HOP-RESIN.

The action of oxygen on vegetable oils results, first, in the formation of a balsam, then of a resin. The former are merely mixtures of ethereal oil with resinous substances, while by further exposure to the atmosphere the oil is completely evaporated, leaving a simple resin. The artificial balsams, produced by the solution of resinous substances in volatile oils, may at some future time be pressed into the brewer's service for barrel pitching. It would not be difficult to imagine a varnish or balsam made from a tasteless resin in combination with a volatile liquid, which, when applied as a paint to the inside of the package, would oxidize, leaving the resin as a solid coating. The first of these substances with which we shall have to do, and the one that will be most familiar to the brewer, is the *hop-resin:*

It is even now a matter of dispute whether the bitter principle of the hop proceeds from a substance, hop-bitter, having an independent existence in the hop extract, or whether the bitter flavor proceeds from the hop-resin. Rautert claims that they are identical, that the hop-resin is at once the most important element of the hop, and gives it its bitter flavor. He says in an article on the subject in the *Bierbrauer*, for 1859:

"Hop-resin is not easily soluble, particularly in pure water, and where the hop oil is not present. But water containing salts, such as tannin, or g m, or sugar, dissolves a considerable quantity, especially when hop oil is also present. It was doubtless owing to this circumstance that when some time since a search was made for a bitter resinous substance that should be easily soluble in pure water, *i. e.*, lupulin, the scientists came to the conclusion that none such existed in the hop. It has since been decided that this resinous substance is the bitter of the hop; it is not very soluble in water, and constitutes from twelve to eighteen per cent. of the hop. To the hop-resin must be ascribed all those effects on the beer, to secure which hops are employed. Hop-resin is of a yellowish brown color, very much resembling brewer's pitch. Being somewhat soluble in the saliva, it has an intensely bitter taste as long as kept in the mouth. It has not yet been found possible to obtain from the hop a resin that is not bitter, a fact which goes far to explode the opposite theory as to its bitterness. Exposed in thin layers to the air, it undergoes after some time a decomposition, after which it becomes insoluble in many substances in which it was formerly soluble. This change will take place more rapidly in the sunlight."

In opposition to this, Mulder, in his "Chemistry of Beer," says: "The particles derived from the hop which we can trace and account for in the beer are the hop-resin and the hop-bitter. If we take beer and evaporate it to solidity, we can dissolve both these substances out by means of alcohol, or we can take out the hop-resin with ether first, and afterward the hop-bitter with water."

Lermer, by means of a tedious and delicate process, has lately succeeded in producing from hops a crystallizable substance, to which he has given the name of hop-bitter acid, in consequence of it showing an acid reaction when dissolved in ether. The brittle white crystals do not remain long unchanged; in twelve hours they become yellowish and soft. In water this substance is insoluble and tasteless, but the bitter principle is quickly developed if it is dissolved in alcohol and the solution then diluted with water. Whether or not it is soluble in worts, Lermer does not say. The substance requires still further study, and it may eventually turn out to be developed by Lermer's process from the resin during the process of production.

At some future time we may become acquainted with further particulars with regard to this substance, but we must remember that when beer has been left with a surplus of saccharine in it on storage it continues to ferment, and during fermentation the resin is eliminated, and the beer gradually *loses in bitterness.* The solution of hop-resin is greatly affected by the passage through the latter of carbonic acid gas, which affects its more rapid expulsion, and will account for the large quantity of hop-resin that is worked out of beer at the commencement of fermentation, in proportion to the quantity of sugar that has had time to be converted into alcohol.

Brewer's Pitch.—From the wounded bark of the fir tree a balsamic substance flows that is carefully collected, and boiled with water until the greater part of the volatile oleaginous components have been driven off. The semifluid substance is then filtered through coarse linen to remove chips of wood or bark, and returned to the kettle where it is boiled until the whole of the water has been driven off. Should any water remain in the pitch it will cause bubbles and an unequal coating on the inside of the packages. The brewer will bear this in mind in buying pitch. The test for water in pitch may be made by making up a cube of the material and holding it in a flame. If it be not free from water it will commence to sputter at once.

The whole of the ethereal oil is not driven off in the process of manufacture; a portion remains behind with the resin and gives the pitch its peculiar odor, varying according to the species of fir from which it was obtained. Although the chief use of the pitch is to close the seams of the packages, make them air tight, and keep the beer from contact with the porous wood, it has, according to Habich, a further utility which must not be under-rated. The pitch is said to preserve the beer by retarding the after-fermentation. *Asphalt*, or the substitute for it that is generally used in the brewery, viz., the residue obtained from the distillation of coal tar, mixed with linseed oil and thinned with turpentine, has been frequently used for painting walls, while felt soaked in some such mixture has been used for roofing. This has often resulted in irregularities during fermentation, which disappeared when the obnoxious odor was removed. The cause of the trouble was doubtless the vapors of benzoline and naphtha which remained in the tarr substances, and which are well known to be injurious to fermentation.

The next class of substances with which we have to do has received, particularly of late, a great deal of attention; they are the

FATS AND FATTY ACIDS.

A simple proof of the fatty nature of a substance is shown by its leaving a permanent greasy stain on paper. They are insoluble in water on the surface of which they float—at an ordinary temperature some of them are solid like tallow, some semi solid like butter, and some liquid like oil. All of them may be reduced to an oily constituency by exposure to the heat. These fatty substances are composed of glycerine and one or more fatty acids. The fatty acids are in part insoluble, the remainder being difficult of solution in water, and they all swim on the surface of that fluid; some of them are very volatile. Among the first that are of interest to us we shall find—

Stearic Acid, Margaric Acid, and Oleic Acid.—We will use them only as illustrations of solid and fluid fatty acids. Stearic acid is largely contained in the substance of which the highly transparent wax candles are moulded, the liquid acids being expressed for that purpose. In combination with potash, these fatty substances form soft soap, while with soda they form the ordinary hard soap. In combination with glycerine they are fats. In the manufacture of soap these fats are boiled with potash lye until the fatty acid unites with the potash and forms soap, while the glycerine is found in the refuse of the soap boiler's vat.

Butyric Acid is found in combination with glycerine in butter. If by a peculiar process the butter is deprived of part of its glycerine it becomes rancid, the peculiar smell of rancid butter being caused by an excess of butyric acid.

In the brewery, generally by gross carelessness, butyric acid is developed, giving to the worts on the coolschiffe the unpleasant taste and smell called summer rancidity. It may nearly always be accepted that where a brewer complains of butyric his brewery or plant or utensils will be found in some manner very dirty. The chemical changes that occur are as follows: The component parts of butyric acid are carbon eight equivalents, hydrogen eight equivalents, and oxygen four equivalents. At the commencement of the affection a development of gas commences on the coolschiffe, and carbonic acid gas and hydrogen gas are largely given off. If from one part of glucose we abstract four parts of carbonic acid gas, consisting of carbon four equivalents, oxygen eight equivalents, and four parts hydrogen, we shall find remaining the components of butyric acid, viz., $C_8H_8O_4$.

St. John's Bread, or locust beans, as they are popularly called, contains a large proportion of glucose, but the remaining components, under certain circumstances, decompose rapidly and develop butyric acid in large quantities. During fermentation this butyric acid combines further with ether, composed of four equivalents carbon, four equivalents hydrogen, and one equivalent oxygen. Butyric ether, as it is called, has somewhat the odor of rum; in fact, rum owes its characteristic odor to the presence of butyric ether. This locust, or St. John's bread, has been known to be used by English brewers in their beer, which has in consequence developed a peculiar "rum" flavor.

Valerianic Acid, so called because first obtained from valerian root. It is worthy of the brewer's notice by reason of the volatile hop oil, changing by oxidization on exposure to the atmosphere to this acid, which gives its characteristic odor, that of strong cheese, to old hops or those that have been carelessly stored.

Fatty substances found in malt and grain next draw our attention. Although an important subject to the brewer, it has hitherto received but little attention, and we cannot treat it so fully as its importance deserves. In these days of progress, when the brewery trade has made such strides as to become a gigantic consumer of grain, a faction in the barley trade to make or mar a market causes brewers to manifest some little anxiety as to the adaptability of other cereals to their processes. Hitherto, efforts in this direction have been only partially successful. It has been found difficult to use ordinary raw grain without subjecting it to some process that is almost as costly, and to the brewer more troublesome than malting or buying malt. The least expense such experiments entail are alterations of plant, for which space is not always available, and after the risk has been run, it frequently happens that the product is inferior to the article in demand, to the loss of the brewer's reputation. The greater proportion of these mishaps may be attributed to the peculiar fatty substances of each cereal, which impart to the beverages prepared from them their characteristic odor. Corn meal, for instance, contains a larger proportion of starch than barley malt, compared bulk for bulk with the latter; which may be easily converted into fermentable saccharine with the aid of a certain proportion, say one-third to one-half, of barley malt. It has been used successfully by some brewers in the proportion of one-fifth malt to four-fifths corn meal, but until the present time the fatty substances and acids of the corn meal have proved an effective barrier to its successful application, though many brewers have experimented in its use and would gladly employ it for economy's sake. An intimate knowledge of the nature of these fatty substances would doubtlessly suggest some means of neutralizing or avoiding them, and this will certainly be achieved as the trade progresses at some future time. The most exhaustive research into the character of these substances hitherto made, is that of the chemist Stein, from whose treatise we obtain the following facts:

By means of ether we dissolve out the fatty matter from raw barley, and afterward drive off the volatile spirit at a gentle heat; we obtain a certain quantity of a reddish-yellow fat. When fresh, the smell of this fat strongly resembles that of a heap of barley, and becomes more prominent when we heat the fat in water. Wagner obtained from fresh Jerusalem barley a colorless and odorless fat, of the consistency of castor oil, while that obtained by Hanamann from a similar source was claimed to resemble in odor fresh clover.

The fat obtainable from green (unkilned) malt has a peculiarly pungent smell, while that of air-malt smells more like the barley-fat. The most interesting is, however, the fat obtainable from kilned-malt. From such malt Stein obtained always, in his carefully conducted experiments, more fat than from air-malt, tending to show that during kilning the fat had taken up some other substance. It might be supposed that it had combined with oxygen, causing a great change in its odor. If we extract from kilned malt, by means of ether, the whole of the fatty substance, and then dissolve out from the malt all soluble matter, we shall find that the last extract, though having a certain scent of its own on being warmed, is not nearly so pungent, nor is it the same as that of malt extract ordinarily; but if we add to this the first extract we obtained, viz., the solution containing the fatty matter, and again apply heat, we shall find the characteristic odor of malt extract at a lower temperature than we needed before. From the above facts we may infer, with little fear of being incorrect, that the changes of aroma that occur in grain during the process of malting from the steep to the kiln are all centered in transformations that are effected in the fatty substances as originally present in the barley. It may now be understood how the length of time during which the barley is allowed to sprout or the long growth of the plumule causes a more thorough conversion of this fat, and accounts for the better aroma possessed by well grown malt. According to Stein, the quantity of fat contained in barley and malt was as follows:

One hundred parts of barley	3·556
In the air malt made therefrom	2·304
In the kiln-dried malt	3·106

During germination fat had therefore been expended; it consists of carbon, hydrogen, and a small quanty of oxygen; by an absorption from the atmosphere of a further quantity of oxygen, these elements would be resolved into carbonic acid gas and water. In all grain the fat goes with the albuminoids, and those parts rich in albumen are always richer in fatty matter. Barley meal contains, according to Hanamann, 0·8 to 1 per cent. of fat, while the bran or inner husk of barley contains 3 to 3·5 per cent., and that of wheat as much as 5·6 per cent. Kaiser relates, that in a distillery where a grade of maize very rich in fat was employed, if the mash was overheated drops of fat could be seen floating on the surface; at a low temperature they did not appear. Some inferences as to the cause of cloudiness in worts where the closing heat in the mash has been carried very high, may be drawn from these statements. In addition to the above it will not be out of place to recall to mind the assertion, supported by actual experiment of Mr. Pasteur, to the effect that in all vinous fermentations more or less fat is developed. To a saccharine solution free of fat he added yeast, which he had deprived of all fat by means of ether; and in the yeast developed he found from one to two per cent. of fat.—*Brewer's Gazette.*

NEW SOLVENT FOR GUMS.

Solvents for gums are not so numerous that the practical worker can afford to neglect any promising line of research; and there may possibly be some advantage in the "improvement" for which Mr. W. F. Jack, of 16 Mark Lane, E. C., lately obtained provisional protection, but allowed it to lapse. It has hitherto been the practice to use naphtha and other distillates of coal tar for dissolving India-rubber and other gums, all having a pungent and disagreeable odor. Mr. Jack obtains his solvent from wood tar or the oils thereof (which have hitherto been comparatively valueless), either by distillation or by any other process, either by heat or lowering the temperature, with or without the aid of an acid or alkaline bath, preferring to use the alkaline bath at a heat varying, say, from 100° to 400° Fahrenheit; the result being an oil with a pleasant and wholesome odor, which can be used either as a solvent for gums, or by itself for lighting and heating purposes, or in conjunction with alcohol, ether, or other spirit, camphor, or other oils, singly or in combination. By mixing the solvent or the residue obtained after distilling off the lighter oils with the fatty alkaline and other materials for making soap, a soap is made of an antiseptic nature and refreshing odor. The heavier portions of the residue may be used as a lubricant, either alone or in combination with other oils.

THE ELECTRO-MOTIVE FORCE OF ALUMINUM.

This subject has been recently studied by Signor Malavasi, of the Modena Academy. In contact with zinc (he says) aluminum always appears electro-positive, though it is less oxidizable. In dilute acid, on the other hand, it is electro-negative. If an aluminum plate be cleaned with oil and pumice stone, it is, on contact with zinc, positive; but, if it be cleaned with water and pumice stone and dried in the sun, it is negative. On being immersed in water after the cleaning with oil, the aluminum plate is only positive at the beginning—very soon negative. In water, the aluminum plate gets coated with a gelatinous mass (iron oxide, hydrate, and clay), the zinc plate with a crust; thus both are oxidized, with the above mentioned effects. Three elements—zinc, copper, water—have the same electro motive force as five elements, zinc aluminum. On heating the junction, the current passes from aluminum to tin, copper, antimony; thus the behavior is somewhat like that of lead. At a higher temperature, the current between aluminum and tin is reversed. Aluminum plates are not markedly polarized in a circuit, though the positive aluminum electrode is thereby quickly dissolved. If the current is passed through after the aluminum plate has remained long in water, the polarization is more pronounced. In a combination zinc-aluminum water, or dilute acid, the current mostly rises at first, even to the double, and then slowly falls; and this the author attributes to the gradually strengthening adhesion of the water to the metals, especially the aluminum; the more so that, on carefully cleaning the aluminum plate with water and pumice, the rise takes place more quickly. This is also indicated by the increase of polarization, after long immersion, on the current being passed. This does not produce an increase of conductivity of the liquid. On alternately immersing, raising, drying, and again immersing, one of two aluminum plates, that remaining in the water, appears gradually positive, like zinc. In acid water, the change of the aluminum came out more strongly than in pure water. In copper aluminum elements, especially when the copper plate is large, the injurious polarization of the latter can be partly compensated by the rise in the electromotive force of the aluminum, so that thereby the decrease of current strength is partly prevented.

EFFECTS OF COLOR ON DISTANCE.

By C. A. Bucklin, M.D., New York.

That artists unconsciously avail themselves of a universal visual imperfection in producing distance on canvas, is a fact which in interest is only exceeded by the fact that all eyes have visual imperfections.

Let us compare, experimentally, the human eye with a simple optical instrument, and we will find that the eye has even more defects than the instrument.

I. If we allow a ray of sunlight to fall upon a prism of glass, after passing through it, the ray divides itself into various colors; they are all bent toward the base of the prism; the violet rays are bent the most, the red rays are bent the least.

This demonstrates that the red rays are more difficult to bend than the violet.

II. If the light from a candle, twenty feet distant, falls upon a common magnifying glass (No. 2), the rays will be united in one point about two inches behind the lens. If we place a sheet of paper at this point we will see formed upon it a round point of light; if we carry the sheet of paper a few inches farther back, a distinct inverted image of the candle will be seen. If the candle is then brought a little nearer to the lens the image will vanish, and the former round light point will gradually take its place, which indicates that the rays are united farther behind the lens than they were. That is, by bringing the candle nearer we have made the rays more difficult to bend or unite.

Bringing the candle nearer makes the rays diverge, and diverging rays of light, as well as diverging projectiles, are difficult to make converging.

We have seen that red rays were more difficult to bend than violet.

Now we have found that divergent, or rays from a near object, are difficult to converge.

This makes it evident that *color* and *distance,* independent of light and shade, are interchangeable. A lens should unite rays from violet objects and rays from red objects at the same point; but a simple lens does not.

The discussion between Newton and Euler as to whether this error existed in the human eye, is not without interest. Newton's belief that the eye was not achromatic, and also that it was impossible to produce achromatic refractive instruments, led to his inventing and constructing the reflecting telescope.

Euler's incorrect belief that the eye was achromatic, led to the construction of achromatic telescopes and microscopes.

We have but to compare the glass lens with the lens in the human eye (as was done by Maurolycus in the last half of the sixteenth century). The sheet of paper representing the retina, the candle the observed object, and the dark space intervening between lens and paper, the dark chamber of the eye. Thus we have compared the eye with a simple optical instrument. The chromatic aberration of the human eye is considerably less than that of a glass lens.

Without referring to the details of Fraunhofer's[*] experiments, by which he not only demonstrated the existence of this error in the human eye, but with which he measured it, I will give you his results. At the far point of distinct vision, with the eye at rest, a violet object must be twenty-six inches nearer in order to be seen with the same distinctness as the red object. Artists all agree that independent of light and shade, coloring parts of a painting violet retires them, while coloring them red advances the same. I consider that their success in producing this effect depends principally upon this universal visual imperfection in the human eye.

If I have succeeded in calling the attention of those who have but little time to study optics to the fact that all eyes suffer from chromatic aberration, and have given them a general idea of the nature of this visual imperfection, my aim has been reached.—*Medical Record.*

ON WATER AND AIR.[†]

BY JOHN TYNDALL, D.C.L., LL.D., F.R.S., Professor of Natural Philosophy at the Royal Institution of Great Britain

FIFTY-TWO years ago, commencing on a day in the year 1827, Mr. Faraday gave the first course of juvenile lectures in this place, and the lectures have been continued every Christmas without interruption from that time to the present. For years before his death, when he had given up all other engagements, it was his habit to lecture every year to boys and girls at Christmas, for he thought it a most important thing that that they should not grow up in the midst of this wonderful system of nature in which we dwell without knowing something about it. There cannot, I think, be a doubt that a great deal of the interest that is now taken in the scientific education of the young may be traced back to those juvenile lectures which Faraday delivered in this room.

A knowledge of the phenomena and laws of nature is sometimes called "natural knowledge." The Royal Society, for instance, which was founded 220 years ago, announced its object to be "the improvement of natural knowledge;" and I trust that we who are here assembled together in the Royal Institution, which was founded 80 years ago, will, for the next fortnight, work cheerfully together in the great field in which natural knowledge is to be gained.

I have chosen for this course of lectures two of our most familiar substances—water and air. Water is a very common article of diet. If you take a man weighing 11 stone, and weigh the muscles of that man separately from the bones, they will weigh about 64 pounds; but if you dried those muscles, so as to convert them into a dry mass, they would be reduced in weight to 15 pounds, so that, out of 64 pounds, nearly 50 pounds are pure water. Hence I think you will agree with me that I am not wrong in stating that water is a very important article of food. Every mutton chop and every beefsteak that we consume contains water in this proportion.

But we not only thus feed upon water, but we drink it directly. Whence comes our drinking water? Well, any thoughtful boy or girl here present who had time to think would say that, eventually, it comes from the clouds. How does it get there? That question can be answered thoroughly by and by. At the present time we know, or at all events we assume, that the water comes first of all from the clouds. If you trace the course of the Thames backwards, you find that the very broad river that we have here in London is joined by other rivers right and left, until, finally, you come to the Cotswold Hills, where you find that what is here the Thames comes down to a small rivulet. This rivulet is joined by other rivulets on the right and left as you go down it, and then, at last, the river assumes the breadth at which we have it here when it reaches London. Now, this water which comes from the Cotswold Hills falls on those hills as rain. But not only does the water flow thus over the surface of the collecting valleys, and then flow to the sea in the form of rivers, but it in part sinks into the ground and percolates through the soil, and here and there appears as a pellucid spring. That is the origin of spring-water. It comes originally from the clouds, but it has percolated through the earth and come out somewhere, and there we have our clear spring.

Now, the hardest rocks are more or less soluble in water. You know that sugar and salt are very soluble; but rocks are also more or less soluble in water, so that all our river water and spring water has more or less of mineral matter dissolved in it, as sugar is dissolved in a cup of tea. Well, how do we know this? A great portion of the mineral matter may be removed from the water merely by boiling, and it is so removed in all our utensils which are employed in the kitchen. Just before the lecture I went into our own kitchen upstairs, and I looked into this kettle, and I found a thick mineral incrustation. I dare say that I can get this very hard substance out of the interior, and if you look at the interior surface of that kettle after the lecture, you will see that it is covered by this very thick crust, which is so very hard that I can hardly get it to break away. Here it is. There is a crust of this thickness on the interior surface of the kettle, and this is due to the hardness (as we call it) of the water. By boiling, a great amount of the mineral matter is precipitated and is rendered solid, and it settles upon the interior surface of the kettle, and produces that incrustation to which I have referred. Here is a copper tube which belonged long ago to a boiler at the Athenæum Club; and if, after the lecture, you come forward and examine this tube, you will find it coated so that it is almost choked up with a series of beautiful concentric incrustations of the solid matter which was contained in the tap-water supplied to the Athenæum Club and which was deposited upon the interior surface of the tube.

Not only will boiling liberate and re-solidify dissolved matter, but evaporation does the same. If you go to St. Govor's Well in Kensington Gardens, and look at where the water drips or splashes down from the little outlet, you will see a red mark where it falls. That is oxide of iron, and if you taste the water you will find that it has an inky taste. As the water splashes down, it is in part evaporated, and the iron is liberated there in the form of this oxide of iron. The reason why caverns are usually found in limestone strata is that limestone is more soluble in water than most other rocks; and if you wander, as I have done, in limestone caves, you will usually find in each cave a stream of water which has washed out the limestone and produced the cavern; and sometimes you see from the roofs of those caverns—I was going to say most beautiful icicles—but stalactites hanging down. These are due to the water which has entered into the fissures in the roof above, and percolated through the roof and dissolved some of the limestone, and made its way into the cavern, where the water is in part evaporated; and, in consequence of the evaporation, the solid matter has been deposited, and you find that, as it evaporates, these beautiful stalactites grow longer and longer from the roof toward the floor. Then drops of water fall from the end of the stalactites upon the floor, and there the water is still further evaporated, and a heap is produced called a stalagmite; and, as the water continues to drip, more and more of the solid matter is deposited below, so that the stalagmite grows from below upward, while the stalactite grows from above downward, and by and by they meet in the center, midway, with the point of the stalactite actually in the center of the stalagmite, and most wonderful and fantastic pillars are thus produced. If you visit any of the great limestone caves you will see examples of this kind. Here are some stalactites from St. Michael's Cave at Gibraltar. They are so beautiful that it seems a kind of desecration to break them. Here we have beautiful stalactites produced by the evaporation of water containing a mineral in solution, and that mineral is what we call carbonate of lime.

And now we have to examine something about this carbonate of lime. It is a body compounded of carbonic acid and lime. Everybody knows what lime is. I have here some quick-lime in this vessel. In order to show the influence of boiling, I have here water boiling in two different flasks. One of them has, perhaps, been boiling an insufficient length of time to deposit all its solid matter, but I think you will see that there is a very considerable difference between these two flasks. Now, these are two different kinds of water. One of the flasks contains water for which I am indebted to a distingushed engineer, Mr. Homersham, who has made certain water-works at Canterbury. It is the Canterbury water, which has been softened by a process that we shall learn about by and by. You see that the water in this flask is perfectly clear because all the mineral matter has been removed from it before boiling; but the water in the other flask, which is the tap-water of our house, is thick and turbid. You see that the mineral matter has been let loose, and is forming a kind of mud, in point of fact. If I place the flask in this beam of light those at the right and the left will see that sparkling stuff, which is the mineral matter—the carbonate of lime—which has been liberated by the boiling; and it is this stuff which, when deposited upon the interior surface of our kettle, produces that incrustation to which I have referred. This open vessel merely shows the effect of evaporation. A quantity of water from St. Govor's Well in Kensington Gardens was placed in this basin this morning and evaporated, and there is the substance which gives the water its peculiar taste and its peculiar medical value. This is the substance which, when it is liberated by evaporation, produces that red splash which you see when you look at the well.

Now, we want fully to understand the meaning of this phrase that I have used—carbonate of lime. Carbonate of lime is, as I have said, a mixture of two distinct substances—carbonic acid gas and lime. I will just remind you of what this carbonic acid is. There is a quantity of it here. My friend, Professor Dewar, is kind enough to help me, and here he has been exhausting a glass globe, and here is another exhausted globe. At the present time the two globes balance each other. Now, if I allow carbonic acid to enter one globe and air to enter the other, you will find that the globe into which the carbonic acid enters will sink down. Why is that? Because the carbonic acid is heavier than the air; and it is so heavy that if put into a vessel it will lie at the bottom. Here is a vessel which is now full of it, and if Mr. Cottrell gives me a match I will see whether the gas is not there; for, as many of you no doubt are aware, it is a peculiarity of this gas that it will not support a flame. You see that the flame goes out very soon when I dip it into the gas.

Now, in order to show the weight of the gas, I will blow a soap-bubble, and throw the soap-bubble into this invisible gas. The gas is there at the present time like a liquid; and, although nobody can see it, I think you will find that when I blow the bubble and throw it into the gas, the gas will be sufficiently heavy to support the weight of the bubble. [The lecturer blew a soap-bubble from a thistle-headed glass tube, and allowed the bubble to fall into a large glass vessel of carbonic acid gas. The bubble floated about midway down the vessel.] You see that it does not sink.

Well, now, in order to show you again the heaviness of this gas, I will pour it out before you, although, as it stands there, it is perfectly invisible. I want you to have a perfectly distinct idea about it. [The vessel in which the soap-bubble had been floating was then tipped up in front of the electric light, so that its shadow was received on a white screen. The carbonic acid streamed gently downward from the lip of the vessel and cast a shadow upon the screen.] There you see the gas falling, although it is perfectly invisible under ordinary circumstances. This heavy gas falls down before you like a liquid.

This, then, is one of the constituents of our carbonate of lime. The other constituent is this ordinary lime. If you mix this lime with water, the water dissolves a certain amount of lime, and then we have lime water; and here, thanks to Mr. Homersham, I have a specimen of lime water which is obtained from the Canterbury works in a way which I will presently describe to you. Lime water is produced, as I have said, by a solution of ordinary lime in water. Lime is not very soluble. It requires about 70 gallons of water to dissolve a single pound of lime. But here we have our lime water; and if you were to taste this solution you would find it very pungent to the taste, because of the lime which is dissolved in it. Now, I wish to make carbonate of lime in your presence, and I will take this beaker, as it is called, and I will pour a portion of this lime water into the beaker. There it is. Mr. Cottrell has here an apparatus for making this substance which we call carbonic acid—that heavy gas which was poured out a moment ago in your presence. I intend to let the carbonic acid bubble through the lime water. You see, I am going to the A B C of the question, and I want to bring you from the A B C as far up as we can climb. But at first I am going to the elements of the question, and those who honor these lectures with their presence will, of course, remember that the lectures are addressed to boys and girls, and that learning or depth would be very much out of place here.

Now, I have the carbonic acid in this vessel, and I will bring it into contact with the lime water. You will then find that that clear liquid will become milky. Mr. Cottrell will allow the gas to bubble through the water, and you will see in a very short time that the liquid is rendered milky. I have placed this black cloth here [behind the vessel containing the lime-water]. It is one of the devices that we employ in order to make things visible. The change in the appearance of the liquid is due to the formation of this carbonate of lime, which is an insoluble white powder and which becomes diffused through the water, producing that milkiness which you see before you.

Instead of making the carbonic acid in the way in which it is made there, it may be made by means of marble or chalk, which are themselves carbonates of lime. Carbonate of lime is a compound of lime and carbonic acid; and if you pour upon the marble or chalk an acid which is stronger than the carbonic acid, the carbonic acid will be liberated. Everybody may do this for himself. Here I put a few bits of chalk into this vessel, and if I pour upon them a little acid, you will find that it effervesces. I do this for the purpose of enabling you to repeat the experiment for yourselves. Here is a small beaker—a small glass, and we will put into it some chalk, and pour upon it a little hydrochloric acid, and, as I have said, we shall have effervescence. There you see the mixture effervescing. Mr. Cottrell will pour into a beaker a quantity of lime water, and allow the carbonic acid gas to bubble into it. There you see the gas is bubbling through the water, and you will find that the lime water becomes milky as before.

Here we have a bottle of champagne, and I want to show you that we can make our carbonate of lime from the carbonic acid issuing from champagne. This is a bottle of Mumm's extra dry champagne. I will cut the wire and remove the cork. Here is a cork with a bent glass tube passing through it. We will put it into the bottle. The champagne is not very well up, so we will stir it a little. [The bent tube issuing from the neck of the champagne bottle was held with its farther end in a glass vessel of lime water (S), so that the gas given off by the champagne might bubble into the solution. In a short time the lime water became turbid, as in previous experiments.] Here we have got our chalk produced from the carbonic acid of the champagne.

And now I want to show you that carbonic acid is also a gas that we exhale from our lungs. I will take this small vessel and pour a little lime water into it, and then simply blow into the vessel. We inhale the atmospheric oxygen, and, after this has done its work in the body by burning part of the body, we exhale carbonic acid. Here we shall have the carbonic acid coming from my lungs, which carbonic acid will unite with the lime in that water, and produce carbonate of lime or chalk in your presence. [The lecturer olew into the lime water by means of a glass tube.] You see a single inhalation is sufficient to produce this chalk by the carbonic acid from the lungs.

Now I am about to approach a very important point, and that is a point that practically bears upon the question of the solution of minerals in water. This thing which we call carbonate of lime exists in two forms. It exists as a single carbonate, which takes up a certain amount of carbonic acid; and it exists as a double carbonate or bicarbonate, which takes up twice as much carbonic acid. I say that the carbonate of lime exists in two forms—the single carbonate and the bicarbonate; and what you have now to remember is that the single carbonate is almost insoluble in water, and that the bicarbonate is very fairly soluble in water. What is the consequence? The water coming from the clouds has always a certain amount of carbonic acid dissolved in it. When such water falls upon our chalk hills, what occurs? It soaks into the chalk; it percolates through the chalk; it dissolves the chalk; and the chalk so dissolved in the rain water is present as a carbonate of lime. If the carbonate were to remain in the form of single carbonate, the rain water could hardly dissolve it at all; but, as it is converted by the rain water into the condition of bicarbonate, the rain water dissolves a great deal of it. The conversion of the carbonate from the single carbonate to the double carbonate renders it very easily soluble in water. I have here some water from the neighborhood of Canterbury, where there is a well from which is pumped a million and a half of gallons every day from the body of the chalk. Here is the hard Canterbury water, and I pour a quantity of this hard Canterbury water into the beaker. Now, I say that the lime there is in the soluble form. It is in the form of the double carbonate, or the bicarbonate, which is another expression for the same thing. Now I have here some lime water. This Canterbury water is beautifully clear and is pleasant to the taste, but you would find it exceedingly difficult to wash in this water. In point of fact, if you operate with soap in this water you find it very difficult to get a lather in it. For a certain time you cannot possibly get a lather. That water contains, I should say, more than 20 grains of carbonate of lime dissolved in every gallon. Where washing operations have to be carried on, on a large scale, with this water, an immense amount of soap is wasted, not to wash, not to cleanse your hands, not to cleanse your linen, but simply, first of all, to remove the lime from the water before the water can produce a lather, and before the water can be used as a washing medium. Well, now, the question is, how is this to be rendered soft? Or, can this water be rendered soft on a large scale, or in an effectual way? Yes. That question has been answered in a most satisfactory manner by Dr. Clark, of Aberdeen, and he has invented a process for the softening of water, which, I think, is likely to come into great request in the future. At first sight it is a very extraordinary process; for what does Dr. Clark do? He takes the lime from the water by putting more lime into it. Now that appears to be a strange assertion; but give me your attention, and there is not a boy here present that will not understand what I mean by that expression. There [pointing to a vessel of hard water] is the lime in the form of what we call bicarbonate. There [referring to another vessel is the lime, not united with carbonic acid at all, but

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[*] Mauthner: "Optische Fehler des Auges," p. 35.

[†] Being a course of six lectures adapted to a juvenile auditory, delivered at the Royal Institution of Great Britain, Christmas, 1879. Specially reported for the *Journal of Science.*