reduction of 250 atmospheric pressures condenses the gas into a vesicular or vaporous form. This misty state of the gas is extremely transitory; for radiating heat almost instantaneously makes the drops of vaporous gas pellucid—in other words, brings them back to their gaseous form. In my researches, I have aimed at converting oxygen into a relatively permanent liquid to be collected in a receiver, so as to be able to measure its density and maximum tension.

On the 11th of January I forwarded from Geneva the following telegram to M. Dumas, Secrétaire Perpétuel de l'Académie des Sciences:

"I have just liquefied hydrogen with a pressure of 650 atmospheres and -140 degrees of cold. The gas solidified under the effect of evaporation. The jet had a flashing bluish color somewhat like steel. The gushing jet fell on the ground, making a noise not unlike a heavy charge of shot, accompanied by a strident hiss. Lumps of hydrogen were kept intact in the tube."

M. Dumas immediately laid my discovery before the Société d'Encouragement. From a report of a lecture of his on the subject I take the following lines:

M. Dumas, the illustrious chemist, began by reminding his hearers, with legitimate pride, that he had foreseen some forty years ago, in his *Traité de Chimie*, that hydrogen was the gaseous form of a metal. After dealing at some length with the inductions which had led him to that conclusion, M. Dumas laid some stress on the distinction to be made between M. Raoul Pictet's and M. Cailletet's experiments. M. Cailletet has proved the possibility of reducing all gases to the liquid and the solid states. M. Pictet has really reduced the permanent gases to the liquid and the solid states."

And now to conclude. I here beg to thank the scientific world for the handsome welcome they have given my discovery. "Still, the scientific world is not the world. A suppressed titter has rippled on the faces of the ignorant, followed by the query; "What's the use of it?" Well, it is perhaps the fault of the scientific world if so groveling an exclamation is all but universal. Books, and especially manuals treating of physics, chemistry, and other sciences, lay more stress on tangible results than on the workings of the creative mind. Is it astonishing that man, who is naturally prone to value none but paying facts, should, when left to the mercies of a practical manual, remain unsympathizing whenever his attention is called to the laws which are at the root of creation? The philosophical temper which reverences God on account of the perfection of His thought ought to be the fruit of scientific education. Science is a religion which can and ought to make man God-loving, by sedulously turning his mind to the divine first principles which rule the world.—*Nineteenth Century*.

LIQUEFACTION OF GASES.

It was reserved for Dr. Andrews to show experimentally that the liquid and gaseous states are perfectly continuous. His conclusion that every body, whether liquid or gaseous, has its own critical point, contained the germ which, in its development, has ultimately led to the liquefaction of the "permanent gases." It follows from these memorable experiments that if a gas be kept above its critical temperature, no amount of pressure will be able to liquefy it; the most that can be done is to reduce it to a homogeneous body, which is neither a gas nor a liquid. If while it is in this neutral state the temperature be lowered, it will condense into a liquid; but if only the pressure be diminished, it will return to the gaseous state.

Here, then, at last we see the two conditions necessary to bring about liquefaction; viz., high pressure and low temperature. Dr. Andrews clearly apprehended these two conditions, for we find him subjecting oxygen to pressures exceeding any used by Faraday, while surrounding the gas with one of the most powerful refrigerating agents known, viz., a mixture of solid carbonic acid and sulphuric ether. Still his endeavors met with no success; oxygen gave no tokens of tractability.

M. Berthelot, the eminent French chemist, still more recently, carried the pressure up to 800 atmospheres, but without effecting liquefaction.

It occurred, independently, to M. Louis Cailletet, of Chatillon-sur-Seine, and M. Raoul Pictet, of Geneva, that the incoercible gases might yield to the intense cold that would be produced by allowing them to expand suddenly when compressed to a very high degree. According to Poisson's formula, this expansion should lower the temperature of the gas by about 200 degrees Centigrade. Both set to work and devised apparatus essentially differing from each other, but in both of which the embodiment of this principle forms a salient feature.

It is not to be supposed that M. Cailletet's success is the mere outcome of a fortuitous combination of circumstances. There are instances of this happy chance in the history of scientific discovery, but they are few. His success is entirely the result of a well-directed and sustained investigation. At different intervals during the last ten years this subject has engaged his attention. Availing himself of the mechanical power at his iron works at Chatillon, he collected

CAILLETET'S APPARATUS FOR THE LIQUEFACTION OF GASES.

a large amount of data, which, in the true spirit of a physicist, he kept by him until perfectly satisfied that he had finally solved the problem. This was on the 2d of last December; on the 3d, he wrote a short note to M. H. Sainte-Claire Deville, in which he states with pardonable enthusiasm that he had succeeded in liquefying carbonic oxide and oxygen. As he was at that moment a candidate for a seat in the Mineralogical Section of the Academy of Sciences, and did not wish his latest discovery to influence his election, he advised M. Sainte-Claire Deville to seal his letter and remit it to M. Dumas, the perpetual secretary of the Academy. Nearly three weeks later, on December 22d, M. Pictet communicated his results to the secretary, and singularly enough, the two papers were read at the same meeting of the Academy, viz., that held on December 24th. The priority in this very close race thus belongs to M. Cailletet, but this does not detract one tittle from the merits of M. Pictet's labors.

M. Cailletet's apparatus will be understood from the accompanying illustration, Fig. 1. A tube, T, Fig. 2, of very fine bore toward its upper extremity, and capable of supporting a pressure of 500 atmospheres, is partly filled with the gas to be liquefied. The lower portion of the tube expands to form a capacious bulb, which is filled with mercury, and inserted in a reservoir containing mercury and water. The walls of the reservoir are of steel, and sufficiently thick to allow pressures of 800 atmospheres to be used with perfect safety. The water is forced in by a strong pump, and, according as it enters, the mercury rises in the capillary tube, compressing the confined gas at the same time. A pressure of 200 atmospheres is attained by a few strokes of the pump, and is recorded by a metallic manometer. By means of a plunger, V, the pressure may be very gradually increased up to 500 atmospheres. Meanwhile the capillary tube may be surrounded by a freezing mixture, or by water at any desired temperature.

In the case of most gases, the manometer remains stationary when a certain pressure has been reached. This phenomenon, which is at variance with Boyle's law (a law absolutely true only for a perfect gas), occurs as soon as liquefaction begins. When an appreciable quantity of the gas has been liquefied, upon gradually diminishing the pressure the liquid begins to boil and returns to the gaseous condition. But if the valve V' be suddenly opened, the gas will as suddenly expand, and, undergoing a very considerable reduction of temperature, a portion of it will be liquefied, filling the upper part of the tube with a sort of cloud or mist. These effects are readily seen with nitrous oxide and acetylene, and may be easily exhibited to an audience by projection on a screen.

In the case of the other gases, the liquefaction has not yet proceeded further than its incipient stage. Thus oxygen under a pressure of 270 atmospheres and a temperature of -29 degs. was still gaseous; but on suddenly opening the valve V', the tube was filled with a cloud, which denoted a commencement of liquefaction, if not of actual solidification, as some have thought. M. Cailletet is now constructing an

apparatus with which he hopes to clear away this doubt and also to verify that the gas is not converted into ozone during compression. The same nebulous phenomenon occurs even when the oxygen is not surrounded by a cooling mixture, provided time be allowed for it to lose the increment of temperature arising from its compression.

In the experiments which were made in the laboratory of the Ecole Normale, Paris, on December 30, in presence of several of the leading men of science, nitrogen was subjected to a pressure of 200 atmospheres and the temperature of liquid sulphurous acid (-29 degs. C.) without any signs of giving way. On opening the valve, tiny drops of an appreciable volume were visible for about three seconds. Hydrogen, as anticipated from its close resemblance to a perfect gas, showed itself the most refractory of all the gases; still when compressed to 280 atmospheres and suddenly released, it assumed, though only for an instant, the form of a very fine, extremely tenuous mist. To leave no doubt on the matter and to satisfy the physicists present, the experiment was repeated several times, and invariably with the same result.

On January 14th, M. Cailletet experimented with atmospheric air. Having removed all traces of moisture and carbonic acid, and introduced it into the capillary tube, he surrounded it with liquid nitrous oxide. When the manometer recorded 200 atmospheres, streams of liquid air flowed down the sides of the tube. The pressure was increased to 310 atmospheres; the mercury then having risen to the cool part of the tube, its upper surface was frozen; and on the prompt removal of the refrigerating substance, the meniscus was observed to be covered with a layer which was believed to be frozen or solid air.

M. Pictet has obtained not only the cloudy appearance referred to above, but real jets of liquid oxygen and even miniature showers of hydrogen hail. Both physicists will doubtless continue their experiments until they have completely solved this great problem of modern physics, that is until they have succeeded in fixing liquid oxygen, nitrogen, and hydrogen for use in the chemical laboratory. In an early number we shall describe M. Pictet's apparatus and summarize the results he has obtained. The apparatus shown in Fig. 1 is the original one used at the experiments made in the Ecole Normale, and has been constructed specially for physical laboratories. MM. Ducretet & Co. are the constructors.—*Engineering*.

A GAS-ABSORBER.

By G. GORE, LL.D., F.R.S.

EVERY chemist is well aware that by the single passage of a bubble or stream of gas through a liquid, the former touches only to a small extent the latter, and requires to be passed through several portions of the liquid in succession before it is completely absorbed or purified.

When either Woolf's bottles or bent glass tubes are employed for the purpose, in the former case a considerable

IMPROVED GAS-ABSORBER.

bulk of liquid must be used, and in both cases a number of junctions must be made with the different parts of the apparatus, and a proportionate risk of leakage incurred. I have therefore constructed the apparatus shown by the annexed sketch, for the purpose of quickly saturating a small bulk of liquid with a gas, or speedily absorbing a small quantity of gas by a liquid, without requiring many junctions to be made. It consists of a single glass tube, of about half an inch external diameter, bent into a series of four or six double curves, the upper part of each of which is provided with a neck (closed by an India-rubber bung), so that each limb of the tube may be readily cleaned. The tube is supported and kept steady in the manner shown in the sketch.

Having used the apparatus, and found it very effective and convenient for the intended purpose, and having been unable to find such an arrangement described in any catalogue of chemical apparatus, I have ventured to publish this description.—*Chemical News*.

NEW 500 H. P. COMPOUND ENGINES.

ENGINES of a high class have not been very extensively adopted in Yorkshire, but the necessity for economy in fuel even in the coal districts is effecting that which the textile manufacturer's need of uniformity of velocity at which his machinery should be driven has, generally speaking, failed to do. The engines which we illustrate this week have been built by Messrs. Pearson & Spurr, of Birstall Foundry, near Leeds, and erected by them at the Queen Street Mills, Batley, of Messrs. R. Brearley & Sons. They are from new designs by Mr. G. Sellers, and are intended to work up to from 450 horse power to 500 horse power. The mills, which are entirely employed in the manufacture of the heaviest classes of woollen cloths, are at present driven by a beam engine, assisted by a horizontal engine; but as these are old and of insufficient power to drive the machinery in the extended mills, Messrs. Brearley decided upon securing engines which should work economically

and, as nearly as practicable, uniformly, and for this purpose they have obtained the compound engines about to be described.

Both the high and low pressure cylinders are fitted with double-slide chests, the object of this being, chiefly to secure short steam passages, more ready access to either valve, and to obtain a space between the chests where the rod, supported by two extra glands, should, by a suitable joint, be adjustable, in order to modify the relative positions of the pair of valves without taking off the steam chest covers. The slide valves are of the Meyer type, and are readily adjusted by means of the right and left hand screws, as seen in the plan. The high pressure cylinder is fitted with automatic expansion gear of the Allen type, controlled by a Porter's governor. The low pressure cylinder, it will be seen by the elevation which we published last week, is fitted with expansion gear, adjustable by hand, by means of the hand screw moving the joint block in the rocking quadrant near the governors, and by which

NEW 500 H. P. COMPOUND ENGINE