

undisturbed for 15 minutes and for proof of the experiment prepare another test tube full of muddy water in the same manner, but without adding aluminum sulphate.

After 15 or 20 minutes you will note that the water in the first tube to which aluminum sulphate and sodium carbonate were added is clear, while the mud part in the second tube remain suspended throughout the water. This is explained by the fact that aluminum sulphate reacted with sodium carbonate to form aluminum hydroxide—a gelatinous precipitate which settled to the bottom of the tube, carrying with it the suspended matter.

Aside from the salts which go to make water hard, natural waters quite often contain other mineral salts in solution. The so-called "Mineral Springs" which have previously been referred to (page 78) contain some of these salts and in many cases have medicinal value.

Try the following experiments on any samples of water that you may obtain:

EXPERIMENT 128—Testing for odor

Fill a test tube half full of the water to be tested, shake the tube well and smell at the mouth of the tube. Gently heat the tube for a few seconds and smell again. Notice any increase in odor. Heating usually drives out any dissolved gases which are in the water as impurities.

If the water has any disagreeable odor it may be contaminated with sewage or other foul matter.

EXPERIMENT 129—A test for color and clearness

Examine the sample of water as follows: Hold a test tube of the water in front of a white sheet of paper and notice whether the water is colored and cloudy. If the water is colored or cloudy it is contaminated with impurities.

Quite often when water is drawn from a faucet it appears a little milky. This is due to the high pressure of the water in the pipes. When this is so, allow the water to stand for two or three minutes and you will notice that the water is now clear.

EXPERIMENT 130—How to test for solid matter in water

Pour one-half test tube full of water to be tested into an ordinary tea cup and let it evaporate slowly down to dryness on the stove. Look for a residue or solid matter in the cup after all the water is driven off. Most waters contain small amounts of mineral salts and sometimes organic matter which are tested for in this way.

EXPERIMENT 131—How to test for free alkali in water

Add one or two drops of phenolphthalein solution to a test tube full of the water to be tested. If the water is alkaline it will take on a light pink or red color.

EXPERIMENT 132—How to test for acidity in water

Add a small piece of blue litmus paper to a test tube full of water. If the water is acidic the paper turns pink; the water is slightly acid.

EXPERIMENT 133—How to test for organic matter in water

Fill a tumbler two-thirds full of the water to be tested. Then add 10 or 12 drops of a solution of sodium bisulphate made by dissolving eight measures of sodium sulphate in a test tube one-half full of water.

Now make a solution of potassium permanganate by dissolving two measures of potassium permanganate in a test tube one-third full of water. Add this solution, drop by drop, until the water takes on a violet color. The tumbler of water to be tested until the water takes on a violet color. If the color remains, organic matter is present, the color gradually grows lighter. If the color remains unchanged for an hour, the water is practically free of organic matter.

EXPERIMENT 134—How to test for soluble sulphates in water

Add two measures of strontium nitrate to a test tube one-third full of water and shake until dissolved. If after 10 or 20 minutes the water takes on a cloudy appearance, there are soluble sulphates present in the water.

EXPERIMENT 135—How to test for lime in water

Add one or two measures of sodium carbonate to a test tube one-half full of the water to be tested and allow to stand for 10 or 20 minutes. If the water becomes cloudy or turbid, lime is present.

EXPERIMENT 136—How to test for iron in water

Add one measure of sodium ferrocyanide to a test tube one-half full of water to be tested and shake until all is dissolved. A blue precipitate or blue color which may form at once or after standing for several minutes indicates the presence of iron in the water.

EXPERIMENT 137—How to test for carbon dioxide in water

Add a few drops of clear lime water to a test tube three-quarters full of water to be tested. A white precipitate or a milky color is a test for carbon dioxide.

Lime water is made by adding one measure of calcium oxide to a test tube one-half full of water, shaking well and allowing any solid material to settle. The clear liquid is lime water. Common soda water such as is served at a soda fountain is simply carbonated water which has been saturated under pressure with carbon dioxide. When the pressure is relieved from such water the carbon dioxide bubbles out, producing what is known as effervescence.

SULPHUR

Sulphur is a very important element commercially, and plays a very significant part in the physiological processes of animal life. It is a yellowish, tasteless solid and is practically odorless. The odor commonly ascribed to sulphur is not that of sulphur itself, but is due to sulphur dioxide when sulphur undergoes oxidation. The odor of burning sulphur is due to sulphur dioxide.

In the free state sulphur occurs chiefly in volcanic regions. Large deposits are found in Italy, Sicily, China, Ireland and India. In Louisiana the sulphur is melted under ground by steam and forced out under pressure through pipes. Sulphur also occurs in many important ores as sulphides, for example, galena or lead sulphide; iron pyrites or fool's gold; zinc blende or zinc sulphide; realgar or arsenic sulphide; and in pyrite (iron sulphide).

Sulphur is used extensively in the commercial manufacture of many substances, such as gunpowder, fireworks, matches, dyestuffs, medicinal products, or drugs and fertilizers. Without doubt the most important chemical containing sulphur, which is manufactured, is sulphuric acid. It occupies a key position in chemical industry, and is utilized in hundreds of manufacturing operations. Sulphuric acid is consumed in enormous quantities in the commercial processes applied in the vulcanization of rubber, in the bleaching industry, and in the manufacture of disinfectants and insecticides. The great demand for insecticides by growers of fruit and truck garden products has led to the study of many materials to be used for plant protection. Today this represents an enormous industry and there is a constant search for effective chemical insecticides. Sulphuric acid is a valuable intermediate in their manufacture.

EXPERIMENT 138.—Behavior of sulphur at different temperatures

Heat 10 measures of sulphur in a small, dry test tube. Apply the heat very slowly and notice the different changes. First, the sulphur melts to a light straw colored liquid. Pour a little of this liquid into a glass of water, and then continue the heating of the tube, and observe, second, the change of color to brownish black and the liquid becoming almost solid. On further heating, third, this solid becomes liquid again. Pour the liquid sulphur into another glass of water.

The sulphur obtained when the straw colored liquid was poured into water is a rhombic sulphur, while that formed when the dark black liquid was poured into water is called plastic sulphur or elastic sulphur. This substance becomes brittle on standing for a few days. Sulphur undergoes three distinct changes then in heating and change corresponds to a certain temperature.

EXPERIMENT 139.—Preparation of lime—sulphur solution

Put into a test tube one-third full of water one measure of calcium oxide and one measure of sulphur. Heat the test tube over a flame and boil for several minutes. Notice the yellow colored solution that is formed. This solution is known as lime sulphur solution and is used on a large scale for spraying fruit trees and destroying fungi. The calcium oxide reacted with the sulphur to form calcium sulphide, which is soluble in the water. Filter a part of the calcium sulphide solution, and to the filtrate add acetic acid until the solution is acid to litmus paper. There will be an immediate evolution of hydrogen sulphide, which is evidenced by the odor. Allow 1 drop of the calcium sulphide solution to fall on a polished silver coin, and let it stand for a few minutes. Then wash the coin with water and notice that a black spot of silver sulphide is formed. Exposure of silverware to eggs will produce a similar discoloration due to the presence of sulphur in eggs.

EXPERIMENT 140.—Sulphur dioxide from burning sulphur

Put 2 measures of sulphur in the spoon and heat over the flame. The sulphur suddenly takes fire and burns with a blue flame. The gas produced, having a suffocating odor, is sulphur dioxide, and is formed by the oxidation of sulphur when it burns in the air.

EXPERIMENT 141.—Sulphur dioxide from sodium bisulphite

Put two measures of sodium bisulphite in a test tube one-third full of water and add a few drops of acetic acid. Smell cautiously at the mouth of the tube and notice the smell of burning sulphur.

Sodium bisulphite when treated with an acid reacts to form sulphur dioxide, water and a salt.

EXPERIMENT 142.—Bleaching with sulphur dioxide

Put five measures of sodium bisulphite in a glass tumbler.

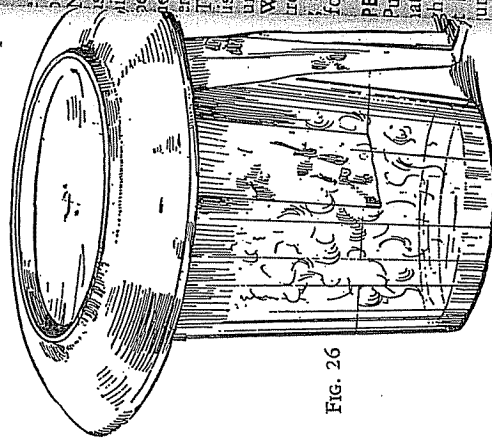


FIG. 26

Now obtain some colored flowers or pieces of dyed cloth and moisten them with vinegar. Put a teaspoonful of vinegar in the tumbler and quickly introduce the flowers. After one-half hour. Figure 26.

Notice the vigorous reaction which takes place when the vinegar is added. This is due to the liberation of sulphur dioxide gas. At the end of a half hour examine the flowers or cloth and notice that some of the colors have been bleached out. Sulphur dioxide will bleach certain colors but not all colors.

Sulphur dioxide is used commercially in bleaching straw, silk and woolen goods, or any material that would be injured by chlorine.

EXPERIMENT 143.—Preparation of sulphurous acid

Put six measures of sodium bisulphite in the gas generator flask set up as shown in Figure 27 and add about one-half inch of water. Place over the end of the delivery tube a test tube one-half full of water so that the end of the delivery tube just extends below the surface of the water in the test

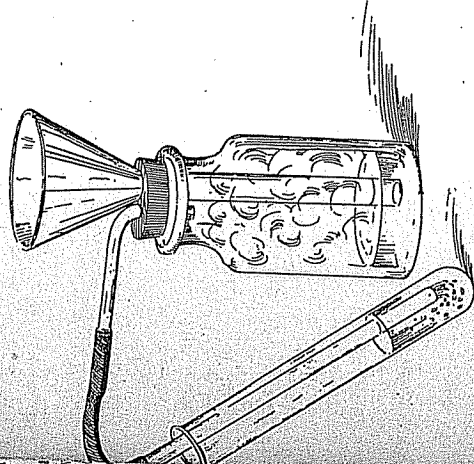


FIG. 27

Now add a little acetic acid, two or three drops at a time, through the funnel which just extend below the surface of the liquid in the generator flask. Notice the action which takes place. After passing the gas, which is formed in the reaction, into the test tube for several minutes, remove the test tube. Test the liquid in the test tube with litmus paper and notice that the litmus paper turns red, proving that an acid has been formed. This acid is sulphurous acid.

The acetic acid reacted with the sodium bisulphite to form sulphur dioxide gas. This gas when passed into the test tube of water reacted with the water to form sulphurous acid.

We have shown that when sulphur is burned in the air or when sodium bisulphite treated with an acid sulphur dioxide is formed. Now in the presence of an oxidizing agent sulphur dioxide can be made to combine with one more atom of oxygen to form sulphur trioxide.

EXPERIMENT 144.—Preparation of sulphur trioxide.

Put three measures of sodium bisulphite and two measures of potassium permanganate in a clean, dry test tube and shake the tube until the two substances are thoroughly mixed. Now insert the gas delivery tube and put the end of the delivery tube below the surface of the water in another test tube one-third full of water. Figure 28.

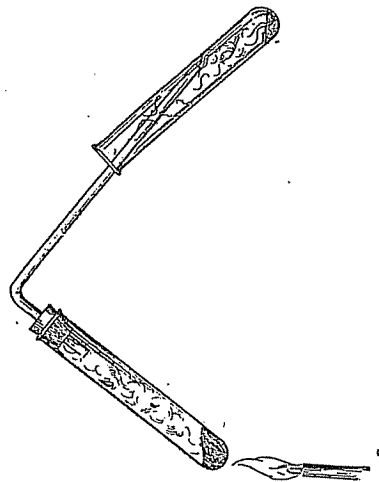


Fig. 29

EXPERIMENT 150—Action of chlorine gas on hydrogen sulphide

Prepare a solution of hydrogen sulphide water by bubbling hydrogen sulphide into water.

Now prepare some chlorine gas by putting five measures of tartaric acid and measures of calcium hypochlorite in a test tube one-quarter full of water. Also place one measure of copper sulphate in a test tube and fill the tube half full of water, warm the mixture gently until the solid is dissolved. Now cool the solution and pass in hydrogen sulphide gas through the gas delivery tube as in the preceding experiment. A black precipitate of copper sulphide will be formed.

Chlorine reacts with hydrogen sulphide to form hydrochloric acid and sulphur.

EXPERIMENT 151—Reducing action of hydrogen sulphide

Dissolve a crystal of potassium permanganate in a test tube half full of water. Now bubble hydrogen sulphide gas, prepared as described in a previous experiment, using a gas delivery tube, into the solution of potassium permanganate. Notice that the purple color fades and a white precipitate of sulphur is formed.

Hydrogen sulphide gas reduced the potassium permanganate, therefore removing its color. In reducing the permanganate it is oxidized by oxygen in the permanganate to water and sulphur. Hydrogen sulphide gas is often used as a reducing agent in the two preceding experiments with chlorine and hydrogen peroxide illustrating its behavior.

You probably have noticed that some white paints turn black after exposure to lead carbonate. This is because such paints contain lead, chiefly in the form of the pigment lead carbonate. The lead reacts with traces of hydrogen sulphide gas in the air to form black lead sulphide. To prevent this discoloration, zinc oxide is used as a pigment in place of lead carbonate. When zinc oxide reacts with hydrogen sulphide, a white precipitate of zinc sulphide is formed.

EXPERIMENT 152—How to restore the color of white paint

Obtain some white oil paintings which have become dark by the action of hydrogen sulphide. Wash these paintings with a little hydrogen peroxide solution and notice that they become white again.

Now pass this gas by a delivery tube into a test tube containing two measures of sodium bisulphide and eight drops of vinegar acid. (Figure 29.)

EXPERIMENT 153—Silver sulphide
Place $\frac{1}{2}$ measure of sulphur on a bright silver coin and wrap in several thicknesses of paper. After a few days you will find a black spot of silver sulphide on the coin where the sulphur was in contact with it.

EXPERIMENT 154—Sulphur in rubber
Rubber contains sulphur used in its vulcanization. Wrap a rubber band around a test tube containing the solution of silver sulphide.

EXPERIMENT 155—Sulphur and silver coin
A silver coin is turned black in a few hours by a paste of mustard and water, as mustard contains sulphur. Eggs also contain sulphur, and this is the reason why silver test spoons turn black when used for eating eggs.

EXPERIMENT 156—Nickel sulphide
Dissolve one measure of nickel ammonium sulphate in a test tube one-quarter full of water. Fill another test tube one-quarter full of water and add four measures of sodium bisulphate. Shake to dissolve the sodium bisulphate and add two measures of nickel sulphide. You will find this in any drug store. Fit the test tube with the gas delivery tube and stopper and when hydrogen sulphide gas is coming off freely, allow to bubble through the nickel ammonium solution. In a few minutes you will notice a black precipitate of nickel sulphide forming in the nickel ammonium sulphur solution.

EXPERIMENT 157—Copper sulphide
Place one measure of copper sulphate in a test tube and fill the tube half full of water, warm the mixture gently until the solid is dissolved. Now cool the solution and pass in hydrogen sulphide gas through the gas delivery tube as in the preceding experiment. A black precipitate of copper sulphide will be formed.

EXPERIMENT 158—Zinc sulphide
Place 2 measures of sodium bisulphate and a small piece of zinc metal in a test tube one-quarter full of water. Heat the tube gently and wait until some of the zinc has dissolved. Now pour some of the clear solution into another test tube, add water to fill the tube one-half full and pass in hydrogen sulphide gas.

EXPERIMENT 159—Ferrous sulphide from sodium thiosulphate
Dissolve one measure of ferrous ammonium sulphate in a test tube one-quarter full of water. Add one measure of sodium thiosulphate and heat the solution for a minute or two. A greenish brown precipitate of ferrous sulphide will form.

EXPERIMENT 160—Ferric sulphide from sodium thiosulphate
Dissolve one measure of ferric ammonium sulphate in a test tube one-quarter full of water. Add one measure of sodium thiosulphate and heat the solution. This time a brown precipitate will form.

EXPERIMENT 161—Nickel sulphide from sodium thiosulphate
Dissolve one measure of nickel ammonium sulphate in a test tube one-quarter full of water. It may be necessary to warm the tube slightly to completely dissolve the nickel ammonium sulphate. Now add one measure of sodium thiosulphate and the black precipitate, consisting of nickel sulphide, will be formed as soon as the solution is heated.

EXPERIMENT 162—Manganese sulphide from sodium thiosulphate

To form a white precipitate of manganese sulphide dissolve one measure of sodium thiosulphate in a test tube one-quarter full of water. Add one measure of sodium sulphate; warm the solution gently and the white precipitate will form.

THE HALOGENS

The elements that go to make up the halogen family are fluorine, chlorine, bromine and iodine. These elements are called Halogens, meaning salt producers. They resemble each other very much in chemical properties but differ widely in physical properties. Fluorine is a colorless gas, chlorine a greenish yellow gas, bromine a brownish-red liquid and iodine a purplish black solid.

The halogens are very active substances, so that they never occur in the free state in nature. Their compounds are very abundant—those of chlorine, bromine and iodine occurring in sea water. The most common of these is sodium chloride or common salt.

As already stated, the halogens are very active substances. They combine with many metals like copper, sodium, potassium, gold, silver, platinum, etc., to form salts of the metals. They also react with non-metals like sulphur, antimony and arsenic to form compounds with these substances. They also react with hydrogen to form the corresponding acids, namely, hydrofluoric, hydrochloric, hydrobromic and hydroiodic acids. Of the halogens, fluorine is the most active and iodine the least active. All four halogens find wide commercial applications.

Chlorine is used extensively as a bleaching agent and germicide. Chlorine gas is shipped in bulk compressed in iron cylinders. The gas is widely used for water disinfection. It also comes on the market known as bleaching powder or chloride of lime. The corresponding acid, hydrochloric acid, is an important technical acid and is used for a number of purposes.

Bromine is used principally in the preparation of bromides, which are used in considerable extent in photography and in medicine. It is also used in the preparation of a number of organic drugs and dyestuffs. Bromine is extracted today in large quantities from sea water and apparently this source is inexhaustible.

The chief sources of iodine are brine wells and the ashes of certain sea weeds. Iodine is used extensively in medicine, especially in the form of tincture of iodine. It finds an important use in the preparation of iodides and of certain dyes and disinfectants. The antiseptic iodoform is a compound of iodine with carbon and hydrogen. Iodoform is analogous to the widely used anesthetic—chloroform—wherein a compound of chlorine combined with hydrogen and carbon. While iodoform and chloroform are valuable drugs, the corresponding compounds of bromine and fluorine are unimportant compounds in medicine.

EXPERIMENT 163—How to make chlorine gas

Put two measures of potassium nitrate, two measures of sodium bisulphate and one measure of sodium chloride (common table salt) in a test tube and heat the test tube gently over a flame for a few moments. Remove the test tube from the flame and smell cautiously the gas which is given off. This is chlorine gas.

Sodium bisulphate reacted with sodium chloride to form hydrogen chloride gas which was oxidized by oxygen from the potassium nitrate to water and chlorine gas.

EXPERIMENT 164—To show the bleaching properties of chlorine

Prepare chlorine gas as in the preceding experiment, placing a small piece of moistened blue litmus paper over the mouth of the tube before heating. Notice the

color change of the litmus paper. The chlorine gas has the property of bleaching certain colors.

What happened was that the chlorine gas reacted with the water on the blue litmus paper, forming hydrochloric acid and oxygen. It is really this free oxygen that does the bleaching.

EXPERIMENT 165—How to Make hydrochloric acid

Put two measures of ammonium chloride and two measures of sodium bisulphate in a test tube. Moisten a piece of blue litmus paper and place it over the mouth of the test tube. Now heat the tube slowly over a flame for a few minutes. Notice that the litmus paper turns red, proving that an acid has been formed. Remove the test tube from the flame and smell cautiously the gas that is given off. This is hydrogen chloride gas.

Dip the glass stirring rod in a little household ammonia and hold the rod over the mouth of the test tube. Notice the white fumes that are formed. These fumes are ammonium chloride.

Hydrogen chloride gas, as prepared in this experiment, when dissolved in water forms hydrochloric or muriatic acid. Commercially, hydrochloric acid is manufactured by heating sodium chloride with sulphuric acid.

BLEACHING POWDER

Bleaching powder or "Chloride of Lime," as it commonly comes on the market, is a compound composed of calcium, oxygen and chlorine. It is prepared by passing chlorine gas over slaked lime, bleaching powder or calcium hypochlorite being formed. Bleaching powder is a very important compound and has many uses in everyday life. It is a very good bleaching agent and readily gives up its chlorine when treated with an acid. In bleaching paper rags, the rags are first boiled in an alkali to remove grease, then placed in a large vat with bleaching powder and sulphuric acid; on removing the rags are pure white. Cotton cloth is bleached by passing it through a vat of bleaching powder and sulphuric acid.

Besides being used as a bleaching agent chloride of lime is employed as a disinfectant, since it destroys germs. Water is sometimes purified with this compound.

EXPERIMENT 166—How to make chlorine from bleaching powder

Make a solution of tartaric acid in water by adding 3 measures of tartaric acid to a test tube containing about $\frac{1}{2}$ inch of water. Then add 3 measures of calcium hypochlorite or bleaching powder and smell cautiously at the mouth of the tube. Note the odor of chlorine gas. The other compound formed in the reaction is calcium tartrate.

EXPERIMENT 167—Bleaching with bleaching powder

For this experiment obtain two or three pieces of colored cloth and some colored flowers; a red carnation works well.

Put 5 measures of calcium hypochlorite (bleaching powder) and 5 measures of tartaric acid in a clean glass and add a few drops of water to moisten the compounds. Then moisten the pieces of colored cloth and flowers with water, place them in the glass and cover the glass with a saucer. Allow the glass to stand for an hour. Notice the effect of the chlorine gas liberated in the reaction.

EXPERIMENT 168—How to make iodine

Put 4 drops of sodium iodide solution into a test tube $\frac{1}{4}$ full of water and mix the contents of the tube by shaking.

Now prepare chlorine gas as already shown in a previous experiment and fill test tube with a gas delivery tube. Allow the chlorine gas to bubble through the iodide solution prepared above and notice after a few moments that the solution turns brown.

Chlorine gas reacts with sodium iodide to form sodium chloride and free iodine. This free iodine that gives the solution its brown color.

Now add 6 or 8 drops of carbon tetrachloride to this solution containing the iodine. Close the mouth of the tube with your thumb and shake several times. Allow the mixture to stand for a few seconds and notice that the carbon tetrachloride has become brown and the brown color has disappeared from the water.

EXPERIMENT 169—How to test for iodine

Prepare some starch solution by putting 1 measure of powdered household starch in a test tube and moisten with a few drops of water. Now heat a test tube half of water to boiling and pour the hot water into the test tube containing the starch paste. To this starch solution add 5 drops of sodium iodide solution.

To a dry test tube add 2 measures of common table salt or sodium chloride, 2 measures of potassium nitrate and 2 measures of sodium bisulfate. Insert the perforated cork with gas delivery tube and heat the test tube slowly over a flame. After the gas starts to come off freely insert the end of the delivery tube into the test tube containing the starch solution and sodium iodide and allow the chlorine gas to bubble through the starch solution for several moments. Notice the blue color which is formed. This is the test for free iodine.

The chlorine gas displaced the iodine in the sodium iodide solution, liberating iodine. Free iodine in the presence of starch produces a blue color.

EXPERIMENT 170—Formation of lead iodide

Fill a test tube one-third full of water and add six drops of sodium iodide solution. In another test tube place about one measure of lead nitrate or acetate obtainable at a drug store and dissolve by adding one-third test tube of water. Now pour the nitrate solution into the sodium iodide solution. A heavy bright yellow precipitate of lead iodide will form. Now heat until it begins to boil, then set aside to cool. Cooling watch closely what happens. Most of the lead iodide will have settled to the bottom, but there also appears above it, numerous little scales or specks of all colors—some golden, some silver, blue, green, red, pink, orange, and violet which sparkle beautifully. The lead iodide, which by this time has all settled to the bottom of the tube, leaves the most beautiful colored specks in the almost clear liquid above. The beauty cannot be very easily described, but soon the beautiful specks settle to the bottom of the test tube leaving only a few lingering above them. Even at the bottom produce a striking effect. It is very interesting to watch the colored particles.

EXPERIMENT 171—Partition solubility of iodine

To a half test tube of water add about ten drops of tincture of iodine (this will find in the medicine closet). The solution in the test tube will be a reddish-brown color. Add to this an eighth test tube of carbon tetrachloride. The carbon will settle to the bottom. Shake the test tube and then let the carbon tetrachloride layer settle to the bottom of the tube. The bottom layer will be a rich violet color.

Reaction: Tincture of iodine is a solution of iodine and potassium iodide in water and alcohol. When carbon tetrachloride is added, it dissolves the free iodine. The carbon tetrachloride settles to the bottom of the test tube because it is heavier than water and it is not miscible with water.

EXPERIMENT 172—Testing vegetables for starch

Make a solution of iodine by dissolving 2 crystals of iodine in a test tube $\frac{1}{4}$ full of water containing 5 drops of sodium iodide solution. You will notice that the solution turns brown, showing that iodine is soluble in sodium iodide solution.

Now cut in half a potato, beet, carrot or any other vegetable that you may obtain and add 2 or 3 drops of the iodine solution to the freshly cut surface. Notice which of the vegetables produce a blue color. The potato contains a lot of starch. A more pronounced blue color may be obtained by boiling a small piece of the vegetable and adding 1 or 2 drops of the iodine solution to the cool solution containing the vegetable.

EXPERIMENT 173—Testing other substances for starch

Test some grains of corn, barley and wheat for starch the same way you did in the preceding experiment. Notice that these substances contain starch.

GAS WARFARE

It was not until the last World War that poisonous gases were demonstrated to be an important factor in modern military science. They were introduced so unexpectedly during the critical period of the world's conflict that the unprepared combatants were

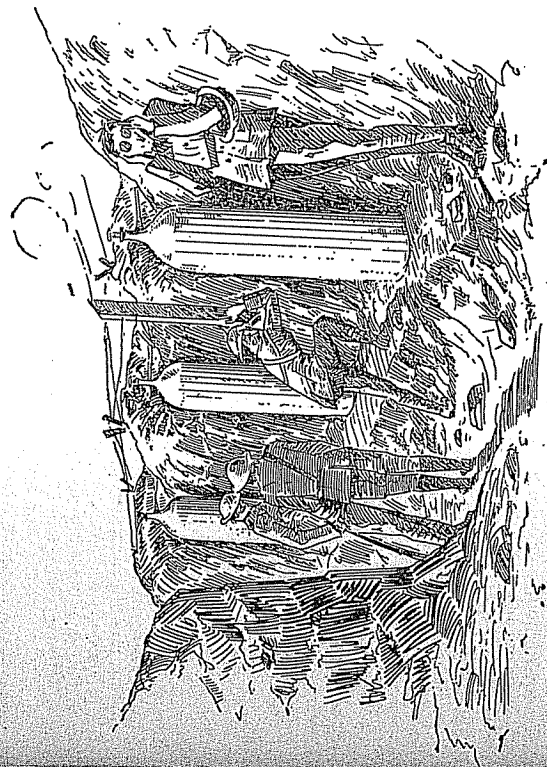


Fig. 30

was greatly handicapped in military efficiency, and months of intensive training in the technique of chemical warfare became necessary before the different countries engaged were able to provide a defense against this new method of attack. In the early development of this new method of warfare, chlorine gas or compounds con-

taining this halogen were used extensively, and they made up the bulk of the poisonous gases. Chlorine itself is a heavy suffocating gas which can be produced cheaply, and is easily transported in steel cylinders. Other chlorine compounds of toxicity which were used in quantity as poisonous gases were chloropicrin and phosgene. Chlorine gas was later abandoned and was replaced by special compounds containing this element in combination with sulphur, carbon and hydrogen, which to be more destructive and efficient for offensive military movements. One of the valuable products developed for the chemical warfare service was a chlorine powder known as "mustard gas." Large chemical plants were operated in the United States during the World War for the manufacture of chlorine gas, phosgene, chlorine, and mustard gas, to be shipped abroad to the military forces engaged in destructive war.

Today poisonous gases fulfill an important commercial service in their uses as protective measures against bank robberies, and for police equipment in controlling lic riots and serious labor strikes. Such cases provide a more effective and weapon of defense than the rifle or police gun.

THE GAS MASK

As a preventative from gas poisoning, the well-known gas mask was invented consisted of a face piece to shut out the gases from the nose, mouth and eyes and which ran a flexible rubber tube to a canister or container which held the chemicals for neutralizing the poisonous gases. On breathing in, the poisonous air passed through the canister where the deadly gases are removed, allowing the good air to pass through the flexible tube, the end of which is held in the mouth, and then into the lungs. The exhaled air is passed out through a rubber slit in the lower part of the face piece. The chemicals used to remove the gases were principally a mixture of charcoal and soda lime.

BORON AND THE BORATES

Boron does not occur as the free element. It has been found in nature in the form of boric acid in many hot springs, particularly in Italy and California. Boron occurs in large quantities in the desert regions of California and Nevada in the form of sodium salt, known as borax, ordinary "Twenty Mule Team Borax." It also occurs as the calcium salt.

Boric acid is used as a mild antiseptic, as a constituent of talcum powder, and as a preservative.

EXPERIMENT 174—Boric acid from borax

In a test tube $\frac{1}{4}$ full of water, dissolve 8 measures of borax heating the solution little to completely dissolve the solid. In another test tube $\frac{1}{4}$ full of water dissolve by heating if necessary, 5 measures of sodium bisulphate. Now pour the sodium bisulphate into the borax solution and cool the resulting solution by holding the test tube in water. After some time a white solid crystallizes out. This solid is boric acid.

EXPERIMENT 175—Borax from boric acid

Put 2 measures of boric acid in a test tube $\frac{1}{4}$ full of water and heat to boiling. Dissolve 2 measures of sodium carbonate and boil the solution for three minutes. Set the tube aside to cool and observe the behavior while crystals precipitate out. These are crystals of sodium tetraborate or borax.

EXPERIMENT 176—Test for boric acid

Dissolve 2 measures of boric acid in a test tube $\frac{1}{2}$ full of alcohol. Now pour this solution into a saucer, darken the room and light the alcohol with a flame. Notice that the alcohol burns with a green flame. This is a test for boric acid.

EXPERIMENT 177—Examination of talcum powder

Repeat experiment 176 using instead of the boric acid 3 or 4 measures of a talcum powder. Some talcum powders contain boric acid.

BORAX GLASS

When heated, borax swells up to a bulky mass, loses its water of crystallization and then melts to a clear glass. This glass readily dissolves various metallic oxides which impart characteristic colors to the glass. This property is used in testing for certain metals. For this same reason borax is used as a flux in brazing or hard soldering to remove the oxides from the surface of the metals to be joined.

EXPERIMENT 178—Cobalt borax glass

Put 1 measure of borax on a clean sheet of paper and mix with it a very small quantity (a speck about the size of a pin point) of cobalt chloride. Now pick up some of this mixture on the loop of your nickel steel wire and heat it over the alcohol lamp flame. The borax will melt as before, but you will find that the glass which is formed will be blue in color because of the cobalt which dissolved in it. If very much cobalt is used the film will appear to be black, so intense is the coloring power, but if only a very slight trace of the cobalt is used the film will be a beautiful azure blue color.

EXPERIMENT 179—Iron borax glass

Take a fresh quantity of borax, about 1 measure, and put it on a clean sheet of paper. Mix with the borax a very small trace of ferric ammonium sulphate. Now put some of this mixture on the loop of your nickel steel wire and heat it. In time you will obtain yellow borax glass due to the presence of iron.

EXPERIMENT 180—Manganese borax glass

Manganese colors borax violet or lilac. Mix a very small amount of manganese sulphate with 1 measure of borax and make a ball of borax glass on your nickel steel wire using this mixture.

EXPERIMENT 181—Nickel borax glass

Nickel colors borax glass brown. Mix a very small quantity of nickel ammonium sulphate with 1 measure of borax and make a ball of borax glass from this mixture.

EXPERIMENT 182—Chromium borax glass

Chromium colors borax glass green. Mix a very small quantity of chrome alum with 1 measure of borax. Make a ball of borax glass from this mixture.

BORON COMPOUNDS

EXPERIMENT 183—Strontium borate

Dissolve 2 measures of strontium chloride in a test tube $\frac{1}{2}$ full of water. In another test tube $\frac{1}{4}$ full of water dissolve 2 measures of borax. Now pour one of these solutions into the other and notice the heavy white precipitate of strontium borate which forms.

EXPERIMENT 184—Magnesium borate

Dissolve 2 measures of magnesium sulphate in a test tube $\frac{1}{4}$ full of water. Pouring this into a solution of borax a white precipitate of magnesium borate is formed.

EXPERIMENT 185—Aluminum borate

Prepare a solution of 2 measures of aluminum sulphate in a test tube $\frac{1}{4}$ full of water, and add to this a solution of 2 measures of borax, dissolved in a test tube $\frac{1}{4}$ full of water.

EXPERIMENT 186—Ferric borate

Prepare a solution of 2 measures of ferric ammonium sulphate in a test tube $\frac{1}{4}$ full of water, and also a solution of 2 measures of borax in a test tube $\frac{1}{4}$ full of water. Upon pouring one of these solutions into the other a heavy precipitate of ferric borate is formed.

EXPERIMENT 187—Cobalt borate

Dissolve 1 measure of cobalt chloride in a test tube $\frac{1}{4}$ full of water. In another test tube $\frac{1}{4}$ full of water dissolve 2 measures of borax. Pour the cobalt solution into the borate solution and a very pretty precipitate of cobalt borate will result.

EXPERIMENT 188—Nickel borate

To precipitate nickel borate prepare a solution of two measures of nickel ammonium sulphate in a test tube $\frac{1}{4}$ full of water. It is necessary to heat the solution a little in order to dissolve all of the nickel ammonium sulphate. In another test tube prepare a solution of two measures of borax and pour the nickel ammonium sulphate solution into the borate solution. A thick greenish precipitate of nickel borate will result.

EXPERIMENT 189—Manganese borate

Dissolve 2 measures of manganese sulphate in a test tube $\frac{1}{4}$ full of water. Dissolve 2 measures of borax in another test tube $\frac{1}{4}$ full of water. Pour the manganese solution into the borate solution and a thick white precipitate of manganese borate will be formed.

EXPERIMENT 190—Calcium borate

Prepare a solution of 2 measures of calcium chloride in a test tube $\frac{1}{4}$ full of water. In another test tube dissolve 2 measures of borax and pour the calcium chloride solution into the borax solution.

EXPERIMENT 191—Chromium borate

Prepare a solution of 2 measures of chrome alum in a test tube $\frac{1}{4}$ full of water. Dissolve 2 measures of borax in another test tube $\frac{1}{4}$ full of water. Upon pouring the solutions together a green precipitate of chromium borate is formed.

PHOSPHOROUS AND THE PHOSPHATES

Phosphorus never occurs free in nature but is found in combination with metals and metals as derivatives of phosphoric acid. It occurs most extensively as phosphate. All fertile soils contain calcium phosphate. Since it is essential for growth, it is an important constituent of fertilizers, the soluble calcium monophosphate being used. The bone of animals is largely calcium phosphate.

Phosphorus exists in two forms. Yellow phosphorus is a transparent, wax-like substance which often takes fire in air at ordinary temperature. It is always kept under water.

White phosphorus is very poisonous. Red phosphorus is a chocolate red amorphous powder and is quite stable in air at ordinary temperature. The phosphates of most metals can be precipitated from solution of the salts since most phosphates are insoluble in water.

EXPERIMENT 192—Nickel phosphate

Place in a test tube $\frac{1}{2}$ measure of sodium carbonate and $\frac{1}{2}$ measure of calcium monophosphate. Fill the test tube half full of water and shake for a moment. The white precipitate which is formed will gradually settle to the bottom of the tube leaving a clear solution on top. This solution contains sodium phosphate which is soluble in water and the precipitate in the bottom of the tube consists of calcium phosphate.

Now place in another test tube two measures of nickel ammonium sulphate. Fill the test tube half full of water and heat for a few moments to completely dissolve the solid. Add the solution of nickel ammonium sulphate by holding the bottom of the tube in water for a moment, and then add a few drops of the clear solution of sodium phosphate to the nickel ammonium sulphate solution. A thick green precipitate of nickel phosphate will be formed.

The precipitate of nickel phosphate is soluble in solutions containing ammonium chloride. Place 3 measures of ammonium chloride in a test tube. Fill the tube $\frac{1}{4}$ full of water and shake to dissolve the ammonium chloride. Add to this solution about $\frac{1}{4}$ of a test tube of the nickel phosphate precipitate and shake the tube vigorously. Notice that the precipitate is dissolved in the ammonium chloride solution and a clear liquid results.

Nickel phosphate is also soluble in acids. Prepare a solution of 3 measures of sodium sulphate in a test tube $\frac{1}{4}$ full of water and add to this solution $\frac{1}{4}$ of a test tube of nickel phosphate precipitate. Notice that the nickel phosphate is again dissolved in the solution, leaving a clear green liquid.

EXPERIMENT 193—Copper phosphate

Prepare a solution of sodium phosphate by adding $\frac{1}{2}$ measure of sodium carbonate and $\frac{1}{2}$ measure of calcium monophosphate to a test tube half full of water.

Now prepare a solution of copper sulphate. Add to this copper sulphate solution a few drops of the sodium phosphate solution and a very pretty blue precipitate of copper phosphate will be formed.

EXPERIMENT 194—Strontium phosphate

Make a solution of sodium phosphate by dissolving sodium carbonate and calcium monophosphate in water.

Prepare a solution of 2 measures of strontium chloride in a test tube half full of water and add to this a few drops of the clear sodium phosphate solution. A thick white precipitate of strontium phosphate will be formed.

EXPERIMENT 195—Aluminum phosphate

Prepare a solution of sodium phosphate as before and add a few drops of this to a solution of 2 measures of aluminum sulphate in $\frac{1}{4}$ test tube of water.

EXPERIMENT 196—Ferric phosphate

Place 2 measures of ferric ammonium sulphate in a test tube half full of water and add to this solution a few drops of sodium phosphate. Now add to this solution a few drops of sodium phosphate which often takes fire in air at ordinary temperature. It is always kept under water.

EXPERIMENT 197—Manganese phosphate

Dissolve 2 measures of manganese sulphate in a test tube half full of water by stirring. Cool the solution and add a few drops of sodium phosphate as prepared above. The white precipitate tinged with pink is manganese phosphate.

EXPERIMENT 198—Calcium phosphate

Place 2 measures of calcium chloride in a test tube half full of water and stir vigorously for a minute or two. Now add to this solution a few drops of sodium phosphate made as before. This white precipitate formed is calcium phosphate; the substance chemically as phosphate rock.

EXPERIMENT 199—Cobalt phosphate

Dissolve 1 measure of cobalt chloride in a test tube half full of water and add a few drops of sodium phosphate solution. A beautiful light blue precipitate of cobalt phosphate will appear in the test tube.

EXPERIMENT 200—Magnesium phosphate

Dissolve 2 measures of manganese sulphate in a test tube half full of water. To this solution add a few drops of sodium phosphate solution prepared as before.

EXPERIMENT 201—Chromium phosphate

Dissolve 2 measures of chrome alum in a test tube $\frac{1}{4}$ full of water. Fill a test tube $\frac{1}{4}$ full of sodium phosphate solution prepared as before. Now add a few drops of chrome alum solution to the sodium phosphate solution and a light blue precipitate of chromium phosphate will form.

THE ALKALI METALS

The alkali metals are lithium, sodium, potassium and rubidium and they are very similar in their chemical behavior. The two most common are sodium and potassium. These metals are called alkali metals because they are a part of the compounds which are known as alkalies or bases, such as caustic soda (sodium hydroxide) and caustic potash (potassium hydroxide).

Because of their extreme reactivity none of these metals occur free in nature. They are found as compounds distributed in sea and mineral water, salt beds and rocks. Free metals are soft, with a silvery luster, but tarnish quickly in air because of their reaction with oxygen. They are kept in kerosene out of contact with the air. They react vigorously with water, setting free hydrogen from the water.

Some of the more important compounds are sodium hydroxide, the chief component of ordinary lye; sodium chloride, or common salt; sodium carbonate, or washing soda; sodium bicarbonate, or baking soda.

EXPERIMENT 202—How to make sodium hydroxide

Dissolve 2 measures of sodium carbonate in a test tube $\frac{1}{2}$ full of water. To this solution add 2 measures of calcium oxide and shake the tube. Heat cautiously and stir for a few minutes to complete the reaction and filter the solution into a test tube. The calcium oxide reacted with the sodium carbonate to form sodium hydroxide and a white precipitate of calcium carbonate. The clear filtered solution is sodium hydroxide.

To a test tube $\frac{1}{2}$ full of water add 3 drops of phenolphthalein solution and place 1 measure of sodium hydroxide solution prepared above. The red color proves that sodium hydroxide is a base. Save the sodium hydroxide for the following experiments.

EXPERIMENT 203—Manufacture of sodium bicarbonate or baking soda

Sodium bicarbonate is manufactured on a commercial scale by what is known as the Solvay process. This consists essentially of treating a saturated solution of common salt in ammonium hydroxide with carbon dioxide gas. The carbon dioxide gas reacts with the ammonium hydroxide to form ammonium bicarbonate which in turn reacts with the sodium chloride to form sodium bicarbonate. This is insoluble in the ammonium chloride formed in the reaction and precipitates out.

Take a saturated solution of common salt by shaking a teaspoonful of common salt in a flask or bottle with about 3 spoonfuls of common household ammonia. Filter out a half inch of this strong solution into a test tube.

Now pass carbon dioxide into this strong solution for half an hour. Notice the precipitate which forms. This is sodium bicarbonate. The carbon dioxide is prepared by putting 3 spoonfuls of washing soda or baking soda in the generator bottle and adding enough water so that the end of the funnel comes just below the surface of water in the bottle. Now add small amounts, 2 or 3 drops at a time, of vinegar or solution of tartaric acid to keep up the flow of gas.

EXPERIMENT 204—To convert sodium bicarbonate into sodium carbonate

Put 1 measure of sodium bicarbonate into a test tube half full of water and add 2 measures, no more, of phenolphthalein solution. Notice the pink color which is produced. Now heat the solution for several moments and notice that the pink color changes to colorless. This is because sodium carbonate which is formed when sodium bicarbonate is heated has stronger basic properties than sodium bicarbonate. The gas liberated in the reaction is carbon dioxide gas.

The hydroxides of many metals are insoluble and are precipitated by addition of sodium hydroxide to a water solution of salt of these metals.

HYDROXIDES

EXPERIMENT 205—Aluminum hydroxide

Dissolve 1 measure of aluminum sulphate in a test tube half full of water and add 2 measures, no more, of sodium hydroxide solution just prepared. A thick white precipitate of aluminum hydroxide is formed.

EXPERIMENT 206—Ferric hydroxide

Dissolve 1 measure of ferric ammonium sulphate in a test tube half full of water and again add a few drops of the sodium hydroxide solution. A very pretty red-brown precipitate immediately forms which is iron hydroxide. This material is similar to rust, and is used in paints.

EXPERIMENT 207—Nickel hydroxide

Dissolve 1 measure of nickel ammonium sulphate in a test tube half full of water, and add a few drops of the sodium hydroxide solution. A thick white precipitate of nickel hydroxide is formed.

EXPERIMENT 208—Manganese hydroxide

Place 1 measure of manganese sulphate in a test tube half full of water and add a few drops of sodium hydroxide solution. A thick white precipitate of manganese hydroxide is formed.