that the three-atom hydrate of methylic alcohol behaves like the same hydrate of ethylic alcohol, though not accompanied by condensation as the latter is; that the order of succession of individual substances in any homologous series is indicated by their degree of transpirability as clearly as by their comparative volatility—the largest molecules having the slowest rates.[*]

Rellstab's [†] researches were made on the various organic homologues. He finds, as do all experimenters, that the viscosity of all bodies decreases as the temperature increases; that the quantity of gas set free in the substance has no observable influence on the viscosity; that for an increase of CH_2 in the chemical constitution of all bodies there is an increase in the viscosity, which increase is greater in the alcohol radical than in the acid radical; all increase or decrease of viscosity corresponds with the increase or decrease of the boiling points, without being a simple function of the same.

Gueront[‡] has experimented more recently on some of the same bodies with corresponding results, also done other valuable work on the subject.

Sprung's[§] experiments were on the various salt solutions. He found that the viscosity of water was decreased at lower and increased at higher temperatures by the introduction of a soluble salt, an unexpected result

APPARATUS FOR DETERMINING THE VISCOSITY OF LIQUIDS.

The essentials in the line of apparatus are:

1. A uniform cylindrical capillary tube, the length and diameter of which are known with exactness.
2. A bulb or bulbs to connect with the tube, the capacity of which is known.
3. A constant known pressure which can be applied to drive the liquid through the tube.
4. A suitable vessel to contain water with which to control the temperature of the liquid and apparatus.
5. A good thermometer, sensitive enough to be read to the tenth of a degree C. with the eye.
6. An accurate timer.

The capillary tube is the most difficult part of the apparatus to secure; its diameter should not exceed 0·3 mm., and it must be perfectly uniform, or at least must not vary as much as one-half per cent. from uniformity. Its cross section should be a perfect circle also. Its length about 15 cm. In the construction of my apparatus I sought to eliminate every source of error possible. To this end I had a reversible faucet made through which the pressure was admitted to the tube. To use this, my capillary apparatus must differ essentially from that of other experimenters. This will be readily understood by reference to Fig. 1. A is the movable, B the fixed part of the faucet; C C the bulbs to contain the liquid experimented on, and D the capillary tube. g is a mercury manometer, and d rubber tubing to connect the parts. The holes, c, were drilled in, the one as far as and opening into the annular groove, b, the other opening into the groove, b' ; these grooves make connections with two outlets each, one of which goes to the manometer, the other to one of the bulbs, in each case. The pressure is admitted at e, and its course through the apparatus is shown by the darts. When A is turned through a half revolution by means of h h, the direction of the pressure is reversed, as will be seen by inspecting the figure.

This arrangement of the apparatus will be found not only to result in a great saving of time, but in more accurate results. When the solution to be operated upon is once in the bulb, C, as many observations can be made on it as one wishes without refilling, by simply turning the faucet and thereby reversing the direction of the pressure, and noting the time required for the liquid to pass from i to i' or the reverse. This part—the bulbs and tube—is immersed in water in a double walled vessel with glass sides, to regulate the temperature. A very slight change of temperature has considerable effect on the time required for the liquid to pass through the tube from one bulb to the other. A great deal of care is necessary in putting the liquid into the bulb to keep out all trash or motes that may be floating in the air, and that would stop the tube; of course the liquid itself must be free from all solid particles.

The various experimenters have, naturally enough, made distilled water a basis for comparing results and for testing the accuracy of the apparatus employed. I give below a table showing the results obtained by Poisenille, Graham, Rellstab, Sprung, and myself on distilled water, at the temperatures in the first column. The time is a function of the viscosity and is given in the table, that required for the transpiration of a fixed volume at zero being taken as 100. From the table it is seen how rapidly the viscosity (or time) decreases with the rise of the temperature; the viscosity at 50° C. being less than one-third of that at 0°.

Temperature.	Pois.	Graham. I.	Graham. II.	Rellst.	Sprung.	Trueb.	Mean.
0°	100	100	100	100	100	100	100
25		49·5	50·5	48·7	50·5	50·6	49·9
30	45·2	44·7	45	45	45·1	45	45
35		40·2	41·1	40	40·7	40·7	40·5
40	37	36·8	37	37·2	37·1	37·2	37·1
45		33·9	33·9	34·5	34	34·1	34·1
50	30·8	31·1	31	31·2	31·3	31·4	31·1

The viscosity of a liquid is due to the resistance of motion between adjacent surfaces. We are not concerned now with the mathematical considerations involved in its computation. Our present purpose is with the results of experiments on some organic bodies, and with what bearing these may have, if any, on the molecular formulæ of the same. If, between two smooth straight surfaces, powders of various degrees of fineness be introduced, the friction between the surfaces will increase as the powder increases in coarseness. Some modification of this general statement will be necessary, depending on the nature of the powder and its relation to the surfaces. I see no reason why the same thing is not also true with liquid surfaces. If the molecules of a dissolved body are larger than those of the solvent, they will project beyond the surface formed by a layer of this solvent,

* Further information concerning Poisenille's and Graham's researches can be found in "Watts' Dictionary," vol. iii., p. 722, where quite a full account is given.

† See "Ueber Transpiration homologer Flussigkeiten," Bonn, 1868.

‡ See *Comptes Rendus*, tome 78, p. 351; tome 79, p. 1201; tome 81, p. 1025; and particularly tome 83, p. 1291.

§ See "Experimentelle Untersuchungen ueber die Flüssigkeitsreibung bei Solzlosungen." Berlin, 1876.

of the thickness of a molecule, and consequently retard the motion of this layer on its neighbor. The amount of this retardation will be a function of the size and number of the molecule introduced. There will, also, be modifying influences here, depending on the nature of the bodies concerned, the affinity of the two bodies, and their consequent combination, thus making larger molecules and groups of molecules that move together.

With substances that have a close chemical constitution, however, comparisons are of interest and worth the pains of making them.

During the last winter I undertook a series of investigations on the viscosity of the sugars, dextrine, and gum arabic. Space will not allow of but a very few of the results.

By assuming the time required for the transpiration of a given volume of distilled water, at 30° C., as 100 seconds, that required for the same volume of a 5 per cent. solution of

Cane sugar is 114·6 seconds, or 14·6 seconds longer.

Grape	"	" 113·7	"	13·7	"
Milk	"	" 114·4	"	14·4	"
Dextrine,	"	" 142·4	"	42·4	"
Gum arabic,	"	312·8	"	212·8	"

There is a curious agreement in these figures; the average of the sugars is 14·2, dextrine is just three times 14·1 ($3 \times 14·1 = 42·3$), and gum arabic is $15 \times 14·2$. What is the reason for this coincidence? It would seem as though the molecule of dextrine is three times as large as that of sugar, and that the molecule of gum arabic is fifteen times as large, and also that the sugars differ but little in the volume of their molecules.

With solutions of greater strength dextrine and gum arabic, or at least dextrine, departs a little from being so exact a multiple of sugar.

In order to test the accuracy of these relations I determined the relative diffusibility of the sugars. It is well known that the rate of diffusion of any substance in water depends directly on the volume of its molecules—the less the molecule the greater the diffusion and *vice versa*. The results are given below:

	Formula.	Molec. weight.	Trans. time.	Diffus'n ratio.
Cane sugar	$C_{12}H_{22}O_{11}$	342	14·6	9·05
Grape sugar	$C_6H_{12}O_6,H_2O$	198	13·7	11·05
Milk sugar	$C_{12}H_{22}O_{11}H_2O$	360	14·4	10·9
Dextrine	$C_6H_{10}O_5$	164	42·4	
Gum arabic	$C_{12}H_{22}O_{11}$	342	222·8	

The tendency of these bodies to undergo chemical decomposition interferes considerably with getting their diffusion ratios: yet the results obtained agree in direction in every case. The transpiration time of cane sugar is the greatest, its diffusibility should by theory be the least, which agrees with the experiment, so also with the other two. Reasoning from the transpirability and diffusibility to the formulæ and molecule, it seems that the formula of grape sugar ought to be doubled, as its *molecular volume* can differ but slightly from that of cane sugar; or if not its molecule is of about half the density of that of cane sugar. By writing the formula, $C_{12}H_{22}H_2O$, and allowing some condensation more than takes place in cane sugar, the results are harmonized. Dextrine accordingly would be $3(C_{12}H_{20}O_{10})$, or $C_{36}H_{60}O_{30}$, and gum arabic $15(C_{12}H_{22}O_{21})$, or $C_{180}H_{330}O_{150}$.

HOT ICE.[*]

PRELIMINARY NOTE ON THE EXISTENCE OF ICE AND OTHER BODIES IN THE SOLID STATE AT TEMPERATURES FAR ABOVE THEIR ORDINARY MELTING-POINTS.

By THOMAS CARNELLEY, D.Sc., Professor of Chemistry in Firth College, Sheffield.

IN the present communication I have the honor to lay before the Royal Society a detailed description of experiments, proving that under certain conditions it is possible for ice and other bodies to exist in the solid state at temperatures far above their ordinary melting points. On a future occasion I hope to submit to the society a full account of the investigation of which these experiments form a part, together with the conclusions to be drawn therefrom. The bodies whose behavior I propose to discuss at present are ice and mercuric chloride.

ICE.

In the case of ice the great difficulty to be overcome is to maintain the pressure in the containing vessel below 4·6 millims., i. e., the tension of aqueous vapor at the freezing point, for it will be easily understood that if the ice be but slightly heated the quantity of vapor given off would soon be sufficient to raise the pressure above that point. After several fruitless attempts the following plan, involving the principle of the cryophorus, was adopted.

A strong glass bottle, such as is used for freezing water by means of Carré's pump, was fitted with a cork and glass tube, and the cork well fastened down by copper wire and paraffin wax. The tube and bottle were then filled with mercury, and the bottle connected with the end of the tube by means of the piece of stout India-rubber pump tubing, a thermometer having been previously attached by a wire to the lip of the tube. The connection was made tight by fine copper wire and wax. The tube was about one inch in diameter, and about four feet long from the bend; after connection with the bottle it was completely filled with mercury, care being taken to expel the air as completely as possible; the whole was then inverted over the mercurial trough, when the mercury fell to 0, the ordinary height of the barometer. The mercury was run out by tilting up the bottle and inclining the tube. By this means a Torricellian vacuum was obtained in the flask and upper part of the tube. The tube was next brought to the vertical, and the bottle placed in a trough. A tin bottle without a bottom was fitted with a cork, so that it might slide somewhat stiffly along the vertical tube.

To begin with, the tin bottle was placed in position and filled with a freezing mixture of salt and ice. Some boiled water was then passed up the tube, sufficient to form a column about two inches deep. The thermometer had been previously arranged so that its bulb might be one or two inches above the surface of the water. The bottle was next surrounded by a good quantity of a freezing mixture of salt and ice, in order that any vapor given off from the water in the tube might be condensed in the bottle as fast as it was

* A paper read before the Royal Society, January 6, 1881.

formed, and thus the internal pressure might never be more than about 1·0 to 1·5 millims. When the bottle had been sufficiently cooled, which required about fifteen minutes, the tin vessel was slid down the tube and its freezing mixture removed. The water had then solidified to a mass of ice, which on heating with the flame of a Bunsen burner melted either wholly or partially, and the liquid formed began at once to boil. The fusion commenced first at the bottom of the column of ice, whereas the upper part fused with difficulty, and required rather a strong heat. The fusion in this case was probably due to the steam evolved from the lower portions of the ice column being imprisoned and unable to escape, and hence producing pressure sufficient to cause fusion.

When the greater part of the ice had been melted the tube was tightly clasped by the hand, the heat of which was sufficient to produce a somewhat violent ebullition. The liquid in boiling splashed up the side of the tube and on to the bulb of the thermometer, where it froze into a solid mass. By this means the ice was obtained in moderately thin layers. The tube at points indicated by the arrows was then strongly heated by the flame of a Bunsen burner, with the following results:

The ice attached to the sides of the tube at first slightly fused, because the steam evolved from the surface of the ice next the glass being imprisoned between the latter and the overlying strata of ice could not escape, and hence produced pressure sufficient to cause fusion; but as soon as a vent hole had been made fusion ceased, and the whole remained in the solid state, and neither the ice on the sides of the tube nor that on the bulb of the thermometer could be melted, however great the heat applied, the ice merely volatilizing without previous melting. The thermometer rose to temperatures varying between 1·0° and 180° in different experiments, when the ice had either wholly volatilized or had become detached from the bulb of the thermometer. The ice attached to the latter did not partially fuse at the commencement of the heating, because, the heat reaching the outer surface of the ice first, evaporation could take place from a free surface and the vapor not become imprisoned, was the case with the ice attached to the sides of the tube.

These experiments were repeated many times and always with the same result, except in one case in which the heat applied had been very strong indeed and the ice attached to the sides of the tube fused completely. On removing the lamp, however, for a few seconds the water froze again, notwithstanding that the portion of the glass in contact with it was so hot that it could not be touched without burning the hand.

The chief conditions necessary for success appear to be—(1) That the condenser is sufficiently large to maintain a good vacuum: in the present case the capacity was about three-quarters of a liter. (2) That the ice is not in too great mass, but arranged in thin layers. Further, in the case where the heat is applied to the under surface of the layers of ice, the latter must be sufficiently thin to allow of a vent hole being formed for the escape of the steam coming from below, otherwise fusion occurs. When the heat is applied to the free surface of the ice the layers may be much thicker.

MERCURIC CHLORIDE,

m.p.=288°, re-solidifies at 270° to 275°, b.p.=303°.

About 40 grammes of pure mercuric chloride were placed in a tube, and a thermometer arranged with its bulb embedded in the salt. The drawn out end of the tube was connected by stout India-rubber tubing with one branch of a three-way tube, whilst the other was attached to the manometer. The remaining branch was connected with a Sprengel pump, fitted with an arrangement for regulating the pressure.

When the pressure had been reduced by means of the pump to below 420 millims., the mercuric chloride was strongly heated by the flame of a Bunsen burner, with the following results:

Not the slightest fusion occurred, but the salt rapidly sublimed into the cooler parts of the tube, while the unvolatilized portion of the salt shrank away from the sides of the tube and clung tenaciously in the form of a solid mass to the bulb of the thermometer, which rose considerably above 300° C., the mercury of the thermometer shooting up to the top of the stem. After slight cooling the air was let in, and under the increased pressure thus produced the salt attached to the bulb of the thermometer at once melted and began to boil, cracking the tube at the same time.

The experiment was next varied as follows:

About the same quantity of chloride was placed in the tube as before, and heated by the full flame of a Bunsen burner. The lamp was applied during the whole of this experiment, and the size of the flame kept constant throughout. The mercuric chloride first liquefied and then boiled at 303° under ordinary pressure, and while the salt was still boiling the pressure was gradually reduced to 420 millims., when the boiling point slowly fell to 275°, at which point the mercuric chloride suddenly began to solidify, and at 270° was completely solid, the pressure then being 376 millims. When solidification was complete the pump was stopped working, but the heat still continued to the same extent as before. The salt then rose rapidly to temperatures above that at which a thermometer could be used, but not the least sign of fusion was observed. From the completion of the solidification to the end of the experiment the pressure remained at about 350 millims.

The above experiment, which was repeated three times, shows, therefore, that when the pressure is gradually reduced from the ordinary pressure of the atmosphere to 420 millims., and the boiling point simultaneously from 303° to 274°, the salt solidifies while it is still boiling and in contact with its own hot liquid, notwithstanding that it is being strongly heated at the same time; and that, after solidification is complete at 270°, the temperature then rises far above the ordinary boiling point (303°) of the substance without producing any signs of fusion. Under ordinary circumstances, mercuric chloride melts at 288° and re-solidifies at 270° to 275°, i. e., at a temperature identical with that at which it solidifies under diminished pressure, as above described.

The solid mercuric chloride obtained on solidification under the combined influence of diminished pressure and the application of a strong heat had a peculiar appearance, quite different to that produced when the substance is allowed to solidify in the ordinary way. It appeared to consist of a mass of pearly leaflets closely packed together round the bulb of the thermometer.

Any final explanation of these phenomena is reserved until further experiments have been made.

APPENDIX.

Since writing the foregoing, it has been said in explanation of the phenomena therein described, that the thermo-

meter, though embedded in the mass of ice, did not really indicate the true temperature of the letter. With the object, therefore, of proving whether the ice is hot or not, I have, at the suggestion of Professor Roscoe, made the following calorimetrical determination:

The arrangement of the apparatus was so modified that the ice, after being strongly heated, could be suddenly dropped into a calorimeter containing a known quantity of water of known temperature. The resulting temperature, after the ice had been dropped in, was read off by a thermometer graduated so as to indicate a difference of 0·05° C. The weight of the ice was found by re-weighing the calorimeter.

So far I have only had the opportunity of completing the two following determinations, and in the second of these the weight of the ice could not be found, as a small quantity of water was lost out of the calorimeter, owing to a sudden jerk at the moment the ice entered it:

(1.) Weight of water in calorimeter, including the value of the latter=185 grammes.
Weight of ice dropped in = 1·3 grammes.
Temperature of calorimeter before=13·4°
" " after = 13·6°

Rise in temperature=0·2°
$M(\theta-t) + 80W = W(T-\theta)$
$(185\times0·2)+(80\times1·3)=1·3(T-13·6)$
∴ T=122° C. Where T=temperature of ice.

(2.) Weight of water in calorimeter, etc.=185 grammes.
Temperature of calorimeter before=12·7°
" " after = 12·8°

Rise in temperature=0·1°

On weighing the calorimeter after the experiment, the increase in weight was only 0·15 gramme, but as a portion of the water had been jerked out during the operation the true weight of the ice, and therefore its temperature, could not be found. But since the calorimeter had slightly risen in temperature, the ice must have been above 80° C.

From the nature of the experiment, as carried out on the present scale, the weight of the ice which can be dropped into the calorimeter is only small, and therefore the rise in temperature is but slight. But since a fall in temperature of a much larger amount ought to have been obtained had the ice been at 0°, it is considered that the above experiments are conclusive. Great care was taken in order to obtain correct temperatures in the calorimeter. The latter was inclosed in several casings, and the water was allowed to stand in it for several hours before the experiment, so that it might first attain the temperature of the room, while the time which elapsed between the readings of the thermometer before and after the ice was dropped in would not be more than from ten to fifteen seconds.

In the course of the next few weeks I intend to make one or two more determinations, and, if possible, on a larger scale.

ADULTERATION OF FOODS.

ONE of the most interesting recent contributions to this branch is a report on an investigation to determine the prevalence of adulteration in food supplies, undertaken, in accordance with instructions from the National Board of Health, by Dr. Smart.

Tea.—Dr. Smart does not consider the so called "facing" of teas with Prussian blue and silicates as injurious. Mixing teas is very common in this country, but it is not harmful to health. His general results were as follows:

The teas examined numbered 117, but of these two which were grown in Georgia, and six sent specially from Japan, may be excluded from present consideration. Of the 109 remaining, 90 were obtained from sources which presumably should have furnished a pure article, while 19 were purchased at such stores as might be expected to furnish an adulterated article, if adulteration was at all prevalent. In no case was a leaf observed which was not a true tea leaf. Of the 90 the only cases of debasement were those already mentioned as having probably originated before importation, while 5 of the 19 were so deteriorated that an analyst would have been warranted in reporting them as fraudulently adulterated—one, gunpowder (Y 2), from an excess of lime sulphate facing; one imperial (W 2), from admixture with sand, and three, imperials (Y 1, 2, and 3), from the presence of exhausted leaves. Whether these debasements were effected in China or in this country is an open question; but from the character of the English importations it is probable that exhausted leaves are dried and recolored in this country, for sale among the poorer classes of the community.

Coffee.—In this popular beverage something more positive was reported; but, on the whole, the examination did not yield serious results. The investigator says:

Most of the dealers with whom I have conversed have been strong in their belief that adulterated coffee is not to be found in this country, as the beans are either home-ground or ground by the supplying grocer. The results of H. B. Hill's examination for the State Board of Health of Massachusetts sustains this opinion, as ten samples of ground coffee, obtained in bulk, were found to be pure, while seven package samples consisted of one with no coffee, two with very little, and four with from fifty to seventy per cent. of coffee, the rest being roasted wheat, peas, beans, and chiccory. But the supplying grocer is not to be trusted in all cases, as out of the few purchased samples of loose ground coffee which have been examined during the present investigation, one contained a small percentage of chiccory, while two consisted largely of chiccory and roasted beans. Only one sample of package coffee was received, and it sustained the accuracy of Dr. Hill's results. Chiccory, corn, wheat, and rye were noted on the microscopic field as adulterants; but adulterants of what? for no coffee had been discovered, and half a dozen successive slides carefully examined failed to show the presence of the nominal article.

Three extracts or essences of coffee were examined, one of which consisted of chiccory and the two others of roasted starches. Two of these bore on the label an offer of a reward for proof that any other extract of coffee was as pure as they, which does not say much in a general way for the purity of extract of coffee. Two samples of chiccory were examined, both of which were found pure.

Sugar.—Cane sugar seems widely adulterated by glucose manufactured from starch. On this point the result was as follows:

Among 47 brown sugars, most of which were furnished by dealers who knew that their samples would be examined, there were found 3 which contained glucose, while among 38 samples purchased for analysis no less than 9 were thus

adulterated The glucose varied from a small admixture of thirty per cent. A remark by one of the dealers who furnished a thirty per cent. sugar is worthy of mention in this place: "Oh! they all have it, but they don't send any of it to you." Another storekeeper from whom a degraded sugar was obtained remarked, as he was putting up the samples, that I was welcome to anything he had, as he did not suppose he was any worse than his neighbors.

The white sugars, powdered, granulated, etc., were free from this adulteration; 24 of them were furnished dealers and 15 were purchased. The sirups, of which 21 were sent in for examination and 12 purchased, were also pure.

Flour.—This important staple furnishes gratifying results. Of 58 samples examined, only 1 had any adulteration, and this was merely corn meal, probably introduced by accident. The same cannot be said of bread.

Bread.—Of 18 samples, 8 contained alum. Although it is by no means decided that the substance, as used by bakers, is hurtful, it is advised that it should be prohibited.

Cream of Tartar.—This substance is one of the articles which are subject to gross adulteration. Only 18 samples were examined, but these were considered to be enough, in view of the character of the results. Six were of satisfactory purity. Eleven contained sulphate of lime, varying from seventeen to ninety per cent.. 3 having nearly the latter figure. Two contained no cream of tartar, but consisted instead, the one of sulphate of lime, alum, and acid phosphate of lime, and the other of alum, acid phosphate, and potato starch. Corn starch was also found in large proportion in one of the lime sulphate powders. Considering the use of cream of tartar in baking, its impure condition is a serious evil.

Baking Powders.—Contained alum and sulphate of lime, and were often decidedly impure.

Ground Pepper.—As ground spices in general are quite impure, Dr. Smart observes:

The examination of the ground black peppers and spices shows to what extent adulteration may be practiced when its detection by the public is a matter of difficulty. The dealer himself appears to have lost the knowledge of the characters of the pure article, as out of 4 samples sent in by respectable houses in this city for the purpose of being examined, only 1 was pure. The others contained baked flour and rice with sand enough to prove the unclean condition of the pepper itself.

Out of 18 samples of ground cayenne pepper only 2 were pure. Out of 23 specimens of commercial ground mustard, 21 were adulterated. Out of 36 samples of ground cinnamon, only *one* was the genuine article! The usual adulterants are colored clays, roasted wheat, beans, rice, sawdust, etc., but, fortunately, no red lead.

In confectionery the red colors are generally harmless cochineal, but the yellows are often from salts of lead. Some yellow lemon balls yielded seven grains of lead chromate to the pound of candy.

THE LIQUEFACTION OF OZONE AND ITS COLOR IN THE GASEOUS STATE.

By MM. HAUTEFEUILLE and J. CHAPPUIS.

MM. HAUTEFEUILLE AND J. CHAPPUIS have recently published some notes on this subject, which supply interesting information. Ozone, such as one usually prepares, possesses so little tension in oxygen, at most 53 mm., that the physical properties of this body are hardly known and distinguished from those or oxygen. The difficulties which Soret has so ably overcome in determining the density of ozone by operating on weakly ozonized oxygen are known. One of the fixed physical properties of this body is its heat of formation, which was accurately determined by Berthelot, in spite of the state of dilution in which it is found on leaving the apparatus for ozonization. The preparation of a mixture very rich in ozone is then the first condition to be fulfilled, in order to acquire new notions of this curious body. We have already established the fact that the isomeric transformation of oxygen submitted to electricity obeys simple laws, and that the proportion of ozone increases but very little with the pressure for every temperature, whereas, in passing from 20° to —55°, the proportion of ozone increases fivefold. Removed from the action of electrical discharges, the mixture of oxygen and ozone ceases to be a homogeneous and balanced system; in spite of that, the mixture is preserved without appreciable alteration as long as a constant temperature is maintained, if we operate on it below 0°. This relative stability of ozone allows us to compress the mixture, and to obtain the tensions of ozone of several atmospheres. As it is necessary to prepare ozone, destined for these experiments, under the strongest possible tension, one must ozonize oxygen at a very low temperature. Consequently the oxygen remains a quarter of an hour in an apparatus of alternating discharges, whose concentric tubes of thin glass are dipped into chloride of methyl, then one passes it into a test tube, terminated by a capillary tube of the Cailletet apparatus. This reservoir, of about 60 c.c., at first empty and kept at —23°, not being able to fill itself at one time under a pressure approaching 760 mm., is put rapidly in communication, five times successively, with the electric apparatus, the capacity of which cannot exceed 20 c.c. In a quarter of an hour one succeeds by this method in filling the test tube with a mixture of oxygen and ozone, very fully charged with the latter gas. The test tube is then taken away from the chloride of methyl and separated from the electric apparatus, and the gas which it contains is driven slowly back by mercury, cooled to 0° in a capillary tube maintained at —23°. The mercury which transmits the pressure of the hydraulic press does not impoverish the gaseous mixture as quickly as might be feared; a solid glaze is formed on the surface of the metal, which rapidly limits the action; the heating of the gas during the compression is more formidable. In spite of these difficulties one succeeds in increasing the tension of the ozone to a considerable degree. From the first working of the piston, the capillary tube becomes of an azure blue; this coloration is intensified in proportion as we reduce the volume of gas; and if the tension of ozone is brought by the compression to be one of several atmospheres the gas is indigo blue, and the meniscus of mercury, seen through the gas, is then of a steel blue. The blue color of the gas becomes less intense, and the mercury regains its usual metallic appearance as soon as the tension of the ozone diminishes. The preceding mixture contains enough ozone for one to observe a thick white mist at the moment of the expansion which succeeds a compression of 75 atmospheres. It is not then necessary to compress the ozonized oxygen as much as the pure oxygen—300 atmospheres—in order to determine by a sudden expansion the momentary

formation of a mist, a certain sign of liquefaction or even of solidification.

A comparative study of the mixtures of oxygen and ozone, and those of oxygen and carbonic acid, shows that in very comparable conditions the expansion ought to be sensibly stronger with the ozone than with the carbonic acid for one to begin to perceive a mist. The ozone would then be a little easier to liquefy than the carbonic acid. The mixture of oxygen and ozone contains an explosive gas, and should always be compressed slowly and cooled; for if one does not meet these conditions the ozone decomposes with the escape of heat and light, and there is a loud report accompanied by a flash of yellowish light. Berthelot has found that the transformation of oxygen into ozone absorbs 14 cal. equivalent to 8 (0°=24 gr.); the ozone may then be placed beside explosive gases; our experiments show that, like them, this body is susceptible to sudden decomposition.

One may also observe a portion of these new facts by compressing the oxygen which has gone slowly through the electric apparatus at ordinary temperature; for if we compress this gas rapidly in a capillary tube, placed in some water at 25°, we often destroy the ozone with explosion, but if this same gas is cooled at —23°, the ozone which it contains may be brought to a tension of 10 atmospheres, and may be preserved for hours in these conditions of temperature and pressure, if the gas is separated from the mercury by a column of sulphuric acid.

It is ascertained then almost equally clearly as in the preceding experiment that the ozone is a gas of a beautiful azure blue, for its color is so intense when we increase its density tenfold, that we have been able to see it in a tube of 0·001 m. internal diameter, when we were operating in a very poorly lighted room in the laboratory of l'Ecole Normale. It is then established that ozone under a strong tension is a colored gas—but may the same be said of ozone at the tension of some millimeters? The blue color characterizes the ozone as surely as its smell, for at all the tensions we find it on examining the gas to a sufficient depth. It suffices in order to make this manifest to interpose between the eye and a white surface a tube of 1 m. in length, traversed by the current which has passed through the electric apparatus of Berthelot. The color which the gas then possesses reminds one of the blue color of the sky. This blue is more or less deep, in proportion to the time the oxygen has remained in the apparatus, and it is consequently more or less rich in ozone. As soon as we stop the electric tube the coloration disappears, the ozonized oxygen being replaced by pure oxygen.

The following numbers, from a paper by the same authors in *Comp. Rend.*, are of interest, as showing the exact influence of temperature and pressure on the ozonizing of oxygen. Diminution of pressure does not tend to increase the amount of ozone produced, but decreased temperature exerts a marked action in increasing the amount of oxygen transformed into ozone:

| Tension of oxygen.	Tension of ozone.				Proportion of ozone by weight.			
	—23°.	0°.	20°.	100°.	—23°.	0°.	20°.	100°.
760	108·70	82·84	53·96	—	0·214	0·149	0·106	—
380	51·68	38·76	31·54	1·48	0·204	0·152	0·125	0·0117
300	40·20	30·60	22·20	—	0·201	0·1525	0·112	—
225	24·80	22·95	15·52	0·088	0·191	0·153	0·104	0·0118
180	22·30	16·58	10·52	—	0·181	0·137	0·089	—

THE OXIDATION OF ALCOHOL.

WHEN a dilute or alcoholic fluid is exposed to the action of free oxygen, the latter gradually combines with the former, and according to the generally received opinion, acetic acid is the product of the change. The formation of acetic acid may be expressed in chemical notation as follows:

$$C_2H_6O + O_2 = C_2H_4O_2 + H_2O$$
Alcohol. + Oxygen. = Acetic acid. + Water.
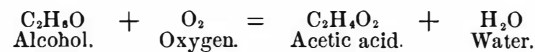
This oxidation is brought about through the influence of a certain ferment called *Aceti mycoderma*, but other organisms are also capable of inducing the same change. Acetic acid, however, can be formed from alcohol without the agency of organized ferments. Dobereiner's celebrated experiment proved that the vapor of alcohol was converted into acetic acid by the agency of porous platinum, which possesses the remarkable property of condensing gases upon its surface, and thus the alcohol and oxygen are brought into sufficiently close contact to combine. Other porous materials besides spongy platinum possess this power, although, perhaps, not to the same degree; but it is right to mention that, according to Pasteur, the oxidation of alcohol into acetic acid is due to the intervention of one of the oxidizing ferments. The cells of these organisms probably act much in the same manner as the spongy platinum—namely, by condensing the oxygen within them, and thus, by rendering it more concentrated, making its energy greater. In a dilute alcoholic fluid like beer, we have all the conditions favorable to the production of acetic acid, and the change is undoubtedly hastened by the porous character of the wooden vessels in which beer is usually stored. Even if the pores of the wood do not possess the power of converting alcohol into acetic acid, which Liebig and many other chemists claimed for them, they at least serve as efficient carriers of the minute organisms which, according to Pasteur, are the principal agents in the phenomena of acetification. In drawing attention to the changes in the oxidation of alcohol, which have so much interest for brewers on account of their disastrous effects on beer, it is necessary to point out that there is an intermediate product. Midway between alcohol and acetic acid there is a substance called aldehyde; as its name implies, it is alcohol deprived of hydrogen, and its formation and subsequent conversion into acetic acid is explained by the following chemical equation:

$$C_2H_6O + O = C_2H_4O + H_2O$$
Alcohol. + Oxygen. = Aldehyde. + Water.
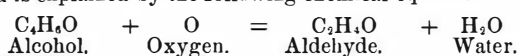
It will be seen that the change is really an oxidation of the alcohol, although the oxygen acts by removing a portion of the hydrogen. The subsequent conversion of aldehyde into acetic acid by means of another equivalent of oxygen is expressed by the following equation:

$$C_2H_4O + O = C_2H_4O_2$$
Aldehyde. + Oxygen. = Acetic acid.
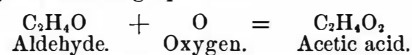
When the vapor of alcohol is oxidized by means of spongy platinum or other powerful oxidizing agents, aldehyde is formed in large quantities, and it is more than probable that the cells of the oxidizing ferments act in a similar manner. In this way aldehyde may often be formed in beer, and as aldehyde possesses a peculiar fruity odor and is very volatile, this body may play an important part in developing the characteristic flavors and aromas of different kinds of beer. The detection of aldehyde in beer is attended with considerable difficulty, but several investigators have identified it as