

the danger of using hydrogen as a buoyant gas in airships. A leak in a gas bag is sufficient to cause the destruction of a dirigible. In order to avoid this danger, the helium is now substituted for hydrogen, and is undoubtedly the only safe gas for use in airships, or in inflating balloons. The discovery of helium is really one of the romances of science. The United States is fortunate in having supplies of natural gas in the State of Texas and in other parts of this country which contain sufficient helium to allow of its separation on a commercial scale. Helium, discovered previously in connection with the rare gases of the atmosphere, is surpassed only by hydrogen in lightness of weight, but it is superior to hydrogen in that it is non-inflammable.

The densities of hydrogen, helium, oxygen and nitrogen, as compared to air, are recorded in the table below. Notice that helium is practically twice as heavy as hydrogen, and consequently has less buoyant power.

Gas	Specific gravity at 0° C and 760 mm.
Air	1.000
Hydrogen	0.06952
Helium	0.13804
Nitrogen	0.96724
Oxygen	1.10527

EXPERIMENT 68—Preparation of hydrogen.

Mix together in a test tube 3 measures of sodium bisulphate and 4 measures ammonium chloride and add about one inch of water. Warm gently until the gas completely dissolves.

Then add 1 measure of powdered zinc and notice the violent reaction that takes place. This is due to the evolution of hydrogen gas. Hold a flame at the mouth of the test tube and notice that the gas given off burns with a blue flame. This flame is complicated by hydrogen combining with the oxygen of the air to form water.

Hydrogen and oxygen form a very explosive mixture, and great caution must be exercised when hydrogen gas is brought in contact with oxygen in large volumes. In the reaction above the sodium bisulphate and ammonium chloride interact to form hydrochloric acid, which then reacted with the zinc powder a soluble zinc chloride and hydrogen gas.

REDUCTION

Hydrogen can be heated at a high temperature in the absence of oxygen without danger. It interacts with many substances under specific conditions with removal of oxygen and production of substances richer in hydrogen. Oxygen need not necessarily be removed by hydrogen to accomplish a reduction, but hydrogen may add or combine directly leading to reduction of the substance. In other words, to reduce is the reagent of to oxidize, and the process of removing oxygen from a substance is called reduction. We do not necessarily need to use hydrogen to accomplish reduction any more than we need to utilize oxygen to accomplish oxidation. Hydrogen peroxide and acid are chemical reagents which react as oxidizing agents.

We likewise have chemical reagents which have the power to bring about reduction. Such substances are called reducing agents. Hydrochloric acid and sodium bisulphate are examples of well known reducing agents.

REDUCTION EXPERIMENTS

EXPERIMENT 69—Reduction of potassium permanganate

Place 2 small crystals of potassium permanganate in a test tube half full of water and shake well to dissolve the crystals. Notice the purple color of the solution. Now add 3 measures of sodium bisulphite and shake again. Notice that the color of the permanganate solution is destroyed. Here we have to deal with a reaction between an oxidizing and a reducing agent. The two are incompatible. The sodium bisulphite has the power to take up oxygen donated by the potassium permanganate, thus converting the latter into a colorless substance. We may say that the potassium permanganate has oxidized the sodium bisulphite, or that the sodium bisulphite has reduced potassium permanganate. In other words, the experiment serves to illustrate both an oxidation and a reduction process.

EXPERIMENT 70—Reduction of logwood

Put 1 measure of logwood in a test tube half full of water and heat until the liquid comes deeply colored. Pour some of this liquid into another test tube and add 3 measures of sodium bisulphite, shake well and notice that the red color, due to the logwood dye, disappears and the solution becomes almost colorless. The colored logwood solution has been reduced to a colorless product by the reducing action of the sodium bisulphite.

BLEACHING

Bleaching is a commercial term widely used in the textile field. It means to decolorize. Cloth is bleached by exposure to sunlight and also by the action of chemicals to remove all color, and produce white goods. Both oxidizing and reducing agents can be used to bleach fabrics. Hydrogen peroxide is an oxidizing agent which finds wide application as a bleaching agent; for example, to bleach tussah silk. The gas sulphur dioxide is a cheap

oxide is a cheap commercial reagent which is a valuable bleaching agent and is especially used in the textile industry and straw trade.

EXPERIMENT 71—Bleaching flowers with sulphur dioxide

Place about 6 measures of sodium bisulphite in a glass tumbler and add the reagent of tartaric acid. The reaction sets in immediately and the color of the flowers is destroyed. Notice the odor of the gas.

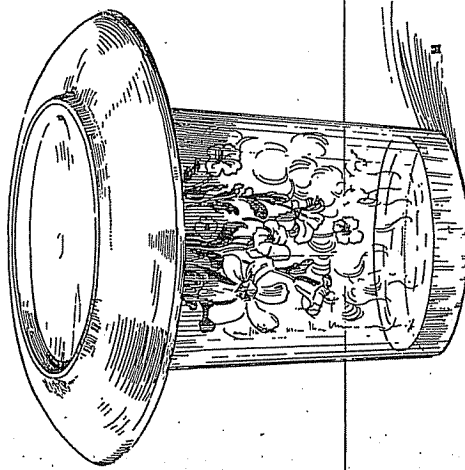


Fig. 22

EXPERIMENT 73—How to make an explosive mixture

Nitrogen is a colorless, tasteless gas. It forms four-fifths of the bulk of the powdered charcoal to carbon dioxide. Do not attempt to perform this experiment by heating oxygen to burn the sulphur to sulphur dioxide. Chemically speaking, this is a very inactive gas, and if it were not for its presence with proportions of chemicals larger than those stated above.

is slightly lighter than air (see density value on page 62 in this series). Since nitrofur found in many natural deposits. The main bulk of natural nitrates is found in water, there the air life on the earth would be destroyed. This gas dilutes the oxygen of the air, and in animal matter as a constituent of protein, in yeast and in vegetable matter, thereby preventing destruction by oxidation of living and inanimate material. Nitrogen is also an essential constituent of many valuable drugs, as the alkaloids, quinine, and strychnine. The fact that nitrogen is a very inactive element would lead one to think urphine and strychnine.

compounds would be unstable and would decompose easily, thus is easy and ERIMENT 74—Nitrogen from the air of the high explosives used during military operations today are nitrogen compounds.

Many of the most highly explosive substances are compounds of nitrogen with hydrogen, oxygen and sulphur. The force of an explosion is due to the tremendous volume of gases that are simultaneously formed when an explosive compound is detonated. Board over the jar from the pan by placing a small glass plate or a piece of glazed cannon or shell. Gunpowder, nitroglycerine, nitrocellulose, or gun cotton, picturing the cover on so as not to lose any of the nitrogen. Light a splinter of wood trinitrotoluene (T.N.T.) and tetranitroaniline (T.N.A.) are some very common explosives removing the cover from the mouth of the jar containing nitrogen, plunge the explosives of nitrogen employed in military operations. A peace time use of nitrogen into the jar. Notice that the flame goes out, showing that nitrogen does not support combustion. Perform a similar combustion experiment with dynamite and nitroglycerine.

Much can be said about nitrogen and its services both in peace and war. As a splinter into a jar of ordinary air,

their nitrogen supply from plants or from other animals which have in turn obtained their nitrogen from plants. Plants obtain their nitrogen from the soil, soil nitrogen being built up by the action of bacteria which are capable of fixing nitrogen of the air or by the addition of fertilizers containing nitrogen. Nitrogen also features in other industries among them lacquer coated textiles and plastics.

Nitrogen combines with oxygen to form several oxides. Nitric acid (HNO_3), at very temperatures, is commonly used as smelling or aromatic salts. Ammonia gas is a compound of nitrogen with hydrogen and oxygen. This important acid is really soluble in water, and the aqueous solution—ammonia water—is the form in which it is commonly met with in the trade. Ammonia gas is condensed and shipped in large quantities today in iron cylinders. Ammonia in this form finds a wide use in the manufacture of many commercial products as dyes and fertilizers. Nitric acid is manufactured by the destructive distillation of coal. It is a valuable by-product in the manufacture of sulphuric acid. This acid, and artificial refrigeration. Formerly most of the ammonia of commerce was obtained by treating chile saltpetre with sulphuric acid. Today the gas is made in large quantities synthetically by combining nitrogen of the air with hydrogen.

RIMENT 75—Preparation of ammonia

Put 4 measures of potassium nitrate and 4 measures of sodium bisulphate in a 100 ml. beaker. Moisten a piece of blue litmus paper and place it over the mouth of the tube. Now heat the test tube slowly over the alcohol lamp, add 1 spoonful of water and heat gently. Remove the test tube from the mouth of the tube. The blue litmus paper turns red. These are nitric acid fumes and fumes of nitrous acid. Remove the test tube and notice the change of smell cautiously, the fumes that are given off. When the test tube is cooled, the fumes are led into water they would dissolve immediately, giving what we speak of as nitric acid solution. Potassium nitrate is a salt of nitric acid and when it reacts with sodium bisulphate the free nitric acid is liberated.

Free ammonia gas and this reaction is used as a test for the ammonium group

(NH_3) in a compound. If the gas produced by heating the above mixture is into cold water, it is dissolved and ammonium hydroxide is formed.

EXPERIMENT 76—Formation of ammonia by decomposition of organic matter

Most organic matter contains nitrogen and when heated in the presence of an organic base, like calcium oxide, the nitrogen is partially liberated in the form of ammonia (NH_3). Ammonia was first prepared by this method and was called "Spirit of Hartsborn."

Place a small quantity of wool, hair, silk or finger nail clippings in a test tube and add 3 measures of calcium oxide and 5-6 drops of water. Place a small strip of red litmus paper over the mouth of the tube and gently heat the tube. Notice that the red litmus paper turns blue, showing that a volatile base is formed. Remove the tube from the flame and smell at the mouth of the tube. You recognize the odor of ammonia if the experiment is properly conducted.

EXPERIMENT 77—Dissociation of an ammonium salt

Put one measure of ammonium chloride in a clean dry test tube and heat over a flame. Notice that the dry salt (NH_4Cl) passes into the vapor state and condenses again on reaching the cooler part of the tube to form again solid ammonium chloride. What really takes place when heat is applied is that the ammonium chloride is split up into molecules of ammonia (NH_3) and hydrochloric acid (HCl), which recombine in the cool part of the tube to form again solid ammonium chloride.

WATER

At ordinary temperatures pure water is a tasteless, odorless, transparent liquid, colorless in thin layers, but distinctly blue when seen in large masses. It is about 800 times heavier than air.

Water consists of two elements—both gases—hydrogen and oxygen, and the proportion of 89 per cent of oxygen and 11 per cent of hydrogen by weight. In volume, water consists of two parts of hydrogen to one part of oxygen.

Water occurs very abundantly throughout the earth. Vast areas of the globe are covered with it in the form of ice, while in the liquid state it is about five-sevenths of the earth's surface, reaching in some places to a depth of 10,000 feet. Large quantities occur in the soil, and as a vapor it is an essential constituent of the atmosphere. More than half the weight of living organisms consist of water. Great many substances dissolve in water, so that water is known as a very good solvent. A substance is said to be dissolved when none of the particles of the substance is seen in the liquid nor separated from the liquid by filtering. A dissolved substance can usually be recovered from a liquid by evaporating the liquid.

The importance of water in the growth of plants can be judged by the fact that from 30 to 120 gallons of water are required by an ordinary plant for the production of each pound of dry substance present. The greater part of this water which is taken in by the roots is given off by the leaves. The stream thus maintained serves life and it to carry on its vital processes. Even though the largest proportion of the water in a plant is retained, in succulent plants, about 90 per cent of the complete weight of the plant is water, this water being an actual part of the organism. In woody plants the percentage of water present in the organism is less, although even in this case the water is an essential part of the living cell. With animals, water is quite as essential as it is with plants. About three-fourths of the total weight of a human organism is water, and about two quarts of drinking water a day, besides

which is present in our various liquid and solid foods are recommended to keep human beings in good physical condition.

Hard Water

Forms soap curds, and makes cleaning difficult.

Makes skin drawn, clogs the pores, preventing proper elimination of poisons by the skin.

Deposits soap curds in hair, dulling lustre.

Makes it impossible to thoroughly cleanse skin.

Makes a water-proof coating of soap curds around each whisker, causes razor blade to be dulled.

Causes streaks on china and glassware.

Makes work difficult.

Wastes soap, necessitates clothes, often necessitates extra hard washing.

Calls for hard scouring — harms finish.

Scale chokes down flow of water. Makes faucets drip.

Deposits rock-like scale in coil. Fuel is wasted.

Wastes fuel. Needs a long time for steam to come up.

Will eventually clog fine tubes, causing overheating, boiling away of water.

Tends to make crust tough. Toughens them, causes loss of flavor.

Impairs flavor.

Hard water is unpleasantly flavored.

Causes rashes blamed on prickly heat. Milk bottles get scummy—harder to clean.

Makes it hard to remove dirt and foreign matter. Prevents thorough cleaning.

Soft Water

Produces luxurious lather easily.

Keeps skin soft and clean. Keeps pores free.

Makes hair clean and glistening.

Keeps skin glowingly clean and free from the blemishes.

Thoroughly softens the toughest beard. Makes shaving easy—makes blades last longer.

Dishes can just be drained clean. Many pieces do not need to be touched by a towel. Cuts grease like magic.

Saves 50-80% of soap formerly used. Makes clothes soft, sweet, clean. Prolongs their life. Preserves lustre.

Keeps pipes free from scales. Faucets seat tightly.

Coils last longer. Minimum of fuel is consumed.

Saves fuel. Steams quickly.

Keeps radiator in efficient condition. Keeps motor operating at proper temperature.

Makes crust flaky and tender. Keeps them tender with all natural freshness. Need less cooking.

Makes them taste better.

A water softener like permuted removes calcium and magnesium.

Eliminates many skin troubles. Makes bottles glisten.

Cleans thoroughly and easily. Insures absolute cleanliness.

DISSOCIATION OF WATER INTO THE ELEMENTARY OXYGEN AND HYDROGEN

EXPERIMENT 78—Decomposition of water by an electric current (electrolysis)

It can be definitely proven that water is composed of two gases—namely, hydrogen and oxygen. For this experiment you will need two or three good dry cells, a shallow dish, some insulated copper wire, two test tubes and two pieces of arc carbon or clean lead.

The apparatus is set up as shown in the illustration (Figure 23). The cells are connected together in series with copper wire by joining the carbon binding post of one cell to the zinc binding post of the other cell. To the free zinc and carbon posts negative electrode or cathode and is given the pieces of arc light carbon or lead, having previously scraped the free ends of these wires with a knife to insure a clean surface.

Now fill the pan about half full of a solution of sodium bisulphate, using one spoonful of the compound to each glass of water required. Fill two test tubes with the solution, close the mouths with the thumbs and invert them upside down in the solution, being careful not to allow any bubbles of air to get into them.

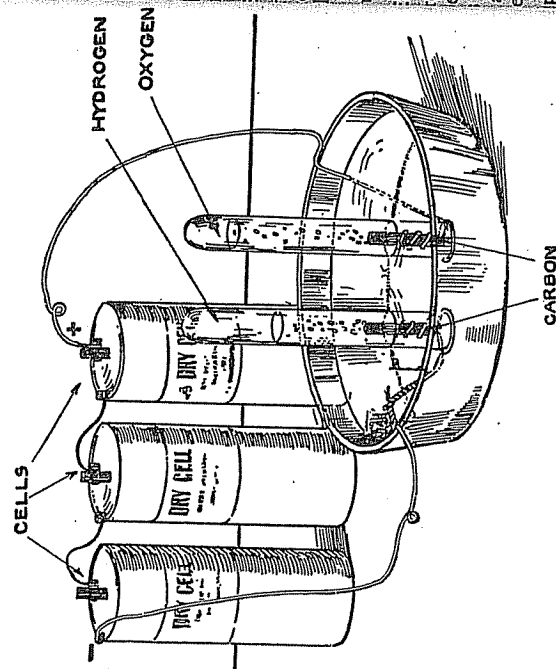


FIG. 23

Now put one of the carbon or lead electrodes under each test tube, being not to allow any air in the tubes. Notice that immediately bubbles of gas begin to form in each test tube from the carbon or lead electrodes and gradually force them down out of the mouth of the tubes. Also notice that there is twice as much

hydrogen in one tube as in the other. This is because water is composed of two volumes of hydrogen to one volume of oxygen. The electrode at which the hydrogen is liberated is the negative electrode or cathode, and the electrode at which the oxygen is liberated is the positive electrode or anode.

EXPLANATION OF THE ELECTROLYSIS EXPERIMENT

When in solution as an *ion*, has a positive charge of electricity. When an electric current is passed through the solution, the positive hydrogen is attracted to the negative electrode or cathode where it loses its charge of electricity and is given off as a gas.

On the other hand, is formed in the solution through chemical reaction, and is also given off as a gas.

Being only very slightly soluble in water, sodium bisulphate is added to make the water a conductor of electricity, since pure water is a very poor conductor.

AQUEOUS SOLUTION

EXPERIMENT 79—A soluble substance

Take one or two teaspoonfuls of common salt in a glass of water. Notice that it can no longer see the salt. If this liquid was filtered, you would find that nothing remained on the filter paper.

Notice that a white solid remains. Allow this to cool and taste a little of the solid. It is the same salt you dissolved in the water, proving that the salt when in solution had undergone a physical change only.

EXPERIMENT 80—An insoluble substance

Try to dissolve one or two measures of sulphur in a test tube half full of water. As well and notice that the sulphur remains in the solid state. Filter off the solid sulphur and evaporate the filtrate or the liquid remaining to dryness in a small pan or tin cup. Notice that nothing remains, proving that sulphur is insoluble in water.

EXPERIMENT 81—Diffusion

Put a crystal of potassium permanganate in a glass full of water and notice what happens. The solid dissolves, you will see the red color traveling up through the water and a few minutes the water will be of a uniform color, due to the complete diffusion of potassium permanganate throughout the liquid.

EXPERIMENT 82—Diffusion of cobalt in water glass solution

Dissolve one tablespoonful of syrupy water glass solution in a tall tumbler full of water. Place the tumbler on a table where it will not be disturbed and drop into the water three or four crystals of cobalt chloride. A column of cobalt silicate will grow in each test tube from the carbon or lead electrodes and gradually force them down out of the mouth of the tubes. Also notice that there is twice as much

EXPERIMENT 83—A chemical garden

Take a two-quart fruit jar with a wide mouth and fill with a previously made solution of water glass. Then plant in the bottom of the jar crystals of ferric ammonium sulfate in the following order: copper sulphate and nickel ammonium sulphate mixture to a clean, dry test tube and fill half full of water. Observe the formation of manganese sulphate. Finally after the diffusion growth is well along, then add some cobalt chloride. A beautiful chemical garden effect will be produced.

EXPERIMENT 84—Diffusion through cellophane

Wrap some crystals of copper sulphate in a tight cellophane bag. Be careful to crack the cellophane by folding. Suspend this bag containing copper sulphate in a jar of water, being careful that no water gets inside the bag. Water will finally pass through the cellophane film and dissolve some of the copper sulphate. The copper sulphate will slowly pass through the cellophane and color the outside solution blue. The passage of a salt through a membrane like cellophane or parchment is called dialysis.

EXPERIMENT 85—Separation of starch from sugar

Prepare a mixed solution of sugar and starch and transfer to a cellophane parchment bag. Suspend in a jar of water and sugar will diffuse through the parchment into the outside liquid. Taste the water after a few hours and you can taste the sugar by the taste. Starch will not diffuse through the parchment into the jar of water. To prove this, test some of the outside solution with starch-iodide paper. Starch is present a blue coloration will be produced. By changing the outside solution to a solution of iodine and liberating particles of finely divided carbon. Magnesium has greater several times all the sugar can be separated from the starch in the cellophane or parchment bag.

EXPERIMENT 86—Separating sugar from a protein

Repeat the above experiment using a solution of egg white and sugar. Sugar will diffuse through the membrane. Like starch the egg protein will not diffuse through the membrane.

CHEMICAL ACTION IN WATER SOLUTION

Most chemicals, as a rule, do not interact when brought together in the same solution. Their molecules are inert and need to be activated before a chemical change can take place. When water is present so that solution can take place they then react. By solution in water the molecules are changed or activated, and the particles of compounds are brought much closer together. Other solvents besides water can be used as a solvent to promote chemical change. For example, liquid ammonia serves as a solvent for carrying out many interesting reactions that cannot be carried out in water solution. Alcohols, acetone, benzene and other organic reagents are in place of water as solvents for carrying out organic reactions. The organic chemist applies an entirely different technique in accomplishing these reactions.

EXPERIMENT 87—Promoting chemical reaction by solution

Mix together on a sheet of paper one-half spoonful of sodium bicarbonate and half spoonful of tartaric acid. Notice that there is no reaction. Transfer this mixture to a test tube and add a few drops of water. A violent reaction results with the liberation of carbon dioxide gas, thereby proving that water is necessary to promote chemical reaction between these substances.

EXPERIMENT 88—A color change due to solution

Take a mixture of one measure of tannic acid and one measure of ferric ammonium sulphate on a piece of paper and notice that there is no evidence of reaction. Transfer the mixture to a clean, dry test tube and fill half full of water. Observe the formation of a black colored product showing that there was a chemical reaction due to the addition of water. The black product formed is iron tannate. This black substance is a constituent of many inks.

DRY ICE EXPERIMENTS**EXPERIMENT 89—Extinguishing a burning candle**

Place a burning candle in the bottom of a pint fruit jar. Then drop a spoonful of dry ice into the bottom of the jar. Notice what happens when the dry ice turns to gas. What happens?

EXPERIMENT 90—Burning sulphur

Repeat the preceding experiment, substituting burning sulphur for the candle.

EXPERIMENT 91—Burning magnesium

Repeat the above experiment by letting the dry ice vaporize and drive all the air out of the fruit jar. Then drop a small quantity of powdered magnesium into the jar of dry ice gas. The magnesium will continue to burn, using the oxygen of the dry ice gas. The dry ice gas is composed of finely divided carbon. Magnesium has greater affinity for oxygen than carbon.

EXPERIMENT 92—Floating a sunken ship

Place a spoonful of dry ice in a thin rubber bag and tie with a silk thread so that it will not escape. Then attach a weight to the bag so that it will sink to the bottom of a jar of water. Note the result as the solid dry ice gasifies inside the rubber bag. The bag will finally float. How do you explain this?

EXPERIMENT 93—Measuring dry ice pressure

Use a U-tube made of glass tubing about 5 mm. diameter and fill the lower curve with a little mercury. Then drop some dry ice into one arm of the tube and close the top of the U-tube immediately with a tight rubber stopper. Observe what happens. By solution in water the molecules are changed or activated, and the particles of compounds are brought much closer together. Other solvents besides water can be used as a solvent to promote chemical change. For example, liquid ammonia serves as a solvent for carrying out many interesting reactions that cannot be carried out in water solution. Alcohols, acetone, benzene and other organic reagents are in place of water as solvents for carrying out organic reactions. The organic chemist applies an entirely different technique in accomplishing these reactions.

EXPERIMENT 94—A miniature gas volcano

Take a heavy walled salt seller and fill with dry ice, then place in upright position in a glass jar filled with water. As the dry ice vaporizes the gas bubbles will travel to the openings of the salt seller lid and the bubbles will travel to the back of the jar of water during the bubbling.

EXPERIMENT 95—Dry ice temperature

Place some dry ice in an ordinary glass tumbler. Read the temperature with your thermometer. Now pour into the tumbler one test tube of strong lye solution, stir into the ice. Notice the change that takes place and observe the change in temperature. Dry ice is a weak acid and will slowly dissolve in alkali. After the dry ice has dissolved then add some vinegar to the alkali solution until litmus paper turns red. Gas is evolved?

ENDOTHERMIC AND EXOTHERMIC CHANGES

Some compounds give off heat when they dissolve in water. This is an exothermic change. Other compounds absorb or take up heat when they dissolve. This solution lowers the freezing point of water.

EXPERIMENT 96—Lowering of temperature by solution

Fill a test tube half full of water, and notice the temperature by feeling of the face or hand. Read the temperature by means of your thermometer, giving each about the same amount of heat. Notice that the water will boil add half spoonful of ammonium chloride and shake well to dissolve the salt. This solution lowers the freezing point of water. This solution raises the boiling point of water.

moneter.

Compounds, like ammonium chloride, sodium nitrate and many others have use of in the ice-salt freezing mixture so commonly used for making ice cream.

EXPERIMENT 97—Raising of temperature by solution

Fill a test tube half full of water and notice the temperature by feeling of the face or hand. Now dissolve in the water half a spoonful of magnesium sulphate. Notice the temperature the same as before. This time the solution is warmer. Compounds like magnesium sulphate, sodium hydroxide, and some others give off heat when dissolved in water. That is, they give off heat when dissolved in water.

ARTIFICIAL REFRIGERATION

The application of the so-called negative heat of solution of common salt in water is known as a *negative heat of solution*. (endothermic) That is, they absorb heat when dissolved in it, thereby lowering the temperature or cooling the water.

EXPERIMENT 98—How to make a freezing mixture

Mix together a glass full of cracked ice and one-half glass full of salt. Try the effect of this freezing mixture upon water by placing a test tube half full of water in it and allowing to stand for several minutes. Notice that the water in the test tube will freeze to solid ice after a short time. Use your thermometer for measuring the changes in temperature.

CHANGING THE FREEZING AND BOILING POINTS

It is easily demonstrated that when a substance is dissolved in water the freezing point of the resulting solution is lower than the freezing point of water. The reason why salt is sometimes thrown on slippery sidewalks. It melts the ice by lowering the freezing point of the water.

It can also be shown that when a substance is dissolved in water, the boiling point of the resulting solution is higher than that of pure water.

EXPERIMENT 99—Solution lowers the freezing point of water

Make a freezing mixture as shown in the preceding experiment. Now add a little of common salt to a test tube half full of water and shake until dissolved.

test tube of salt solution with another test tube half full of water in the freezing mixture and allow to stand. Note the change in temperature by means of a thermometer. This is an exothermic change. Other compounds absorb or take up heat when they dissolve. This solution lowers the freezing point of water.

EXPERIMENT 100—Solution raises the boiling point of water

Take a salt solution by dissolving a spoonful of salt in a test tube half full of water. Now hold this solution together with a test tube half full of water over an alcohol lamp. Notice that the water will boil. This solution raises the boiling point of water.

SUPERCOOLING

It is possible to cool a liquid below its freezing point. Water, for example, can be cooled below its freezing point, 32 degrees Fahrenheit or 0 degrees Centigrade, and remain a liquid. When in this state, water is said to be undercooled.

EXPERIMENT 101—UNDERCOOLED WATER

Take a freezing mixture as explained in previous experiments. Place in the freezing mixture a test tube one-third full of water and keep the test tube quiet. The temperature of the water in the tube may go down as far as 8 to 10 degrees below 0 degrees Centigrade or between 18 and 14 degrees Fahrenheit, and the water remains in the liquid form. Read the temperature of your solution by means of a thermometer. If a small crystal of ice is now dropped into the test tube or the water in the test tube stirred, it will immediately freeze, the temperature then rising to the freezing point 0 degrees Centigrade or 32 degrees Fahrenheit.

DEGREE OF SOLUBILITY IN WATER

Most substances dissolve more readily in hot water than in cold water. There are a few exceptions, however, calcium hydroxide being a good example of a substance which is more soluble in cold water than in hot water.

EXPERIMENT 102—Effect of temperature on solubility

Take seven measures of nickel ammonium sulphate in a test tube one-quarter full of water and shake well. Notice that some of the solid remains undissolved. Now heat the test tube slowly and notice that all the solid goes into solution, showing that some substances are more soluble in hot water than in cold water. Now allow the test tube to cool undisturbed and notice the beautiful green crystals of nickel ammonium sulphate that separate out on cooling.

EXPERIMENT 103—Temperatures Effect on Solubility

Take one measure of calcium oxide to a test tube full of water. Shake several times. Allow the tube to stand until the liquid becomes clear. Pour some of this clear liquid into another test tube and heat slowly over a flame. Notice that the liquid becomes cloudy or turbid, proving that calcium hydroxide which was formed when calcium oxide was added to the water is less soluble in hot water than in cold water.

EXPERIMENT 104—Dissolving liquids in each other

Try to mix a few drops of carbon tetrachloride with a little water in a test tube. Notice that the two liquids do not mix. Now add a little carbon tetrachloride to a test tube. In other words, it is insoluble in water.

Try dissolving a few drops of glycerine in a little water in a test tube. In the glycerine soon mixes and stays in solution with the water.

EXPERIMENT 105—Dissolving a gas in water

Put two measures of sodium carbonate and two measures of sodium bisulphate in a test tube and fill the tube one quarter full of water. Quickly fit the test tube with the gas delivery tube and stopper and insert the other end of the delivery tube into the mouth of an empty test tube so that the gas which is coming from the delivery tube will flow into the test tube just as if water were coming through the delivery tube instead of gas which you cannot see.

After a minute or so the test tube should be full of gas. Keep your finger over the mouth as much as possible and carefully fill the tube one half full of water. Press your finger or thumb tightly over the mouth and shake. Do you feel a vacuum? On your thumb showing that the gas in the tube has dissolved in the water.

EXPERIMENT 106—Removing a gas from solution by boiling

Put one drop of ammonium hydroxide in a test tube one quarter full of water. Now add one drop of phenolphthalein solution. This will color the liquid in the test tube red, as ammonium hydroxide is an alkali. Heat this red liquid for a few minutes and notice that as it begins to boil the red color becomes fainter. By boiling for a great tendency for the liquid to slop out of the tube when boiling.

Ammonium hydroxide is a gas dissolved in water and when heated this gas is driven out of the solution, leaving only water.

EXPERIMENT 107—Diffusion

Fill a clean glass nearly full of clear water and let it stand for a minute to become quiet. Now add a small quantity of mixed dyes and watch closely what occurs.

As the substance dissolves the color seems to flow out of the small crystals, gradually spreading over the bottom of the glass. After a few minutes the color will diffuse upward through the liquid until finally after several hours the entire liquid will be a uniform color.

EXPERIMENT 108—Testing for acidity

Moisten a piece of blue litmus paper with a drop of the water you are testing. The blue litmus paper turns red or pink, the water is slightly acid.

EXPERIMENT 109—Testing for lime

To a test tube of water add two measures of sodium carbonate and shake well. If the water, after standing a while, shows a white turbidity it contains a considerable portion of lime.

EXPERIMENT 110—Testing for sulphates

To a test tube full of water add one measure of strontium chloride and shake well. If the water after 10 minutes shows a white turbidity it contains a considerable portion of sulphates.

EXPERIMENT 111—Testing for iron

To a test tube full of water add one measure of sodium ferrocyanide and shake well. If the water shows a blue tinge either at once, or after standing a while, iron is present.

EXPERIMENT 112—Testing for carbon dioxide

Take up a solution of lime water by adding half a measure of calcium oxide to half a test tube of water. Shake well and let settle for a few minutes. Add to a test tube of water which is to be tested a few drops of this clear lime water. If a white turbidity is formed the water contains carbon dioxide.

The presence of carbon dioxide in water causes it to effervesce and gives it a sparkling taste. Soda water and many bottled mineral waters contain carbon dioxide.

EXPERIMENT 113—Testing for sulphur

Sulphur is present in some mineral waters in the form of hydrogen sulphide. It may be detected even if in very small quantities by dropping in the water a small piece of sulphide test paper. If sulphides are present the paper will turn black or brown.

EXPERIMENT 114—The boiling point of water, compared with salt

Dissolve 10 measures of common salt in a test tube half full of water and fill another test tube half full of plain water. Now heat these two test tubes over a candle or alcohol lamp flame. Hold them so that each tube will get just the same amount of heat. You will find that the water will boil before the salt solution does. Hold the tubes fully so the boiling water will not spurt out on you.

EXPERIMENT 115—Purification of water by distillation

Take a test tube half full of water add one measure of copper sulphate. Shake well. If the salt is dissolved. Then attach the gas delivery tube by means of the perforated cork to the mouth of the tube and insert the end of the delivery tube into a test tube which is immersed in a glass of cold water. (Figure 24.)

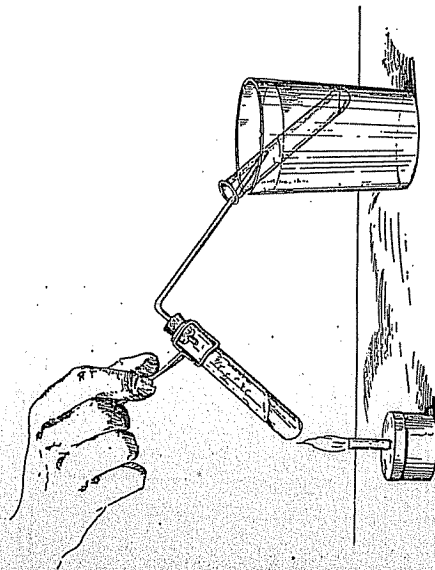


Fig. 24

Now heat the test tube containing the copper sulphate solution and boil the liquid several minutes. You will notice that clear, colorless water condenses in the test tube immersed in the glass of water.

What you really did was to distill the copper sulphate solution. That is, the steam which condensed to water on the inside of the second cooler tube. The copper sulphate being non-volatile remained behind so that we could remove all the copper sulphate from the water in this manner.

WATER OF CRYSTALLIZATION

Many compounds contain chemically combined water. Water occurring in this way is known as water of crystallization. Ferrous sulphate, nickel sulphate, and copper sulphate, for example, contain water of crystallization. Some substances give up or lose their water of crystallization by simple exposure to air. Such substances are called "Efflorescent Substances" and a good example of this class of substance is sodium sulphate.

On the other hand, certain substances on exposure to the air take up water. These are called "Hygroscopic Substances". Substances of this class are called "Deliquescent Substances", and a good example of this class of substance is calcium chloride.

EXPERIMENT 116—Water of crystallization

Put two measures of copper sulphate in a clean, dry test tube and heat over a flame, using the test tube holder so as not to burn the fingers.

You will notice that water in the form of steam is given off and some of this condenses on the inside of the test tube in the form of small drops of water. This water was originally in the copper sulphate and is called water of crystallization.

Notice also that the salt remaining in the test tube has changed color from blue to white. Many salts, when they lose their water of crystallization in this manner, also undergo a change in color. This dry, colorless compound is known as anhydrous copper sulphate, meaning without water of crystallization. Add four drops of water to the white copper sulphate and notice the change of color to blue.

Everybody at some time or other has eaten rock candy or crystallized sugar. This is nothing more than sugar that has been allowed to crystallize out from a concentrated solution of the sugar in water. A substance crystallizing slowly from solution tends to come out in the form of large, shapely crystals, while when crystallizing quickly from a solution it comes out in smaller crystals.

EXPERIMENT 117—Formation of crystals (rock candy)

Dissolve as much sugar as possible in a test tube half full of boiling water.

Suspend a thread or string in this solution by hanging a small weight on the end of it and allow the contents of the tube to cool slowly undisturbed (Figure 25).

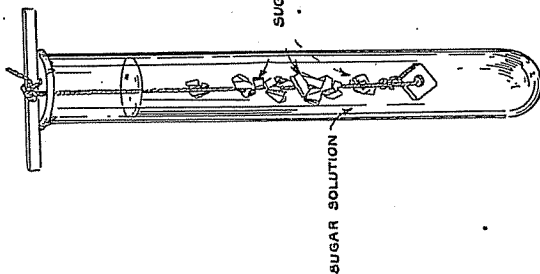


FIG. 25

After a time the sugar will appear in large crystals upon the string which is hung in the test tube.

Large crystals of many compounds can be formed in this manner, or by allowing a solution to cool slowly in a crystallizing dish. Slow cooling is essential if good crystalline development is desired.

EXPERIMENT 118—Disappearing ink

In a small test tube make a solution of cobalt chloride by dissolving three measures of cobalt chloride in one-half inch of water. Shake thoroughly to dissolve all the solid.

Procure a clean pen, or better a toothpick, write upon a pink paper with the pale solution you have made. Allow this to dry. When dry, the writing will be invisible. To bring back to view the words you have written, merely heat the paper, taking care not to scorch or burn it. The writing appears in a beautiful cobalt blue color.

Make the writing disappear again allow to cool or hold it over a steaming kettle. Normally, cobalt chloride is blue. It has a great attractive power, however, for water. Therefore, in the presence of moisture it takes up what is known as "water of crystallization." The blue crystals then turn pink in color. Should the pink crystals be heated they would turn blue again, due to the loss of water.

When the cobalt chloride solution dried upon your paper, minute crystals were deposited which contained water of crystallization. They were pink or colorless. When these tiny crystals turned blue because the water was driven off. When the crystals cooled, they again gathered moisture from the air and became colorless. Often the weather is very clear or when the air in homes is hot and dry, especially in winter, a long time is required for the blue color to fade.

EXPERIMENT 119—How to make a weather barometer

Soak a piece of unglazed paper in a concentrated solution of cobalt chloride and allow to dry. The solution of cobalt chloride is made up the same as in the preceding experiment, using three times the amounts.

When hung in the open air, the color of the paper indicates the state of the weather. When the paper turns blue, that is an indication of a dry, clear atmosphere or condition of fair weather.

When many chemicals separate from their saturated solutions in hot water, they deposit on cooling, in the form of crystals. Each substance that crystallizes has its peculiar crystalline formation. Large crystals are best obtained by allowing the solutions to cool very slowly.

EXPERIMENT 120—Crystals of copper sulphate

Prepare a saturated solution of copper sulphate in water and pour the clear liquid in a small beaker. Then set aside to cool slowly, after placing a piece of cardboard at the top of the beaker to avoid too rapid cooling. After the crystals have completely separated, then remove several of them and examine under your microscope.

EXPERIMENT 121—Crystals of tartaric acid

Repeat the preceding experiment using tartaric acid as your chemical.

EXPERIMENT 122—Crystals of iron alum

Repeat the above experiment using ferric ammonium sulphate as your chemical.

EXPERIMENT 123—Crystals of magnesium sulphate

Repeat the above experiment using magnesium sulphate or Epsom salts.

EXPERIMENT 124—Crystals of Glauber's salt

Repeat the above experiment using sodium sulphate. Conserve all the salts with and development of living plants and animals. Let us then bear in mind that the above experiments by evaporating the respective salt solutions to dryness. Ditcher are not, as generally supposed, undesirable and destructive, but like all other living objects, there are good ones and bad ones, and great as is the loss of life and fertility and suffering for which some bacteria are responsible, the beneficial effects weigh the harmful effects.

TESTING WATER

Absolutely pure water is never found in nature. The impurities found in water of two classes. The inorganic, or those that come from the rocks, and the organic, those that are formed from the decay of animal or vegetable substances.

The principal inorganic matter found in water is common salt and compounds of chief elements which are productive of water hardness are the alkali earth metals calcium, magnesium and iron. Waters containing such substances in solution as calcium, magnesium, barium, and strontium. The most widely occurring of these is commonly spoken of as hard waters, or, if large amounts of mineral matter are present, and when we are troubled with hard water we always look first for calcium as mineral waters. Some of the natural mineral waters possess valuable medicinal properties and consequently are set aside and protected for public use. Springs of mineral type are located in several sections of the United States. The salts occurring in them do not injure the water for drinking purposes but they form insoluble compounds with soap so that we cannot wash with them.

In addition to mineral matter natural waters contain more or less organic matter, which often this is accompanied by certain forms of micro-organisms or living beings which may be very injurious to life. Typhoid fever is quite often contracted from drinking water containing bacteria of this kind. Bacteria when found in drinking water is generally destroyed by adding bleaching powder or chloride of lime to the water. Chlorine gas and ozone are also used for the same purpose with good effect.

SEWAGE CONTAMINATION

Water is made unfit for drinking purposes by contamination with sewage. Therefore, it is very important to make bacteriological tests of drinking water. The problem of today is one that is coming to the front because sewage disposal is a menace to public health. The unthinking citizen believes the problem of sewage disposal is solved when the toilet is flushed or the bath tub is drained. Actual problem may be said to commence at this point. Many cities discharge their untreated into rivers, but seldom do we find any stream in sufficient volume or to unsightly appearances and very offensive odors, and such water is unfit for drinking purposes.

BACTERIA IN INDUSTRY

Many diseases like typhoid fever result from bacterial infection, but it should be emphasized here that, contrary to a popular belief, all bacteria are not harmful. Great prominence has been given them as causative agents in disease. Therefore, perfectly natural that bacteria in general would be looked upon as organisms, which are harmful to man. This is not true. Taking the entire group as a whole, they are beneficial to man in that the good they do far outweighs the harm. While we could not do the most important processes which depend on microbial activity, the greatest service is no doubt the part they play in nature in causing the decay of plant and animal bodies. Were it not for this process of decay, much of the supply of certain everyday elements—elements which we could not do without—would remain locked up in

bodies of plants and animals so that what remained would not be sufficient for the growth and development of living plants and animals. Let us then bear in mind that bacteria are not, as generally supposed, undesirable and destructive, but like all other living objects, there are good ones and bad ones, and great as is the loss of life and fertility and suffering for which some bacteria are responsible, the beneficial effects weigh the harmful effects.

HARD WATER

When water does not lather well with soap, it is commonly known as hard water. The chief elements which are productive of water hardness are the alkali earth metals calcium, magnesium, barium, and strontium. The most widely occurring of these is commonly spoken of as hard waters, or, if large amounts of mineral matter are present, and when we are troubled with hard water we always look first for calcium as mineral waters. Some of the natural mineral waters possess valuable medicinal properties and consequently are set aside and protected for public use. Springs of mineral type are located in several sections of the United States. The salts occurring in them do not injure the water for drinking purposes but they form insoluble compounds with soap so that we cannot wash with them.

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Temporary hardness is due to the presence of calcium bicarbonate, which is formed by the action on limestone (calcium carbonate) on the carbon dioxide dissolved in rain water. This form of hardness is easily gotten rid of by boiling. The heat drives off the excess of carbon dioxide and the calcium carbonate precipitates, giving the water a clear or milky appearance.

It is due to this precipitate that kettles and boilers become gradually covered inside with a brown deposit. In large boiler pipes the deposit is known as boiler scale and it constitutes a serious problem in manufacturing plants. On a large scale slaked lime (calcium hydroxide) made by adding water to lime is used to soften water. The soluble carbonate is converted into the insoluble carbonate which separates out and is removed by filtering.

Hard water due to the presence of sulphate of lime or magnesia cannot be softened by boiling, and water of this kind is known as permanent hard water. You are able to procure a sample of hard water in your locality, treat a half test tube full of it with 2 measures of sodium carbonate. Shake well and if a white precipitate is formed the water possesses permanent hardness. This precipitate may be filtered off this precipitate and see if the water then run through will lather with soap. This water is soft, and it is for this reason that washing soda is used in the laundry.

Some waters contain in addition to dissolved substances as impurities also suspended matter. Often times such suspended matter is so finely divided that it cannot be separated by filtration. When such is the case the suspended matter is easily removed by treatment with aluminum hydroxide, or ferric hydroxide, gelatinous precipitates, which upon settling carry down with them the finely suspended matter in the water.

EXPERIMENT 125—Temporary hardness—How to get rid of it
You are able to obtain some hard water in your locality, test a half test tube full for temporary hardness by boiling for 3 or 4 minutes over a flame. If the water becomes turbid, that is, takes on a white milky color, it possesses temporary hardness. This form of hardness is easily gotten rid of by boiling. The heat drives off the excess of carbon dioxide and the calcium carbonate precipitates, giving the water a clear or milky appearance.

EXPERIMENT 126—Permanent hardness—How to get rid of it
Hard water due to the presence of sulphate of lime or magnesia cannot be softened by boiling, and water of this kind is known as permanent hard water. You are able to procure a sample of hard water in your locality, treat a half test tube full of it with 2 measures of sodium carbonate. Shake well and if a white precipitate is formed the water possesses permanent hardness. This precipitate may be filtered off this precipitate and see if the water then run through will lather with soap. This water is soft, and it is for this reason that washing soda is used in the laundry.

EXPERIMENT 127—Clarifying water
Some waters contain in addition to dissolved substances as impurities also suspended matter. Often times such suspended matter is so finely divided that it cannot be separated by filtration. When such is the case the suspended matter is easily removed by treatment with aluminum hydroxide, or ferric hydroxide, gelatinous precipitates, which upon settling carry down with them the finely suspended matter in the water.

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