

to promote this industry in this country have been inaugurated in the different states of the Union, from the Atlantic to the Pacific coasts. At the present time an extensive effort is being made to develop a raw silk industry in Southern California. The worm can apparently be propagated wherever the mulberry tree can be grown successfully.

SOURCE OF WOOL

Wool comes from a sheep's back. So does a lot of dirt and other materials picked up on his travels. He also exudes from the pores of his skin oily products which are generated by glands in his body. Only about one-half of the fleece is actual wool fibre. Fifteen per cent is grease, 15 per cent salts, and 20 per cent clay and dirt. Therein lies the reason why the woolen industry calls on the chemist to advise it how to prepare crude fleece for public use as clothing. It is a long chemical story from crude sheep's fleece to a woolen blanket on your bed, to a suit of clothes, to a pair of warm woolen mittens, and to a dyed rug on the sitting room floor of your home.

EXPERIMENT 594—Wool scouring

Secure if you can a small quantity of wool fleece before it has been subjected to any scrubbing treatment. Examine it and try to clean it by scrubbing with different detergents.

EXPERIMENT 595—Wool grease

Instead of scouring your fleece with detergents to remove dirt, soak it for several hours with some petroleum naphtha or ordinary gasoline. This will remove the valuable grease known in the drug trade as "lanolin." This wool fat is an important constituent of cosmetic preparations. Finally apply treatment with detergents to remove dirt. These two experiments will serve to reveal to you some of the difficulties facing the woolen manufacturer in preparing his product for public use.

EXPERIMENT 596—Clothing

It takes a sheep and a half to make a man a suit of clothes. Test the fabric used in your shirt and stockings and determine which contains wool.

EXPERIMENT 597—Shoddy

What is the difference between the different forms of woolen cloth—worsted, serges, flannel and shoddy? Examine a piece of shoddy under your microscope. What is there peculiar about its structure?

SOURCE OF COTTON

Cotton is a plant product and comes from the cotton plant. It is a cleaner commercial product than wool fleece and does not offer as many difficulties in purification. This plant is cultivated in all parts of the temperate and torrid zones, and is the source of enormous industries spread over our globe.

EXPERIMENT 598—Cotton industries

Try to enumerate thirty commercial products which are manufactured from cotton. Make a chart showing the industries producing these products.

EXPERIMENT 599—Cotton plant

Obtain if possible some raw cotton and examine it. Who invented the cotton gin? What is this machine used for?

SOURCE OF SILK

This is an animal product and is produced by the silk worm known as Bombyx Mori. This worm is cultivated and reared chiefly in China, Japan and Italy. The silk worm feeds on the leaves of the mulberry tree, and stores up a liquid silk solution in his body. After the worm has reached maturity it then exudes this silk solution in the form of a fine thread and weaves a cocoon. This cocoon is made up chiefly of a protein called *fibroin* and this is the basis of natural silk. Artificial silk, of which rayon is an example, is a modification of ordinary cotton.

EXPERIMENT 600—Cocoons

Secure a silk cocoon and cut it into halves by means of a sharp knife. Observe the dry chrysalis of the original worm encased in the cocoon.

EXPERIMENT 601—Degumming

Take the severed cocoon and boil it for a long time in hot soap solution. Wash with hot water and then dry the fiber and note its silky appearance.

EXAMINATION OF FABRICS WITH THE MICROSCOPE

EXPERIMENT 602—Wool fiber

Under a microscope wool consists of regular cylindrical fibers covered with scales. Make an examination of a wool fiber with your own microscope.

EXPERIMENT 603—Cotton fiber

Cotton fiber looks like a collapsed rubber tube, twisted on its axis. Make an examination of a cotton fiber with your own microscope.

CHEMICAL IDENTIFICATION OF TEXTILE FIBERS

In the home will usually be found some form of commercial lyes. These consist essentially of sodium hydroxide and can be used for the following fabric alkali tests. A tablespoonful of lye to a teacup of water will give a solution of sufficient strength for performing these fabric experiments calling for use of alkali.

EXPERIMENT 604—Identification of wool

A fiber of wool, when burned, is consumed slowly, a ball-like end being formed. The odor is characteristic of burning animal matter.

EXPERIMENT 605—Solubility of wool in alkali

Wool protein is dissolved by being boiled with strong sodium hydroxide solution for a few minutes. Add to an alkaline solution of wool a few drops of copper sulphate solution. Black copper sulphide will be formed, showing the presence of sulphur in wool.

EXPERIMENT 606—Identification of cotton

Burn a fiber of cotton and note that it burns quickly without giving any animal-like odor. The odor resembles that of burning paper.

EXPERIMENT 607—Action of alkali on cotton

Boil a fiber of cotton with strong sodium hydroxide solution. Note that unlike wool it will not dissolve.

EXPERIMENT 608—Action of alkali on silk

Dissolve a fiber of silk in boiling sodium hydroxide solution; cool and then add three or four drops of copper sulphate solution. A lavender coloration will be produced. This is characteristic of proteins which do not contain sulphur.

EXPERIMENT 609—Action of alkali and copper sulphate on cotton

Boil a fiber of cotton with alkali; then cool and add three or four drops of copper sulphate. No lavender or blue coloration will be produced. Cotton does not respond to the test first, because it is not soluble in the sodium hydroxide solution, and secondly, because it is not a protein.

THE CHEMISTRY OF THE BODY

Man is dependent on the plant kingdom for his source of food. In this way man utilizes indirectly the energy of the sun. Plants grow up, wither and fall to the ground. They decompose largely into carbon dioxide and water vapor, which are taken up by new plant life. The nitrogen is converted into nitrates by bacteria in the soil and the mineral matter helps to form new plant life.

Sugars are formed in plant life by the condensation of formaldehyde which is produced by the action of carbon dioxide on water with the aid of sunlight. The sugars are then changed into starch by plant ferments or enzymes and these starches are used by animals to support life. In animals these starches are changed back into carbon dioxide and water and the whole process repeats itself. Up to date, man has acquired through research a very extensive knowledge of the chemical changes taking place in this marvelous life cycle.

In the laboratory we have great difficulty in changing carbon dioxide into formaldehyde and formaldehyde into sugar. In plant life this is done at relatively low temperature which is less than that of the body (98.6 degrees Fahrenheit or 38 degrees Centigrade). This is accomplished by the action of the plant enzymes and is a very remarkable and important process.

In animal life we find enzymes similar to those in plant life. Sugar (dextrose) for example, is changed into starch (glycogen) in the liver and this is later turned into dextrose again in the blood by the action of another enzyme. The dextrose in the blood is converted by still further enzymic action into carbon dioxide and water vapor which are carried to the lungs and passed out on breathing. This change takes place in the muscle cells and furnishes the body heat.

The lean flesh or tissues of our bodies consists chiefly of protein. The fat is very similar to other animal fats. The bones consist chiefly of calcium phosphate and chondrin which forms gelatin on boiling. In old people there is more calcium phosphate present and less chondrin than in younger people, consequently the bones of older people are apt to be more brittle.

The skin consists of toughened protein matter. The hair and nails consist also of protein material and are called keratin. Alkalies attack the skin, hair and nails because proteins are decomposed by alkali. Mild acids, however, have little or no effect on these organisms. The perspiration which comes from the skin contains water, fats, acids and a little urea. We breathe to a very slight extent through the minute pores in the skin. This seems to be an important and necessary process so that it is essential

keep these pores open by bathing, since they are continually closed by fat which condenses in the perspiration.

The blood, which is the most vital part of the body, is composed of water, containing in solution, protein material called fibrinogen, seroglobulin, serumalbumin and saline water. Also suspended in this solution are red and white corpuscles. Neutral salts when taken into the body are decomposed, the acid constituent usually hydrochloric acid from salt, going to the gastric juice in the stomach and the alkaline constituent going to the blood. Therefore, the blood is normally alkaline. When blood is exposed to the air it clots. This is due to the fibrinogen in the blood changing to an insoluble compound called fibrin. The blood usually contains about 0.1 per cent of dextrose. The red corpuscles of the blood contain what is known as haemoglobin. This is an enzyme containing iron. It produces some of the very fundamental changes in the body in the same way that chlorophyll does in the plant. This haemoglobin has the property of taking up oxygen from the lungs and later giving up this oxygen during the oxidation of the tissues. During this oxidation heat and energy are formed. The white corpuscles sometimes called leucocytes are really the policemen in the blood for they tend to ward off sickness by destroying the impurities in the blood such as bacteria. When the number of bacteria becomes too great for these white corpuscles we become sick and then we have to resort to medicine to help the action of the white corpuscles.

A very important constituent of the brain and nerve cells is the substance known as lecithin. This is a complex organic compound containing phosphorus. Ordinarily the foods we eat contain small amounts of this substance, thereby furnishing the body with the necessary amount.

You may ask the question, Why is the blood normally alkaline? This is easily explained by the fact that it is up to the blood to remove the acidic carbon dioxide gas from the body. In an alkaline condition the blood can easily absorb these waste gaseous products of oxidation and in so doing forms sodium bicarbonate. The sodium bicarbonate in the blood gives up carbon dioxide and water vapor in the lungs. This leaves sodium carbonate which is the alkaline constituent of the blood and the blood is now ready to pass again through the body and take up more carbon dioxide.

The teeth differ from the other parts of the body in that they are more resistant to chemical action, namely, that of acids. The mouth of a normal person is alkaline and in this state the teeth are well protected. Decayed matter if allowed to cling to the teeth is converted into acids which slowly but effectually remove the enamel from the teeth and cause them to decay. The enamel of the teeth is composed chiefly of calcium fluoride. You can readily see, therefore, that it is very important to brush the teeth every day and the use of a mild antiseptic as a mouth wash is very effectual.

It is necessary to say at this time a few words in regard to body health. There are several influences which tend to keep up a healthy normal body. These are exercise, fresh air, cheerfulness, cleanliness, sunlight, pure food and pure water. The relationship between chemistry and exercise may be shown if we consider that many chemical reactions take place much more rapidly and with better results if the solution in which the reaction is taking place is heated or stirred continually. Just so in the body. By exercising the body the blood moves faster, the stomach digests our food better, we breathe much more efficiently and as a consequence the waste products of the body are more effectually eliminated and we feel much better.

Sunlight has several effects on the body. It is a powerful germicide and will kill many organisms which are the cause of disease. It also acts as a blood stimulator. You probably have noticed how red the body becomes in the summer time when exposed to the sun's rays.

Cleanliness is a very important contribution toward health. Dirt is a very good medium or culture for bacteria, so that it is quite necessary to keep the body clean. We have always spoken of the importance of keeping the pores of the skin open so that impurities can come out in the form of perspiration and that the pores may breathe in a certain amount of fresh air. Chemistry has contributed toward this influence on the health of the body by furnishing such substances as borax, soap, soda, ammonia, antiseptics and synthetic remedies.

Pure fresh water is a very important factor in everyday life. Natural waters contain small amounts of mineral salts, principally sodium chloride. These are not injurious to the health but rather beneficial. Waters, however, are apt sometimes to contain bacteria which may be very injurious to the health. If a water is suspected as containing bacteria it should be boiled. On a commercial scale water is purified by several processes, namely, treating the water with ozone, bleaching powder, chlorine, ultra-violet light or by distillation. Any of these methods are good if used under the right conditions.

The subject of fresh air is an old one, but one which a great many people disregard. It is very important that the lungs obtain the normal amount of oxygen necessary in the oxidation processes which take place in the body. The effect of poisonous gases when breathed into the lungs was very ably demonstrated during the great war. Impurities in the air such as poisonous gases, etc., have a very remarkable affinity for the blood. They react with the blood to form much more stable compounds than oxygen does. Consequently the blood cannot take up the normal amount of oxygen required in the body, and as a result the blood becomes congested. In the case of extreme poisoning the lungs become so congested that we are unable to breathe further, and death follows. In a poorly ventilated room the carbon dioxide given off from the lungs soon becomes in excess of the oxygen present in the room, with the result that we become drowsy or sleepy. This effect seems to be due to a lowering of the oxygen content in the room and also to a rise in temperature caused by the body heat.

Cheerfulness is not directly related to chemistry but is mentioned here because of the influence it has on the health of the body. A person who is cheerful, particularly during the time of eating, is apt to be less troubled with indigestion than a person who is constantly worrying. Loss of appetite is quite often due to just this thing. Indigestion and loss of appetite are controlled to a large degree by the nerves, which are apt to break down in a person who is not cheerful.

The truth of the old saying that an apple a day keeps the doctor away is now vouched for by science. Apples contain vitamin C, which has been found necessary and valuable in promoting health and protection from diseases like scurvy. All nutrition authorities now report that apples, while they do not contain as much of this vitamin as tomatoes or oranges, do supply an important amount of it, particularly if eaten raw, skin and all.

Let us try a few chemical tests to see if we can learn something about the body.

EXPERIMENT 610—How to test for sugar in urine

The excretion of urine from a healthy person should be free from sugar. If sugar is found in the urine it is an indication that the liver is not functioning properly and the person has what is known as diabetes.

Put three measures of cream of tartar baking powder in a test tube half full of water. After the reaction stops add one measure of copper sulphate and shake the contents of the tube thoroughly. Now add four measures of sodium carbonate and four measures of calcium oxide. Shake the test tube again thoroughly and filter the contents of the tube, catching the liquid in another test tube. This clear liquid is known as Fehling's solution.

Now to a test tube one-third full of this solution add four or five drops of urine and heat the test tube over an alcohol flame nearly to boiling. Now remove the tube from the flame and see if a red precipitate has formed in the test tube. A red precipitate formed in this way is a test for sugar in the urine. The sugar reduces the copper hydroxide formed in the reaction of red cuprous oxide. By this test it is also possible to determine the quantity of sugar in the urine.

Repeat this experiment, using four or five drops of a sugar solution in place of the urine. The sugar solution is made by dissolving three or four measures of sugar in a test tube one-third full of water. Notice the red precipitate of cuprous oxide which is formed by the action of the sugar upon Fehling's solution.

EXPERIMENT 611—How to test for albumin in urine

The presence of albumin may be detected in urine as follows:

Heat a test tube one-third full of the urine to be tested over an alcohol flame with constant shaking. Do not heat above 175 degrees. This can be told by removing the test tube from the flame occasionally and feeling of the test tube with the hand. When the test tube is too hot to hold in the hand the temperature of the urine is above the temperature required. Do not heat the urine to boiling. Now remove the test tube from the flame and allow it to cool. Examine the contents of the test tube. If a precipitate separates out the urine contains albumin.

Repeat this experiment, using a test tube one-third full of the white of an egg in place of the urine. Notice that a gelatinous precipitate settles out. This is due to the coagulation or precipitation of the albuminous material contained in the white of the egg.

Albumin in the urine indicates that the stomach is not working properly, that the albumins are not changed during the process of digestion. They enter the blood in these forms and are passed out in the urine through the kidneys.

EXPERIMENT 612—How to test for proteids in urine

Dissolve three measures of sodium carbonate and three measures of calcium oxide in a test tube one-third full of water. Put the thumb over the mouth of the test tube and shake the contents of the tube thoroughly. Allow the test tube to stand until the solid materials settle to the bottom. Now pour the clear liquid into another test tube. This is a strong solution of sodium hydroxide.

Now dissolve one measure of copper sulphate in a test tube one-third full of water. To a test tube one-quarter full of the urine to be tested add the sodium hydroxide solution prepared above. Shake the contents of the tube thoroughly and then add two or three drops of copper sulphate solution. The formation of a violet color on shaking indicates the presence of proteids in the urine. The purple color becomes deeper on heating the solution to boiling. This reaction is known as the Biuret Test for proteids.

EXPERIMENT 613—Testing urine for acidity

Drop a small piece of blue litmus paper in a test tube one-third full of urine and notice that the litmus paper turns red. This proves that urine is generally acidic. This is due to the presence of sodium dihydrogen phosphate in the urine. The acidity of the urine depends upon the kinds of food taken into the body. Vegetable foods tend to decrease the acid content and even render the urine alkaline.

EXPERIMENT 614—Testing urine for ammonia

Put five measures of calcium oxide in a test tube one-third full of urine and heat the mixture over a flame for several minutes. Remove the test tube from the flame and smell cautiously at the mouth of the tube. Do you recognize the odor of ammonia? Ammonia occurs in urine chiefly in the form of organic compounds known as urea, uric acid and creatinine.

EXPERIMENT 615—Testing urine for phosphate

Dissolve one measure of calcium chloride in a test tube one-quarter full of water. Add a little of this solution to a test tube one-third full of urine and notice the formation of a white precipitate. If the urine is alkaline the precipitate may be due to a mixture of calcium phosphate and calcium carbonate. When urine is alkaline it contains, besides small amounts of ammonia, the carbonates of soda and ammonia.

EXPERIMENT 616—How to test for acid mouth

Moisten a small piece of blue litmus paper with the tongue and see if the litmus paper turns red. If it does the mouth is acid. Acid mouth is usually caused by an upset stomach or by decayed teeth. Normally the mouth should be neutral or only slightly alkaline.

THE CHEMISTRY OF PLANTS—AGRICULTURE

As our knowledge of the chemistry of the processes of living organisms—animals and plants—increases it becomes increasingly difficult to define the boundaries between the animate (living organisms) and inanimate (inorganic or non-living.) The significance of this statement will become apparent to any intelligent boy if he will only stop to consider the dependence of our civilization on the successful practice of agriculture. The primitive source of the food of man is the soil, and consequently the successful practice of agricultural science is necessary if man is to secure food for his existence. The farmer occupies, therefore, a most important place in human economy. The energy which is necessary to promote the different chemical changes involved in animal and plant growth is derived from the sun. Deprived of this source of energy, plants would not be able to grow, agriculture would be destroyed, and man would die.

THE CHEMISTRY OF FERTILIZERS—FARMING

Did you know that chemistry plays such an important part in farming and in the fertilization of soil? No doubt you have often seen the farmer cover his soil in the Spring with manure or other forms of fertilizers and later work them into his soil. You probably asked the question, why are these fertilizers put into the soil, and found that they make crops grow better. That is true, the crops do grow better. But why is this so? By repeated experiments it has been found out that there are certain substances which are very essential to plant growth. We have already learned how plant compounds, such as starch, are built up in the plant by means of carbon dioxide and moisture in the air with the aid of the sun's rays. On the other hand there are other important substances which are taken up by the plant in the soil to form complex compounds. These are potassium, nitrogen and phosphoric acid. These substances must be introduced into the soil in the form of their soluble compounds as they are taken up by the plant roots by means of absorption.

Nature plays a very important part in the formation of nitrogenous substances in the soil. You probably do not know that in most fertile soils there exists millions of bacteria which have the property of converting decayed nitrogenous organic matter into nitrates which are taken up by the plants. Now it is very important in farming to see that the soil is kept in a condition whereby these bacteria are able to thrive in order to keep the soil fertile. Soils which contain large amounts of decayed organic matter are kept in a moist condition so that the air does not get at them are quite often apt to be acidic. The nitrate forming bacteria are not able to live in soils which are acid so that it is very important to see that these acids are destroyed. Acid soils also render other fertilizing substances, such as phosphates, insoluble or in a condition such that

the plant is unable to absorb them in the ordinary process of plant growth. This acidic condition of the soil is generally destroyed by neutralization of the acids with lime.

In the ordinary process of farming, since the plants are continually removing the nitrogen, potassium and phosphorus compounds from the soil, it is necessary to replenish these substances with fertilizing material. Now the amounts and kinds of fertilizer to be put into a certain grade of soil depends upon the condition of the soil and kinds of crops to be raised. One class of plants will require more phosphorus than another class. Many formulas have been worked out including the kinds and amounts of fertilizing substances to be used for different kinds of plants.

Soils are fertilized in four ways, namely, by decayed vegetable matter, by rotation of crops, by animal manure and by artificial or commercial fertilizers.

Decayed vegetable matter such as leaves, grass, etc., is often worked into the soil as a natural fertilizer, but since they contain only small amounts of the essential fertilizing substances, their use alone would be inadequate.

The second method of fertilization, namely, the rotation of crops is widely used in farming and consists in planting fertile land one season with corn, wheat or other crops and the following season with clover, cow-peas or alfalfa. These latter plants have the property of converting nitrogen from the air into soluble nitrates which are restored to the soil to take the place of that used up by the corn, wheat and other crops in the preceding season. The conversion of the nitrogen of the air into nitrates is accomplished by certain germs or bacteria which occur in tubercles or swellings on the roots of clover, cow-peas, and alfalfa plants.

Natural or animal manures are used exclusively as fertilizing materials as they contain large amounts of nitrogen compounds. They also tend to keep the soils loose so that the air can penetrate them. Guano, cow dung and sheep dung are important natural manures containing relatively large amounts of nitrogen. Guano is the excrement of sea-birds and is found off the coast of Peru. Guano is rich in phosphorus, nitrogen and potash.

Artificial fertilizers are used very widely today and several important industries are involved in their manufacture. These are chemical compounds or substances that are

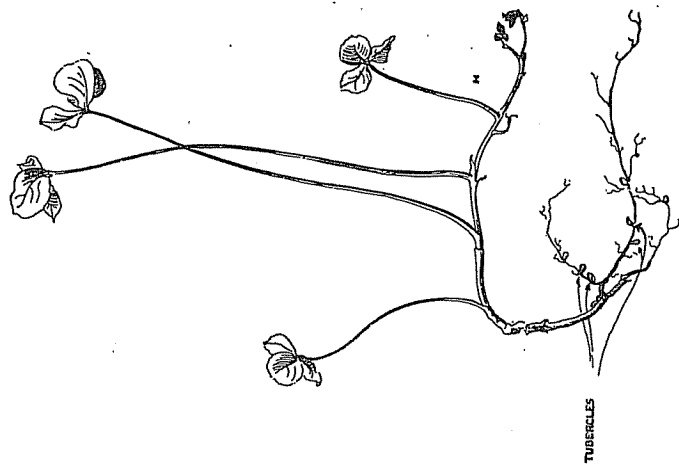


Fig. 36

rich in nitrogen, phosphorus and potassium. Phosphorus is used in these fertilizers in the form of its soluble compound such as calcium acid phosphate. Potassium is used principally in the form of potassium chloride, potassium sulphate and potassium carbonate, while nitrogen is used in the form of ammonium nitrate and sodium nitrate. The commercial fertilizers which are put out on the market are complete fertilizers, such as dissolved potash and phosphates, wood ashes, ground bones, dissolved bones tankage, dry ground fish, nitrate of soda, dried blood, cottonseed meal, linseed meal and castor pomace.

One of the important problems of the science of agriculture is to find out which of the elements that occur in plants and animals are necessary for their growth. Hitherto the farmer has been taught that only ten chemical elements are necessary for the growth and normal support of his crops. It has, however, been a well-known fact among agricultural chemists that a far greater number of chemical elements than ten occur in small amounts in fertile soils, and also in the ashes of plants that have been grown under natural conditions. The elements which have been regarded as the only ones essential for the growth of plants are the following: carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, and iron. It was perfectly natural that in the early days of agriculture these elements which occurred in the largest amounts would receive the first attention by agricultural chemists. However, with the development of new and modern methods of chemistry and with greater refinement in methods of research, it was not unreasonable to expect that a very large number of the chemical elements which have been regarded as non-essential would finally prove to be very important factors in plant growth. This has really proven to be the case. It is now known that the element, manganese, for example, is a very essential plant food. It has been shown that plants will assimilate manganese compounds from the soil. It now also seems probable that manganese actually exists in small quantities in all living organisms, and has important functions that have hitherto been unrecognized. All the facts to date show that manganese is an important and necessary factor in the synthesis of the green chlorophyll of plants, and experiments have already been carried out which show that no other one of the common elements—iron, copper, zinc, boron, or arsenic—will replace manganese. Heretofore, it has been believed that iron and magnesium were chiefly concerned in the synthesis of plant chlorophyll. It has now been shown by recent workers in agricultural science that manganese plays a role of importance equal to that of iron in the synthesis of chlorophyll, and that both of these elements are indispensable for the formation of chlorophyll in plants.

EXPERIMENT 617—Nitrogen forming bacteria

Pull up a clover or alfalfa plant and examine the roots. Notice that along the roots there are numerous small swellings (Figure 36.) These swellings are called tubercles and if these were crushed and examined under a powerful microscope you would find millions of small living bacteria in them. These are the bacteria which convert the nitrogen from the air into soluble nitrates which are furnished to the soil and later taken up by other plants.

EXPERIMENT 618—To show the effect of carbon dioxide on plant life.

Procure two Mason quart jars and place about two inches of damp earth in each. Now plant two or three peas or beans in each jar exactly under the same conditions. Allow the jars to stand until the beans begin to sprout. Then fill one jar with carbon dioxide gas. The carbon dioxide gas is made by putting two spoonfuls of baking soda or sodium bicarbonate in a third empty quart jar and adding a little vinegar or a solution of tartaric acid. After the reaction has gone on for several moments pour the gas

from this jar into one of the other two jars, being careful not to allow any of the liquid to get into this jar. Figure 37.

Now seal the two jars containing the sprouted beans or peas and allow them to stand for several days in the sunlight. Label the one containing the carbon dioxide. Examine the jars from time to time and notice that the plants in the jar containing the carbon dioxide grow faster than those in the other jar. This proves that carbon dioxide is essential to plant growth.

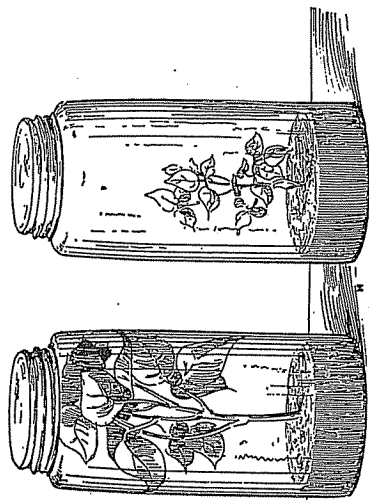


FIG. 37.

A SIMPLE PHOTOCHEMICAL EXPERIMENT TO DETERMINE THE ACTIVITY OF THE ENERGY OF THE SUN'S RAYS

EXPERIMENT 619—(Sodium nitroprusside and thiourea purchased separately)

Four test tubes are numbered and placed in a rack so that equal exposure to light may be secured.

In tube one is placed one-quarter of a test tube each of the three solutions sodium nitroprusside, sodium bicarbonate, and thiourea. In tube two is placed one-quarter of a test tube each of the sodium nitroprusside, and sodium bicarbonate solutions only. In tube three is placed one-quarter of a test tube each of the thiourea and sodium bicarbonate solutions only. In the last tube one-quarter of a test tube of sodium nitroprusside and one-quarter of a test tube of thiourea solution are mixed.

The four tubes are then placed in the sunlight for from four to six minutes. A blue color will form quickly in tube one and slowly in tube four, number two will darken slightly, and tube three will remain unchanged. The reaction will proceed in ordinary light, but at a much slower rate.

The tubes are removed from the sunlight as soon as one and four are distinctly blue, and one-quarter test tube of thiourea solution is added to tube two. A blue coloration will take place quickly without the aid of further exposure to light. One-quarter test tube of nitroprusside solution is then added to tube three. The blue color will not be formed in this case, showing that the sunlight does not cause any change with thiourea in sodium bicarbonate solution.

The tubes are now placed uncorked in total darkness for a period of three to six hours or more. Upon removal it will be noted that tubes one and two have changed to a deep crimson, tube four will be blue and practically unchanged, while tube three will be colorless, although all the necessary reagents for the reaction have been present for several hours.

If one-quarter of a test tube of sodium bicarbonate solution is added to tube four, the blue color immediately takes on a purplish tinge, and if kept in the dark the color will be decidedly red after about one-half hour, showing that the tube "stored darkness", even though it was not apparent, as in tubes one and two, until the sodium bicarbonate addition.

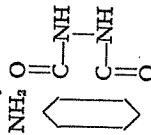
All the tubes are then re-exposed to sunlight and the blue coloration will immediately form in each, since all the reactants are now present in each tube. Another period of darkness will bring the red, etc., until finally the active ingredients are decomposed, due to side reactions. If too long exposures to sunlight are avoided after the blue color is produced, the reaction may be reversed 12 to 20 times. If the solution is placed in a completely filled, sealed container, the change blue to red will fail to take place after several times, showing that the presence of air is necessary, probably for the spontaneous re-oxidation of the iron previously reduced by the action of the sunlight. The solutions required are: one-half oz. of freshly prepared 0.5% sodium nitroprusside (to be kept in an opaque bottle); one-half oz. of saturated sodium bicarbonate; and one-half oz. of 0.5% thiourea.

"COLD LIGHT," OR LIGHT BY CHEMICAL ACTION

EXPERIMENT 620—A demonstration of "chemiluminescence"

One of the most beautiful and striking demonstrations for laboratory or lecture work is that of chemiluminescence or "cold light." Certain chemical reactions, usually ones involving the oxidation of an organic compound, result in the development of light without other visible reaction. Even heat, which is usually associated with light of any kind, is noticeably absent.

This phenomenon of *chemiluminescence* has long been known, but has not previously been employed extensively because of difficulties encountered in the available reactions. These were complex and dangerous, produced only a limited luminescence, or required reagents not readily obtainable. But now three-aminophthalhydrazide has been made available which overcomes all of these objections. The reaction is simple, safe, and develops light of intense brilliancy.



LUMINOL

The name "luminol" has recently been applied to this compound in place of its chemical name for convenience, to associate with it the property of luminescence.

The demonstration requires only the oxidation of luminol in dilute alkaline solution with three per cent alkaline hydrogen peroxide and a second oxidizing agent. All four compounds are necessary in the solution to obtain the strongest radiation. Almost

innumerable variations can be used in the actual procedure, from the mere mixing of the required chemicals to very elaborate displays. A few of the simpler methods are given to serve as guides.

For small audiences or laboratory demonstration, the flask method is the most satisfactory. In a two-liter long-necked flask, a small quantity of luminol on the point of a knife blade is dissolved in a test tube full of five per cent sodium hydroxide and diluted to two quarts with water. In a similar flask, two knife blade portions of potassium ferricyanide is dissolved in water, a test tube full of three per cent hydrogen peroxide added and diluted to two quarts with water. When both solutions are ready and the room is darkened, one flask is grasped in each hand and the contents of them poured simultaneously through a funnel into a six-liter flask. The reaction starts as soon as the liquids mix in the funnel. After the initial development of the light has begun, the flask is swirled and a small quantity of solid potassium ferricyanide added. The brilliance is increased and can be still further intensified by the gradual addition of five per cent sodium hydroxide. At the concentrations given, the original light intensity is small, but the increased brilliance obtained by the addition of further reagents is very beautiful.

For demonstration to larger audiences, it is more convenient to use a large jar containing about 14 quarts of water. In a small flask is dissolved one spoon measure of luminol in five test tubes full of five per cent sodium hydroxide, and in a second flask, 25 spoon measures of potassium ferricyanide in five test tubes full of three per cent hydrogen peroxide. To indicate more clearly the lack of heat in the reaction, the solution may be poured simultaneously over a cake of ice which has been floated in the water. The solutions should be allowed to mix in concentrated form on the ice before being diluted with the surrounding water. After the reaction mixture has diffused throughout the water, the solution is stirred vigorously with a glass rod and further potassium ferricyanide or alkali or both added as desired.

A very beautiful display may be prepared by means of two fine sprays, which are made to interact some distance above the lecture table. Each spray of humidifier is connected to a compressed air source and to one of the stock solutions previously mentioned. Care should be taken that the spray guns are operating at the same rate. By variation of the stock solutions, the resulting mist can be changed from a hardly visible cloud to a brilliant fountain resembling a display of fireworks.*

*The reagent "luminol" may be purchased from the Eastman Kodak Company, Rochester, N. Y.

PART IV

Electro-Chemistry

Before we discuss the part electricity takes in chemistry we must first know a little something about electricity. Electricity, like heat, is a form of energy. About 100 years ago very little was known about the role that electricity played in chemical reactions. Today matters are quite different. Electricity and chemistry are very closely related, many large and important industrial concerns are engaged in manufacturing materials involving the use of electro-chemical reactions.

Today chlorine gas and caustic soda are manufactured by passing an electric current through salt water. From the chlorine gas we obtain bleaching powder. Metals are extracted from their ores by passing a current through their molten or fused salts. Nickel-plating, copper-plating and gold-plating are done by passing a current through a solution containing salts of these metals. The success of these important industries and many others is based on the fact that electricity possesses the power of decomposing chemical compounds.

On the other hand, we can show the relationship between chemistry and electricity in another way. We have already said that electricity is a form of energy. Now, in most chemical reactions, heat is liberated as the form of energy. However, under proper conditions, the energy of certain chemical reactions is liberated in the form of electricity. For example, if we put a copper plate and zinc plate in a solution containing an acid and connect the two plates with copper wires we find that a current of electricity is produced. A reaction takes place in which electricity is the form of energy liberated. Use is made of this fact in the manufacture of the different types of electric cells and batteries. Batteries are simply cells connected together in series in order to produce a stronger current. There are several types of cells, all of which come under two classes, namely, the primary cells, which include both the dry and wet cells, and the secondary cell or storage battery, as it is called.

Finally, we will mention a third relationship of electricity to chemistry. That is, the part electricity plays in furnishing heat to produce chemical change. A good example of this is the manufacture of graphite from carbon by means of the electric furnace. Also the manufacture of calcium carbide for the production of fertilizers, of nitric acid from nitrogen in the air, and many other important industries depend upon the heat generated by the electric current for their success.

Before we discuss any of the different types of cells we will first consider the parts that go to make up a primary cell. These are, first, the jar which holds the solution and the elements; second, the solution of electrolyte, as it is commonly called; third, the cathode or negative electrode, which is usually made of the element zinc; and, fourth, the anode, or positive electrode, which is usually the element carbon.

THE DRY CELL AND HOW IT IS MADE

The dry cell is a very common type of cell and millions of them are used for bell, telephone and other purposes. The jar of the dry cell consists of a cup of sheet zinc which serves as the negative electrode (Figure 38.) A binding post is fixed at the top of this cup. The electrolyte in the dry cell consists of an active paste which consists usually of one part of zinc chloride, one part of zinc oxide, one part of ammonium chloride or sal ammoniac, three parts of plaster of Paris, two parts of manganese dioxide and one part of water, all by weight.

The cell is prepared as follows: the zinc cup is filled to within one-half inch of the top and a carbon rod containing a binding post on the upper end is pushed down into the paste to within an inch of the bottom. Melted pitch is then poured over the paste until it is even with the top of the cup. The pitch is then allowed to cool, and the cell is ready for use. It is only when you close the circuit, that is, connect the two binding posts with a wire, that you start chemical action within the cell. When the circuit is open the chemical action stops.

HOW THE DRY CELL WORKS

After the cell is made and copper wire is attached from the carbon post to the zinc post a current of electricity passes through the wire. This is due to action of the active paste upon the zinc electrode. When the circuit is opened, that is, when the carbon and zinc posts are disconnected, the action stops.

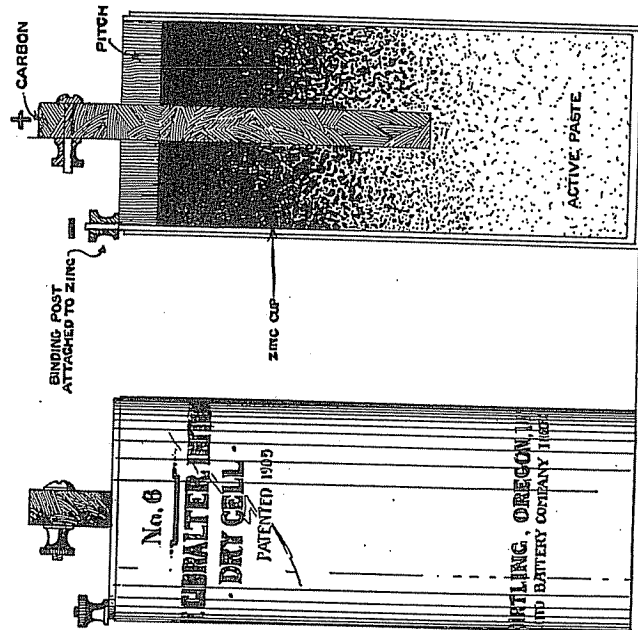


Fig. 38

Now the chemical action which takes place within the cell is as follows: The ammonium chloride and water react to form hydrochloric acid which attacks the zinc. The zinc goes into solution in the form of positive ions, which are atoms or groups charged with electricity. When this happens the zinc electrode assumes an electro negative condition. The positive zinc ions unite with the negative chlorine ions of the hydrochloric

acid to form zinc chloride with the formation of positive hydrogen ions. Now, the positive hydrogen ions move to the carbon electrode where they lose their charge and become gaseous hydrogen. Therefore, when the circuit is closed the chemical action, which takes place, keeps the zinc pole or cathode negatively charged and the carbon pole or anode positively charged. The flow of electricity is always from the negative zinc pole to the positive carbon pole through the solution, and from the positive carbon pole to the negative pole through the wire.

You might ask the question, What happens to the hydrogen gas when chemical action takes place within the cell? The hydrogen gas as fast as it is formed at the carbon electrode is oxidized to water by oxygen from the manganese dioxide. This brings up the phenomenon known as polarization. By polarization is meant the cutting down of an electric current, due to the lowering of potential between the carbon and zinc poles. Polarization in a cell is caused by formation of bubbles of hydrogen gas clinging to the carbon electrode, thereby producing less surface. To prevent this, manganese dioxide is used, which, as already stated, oxidizes the hydrogen gas to water.

THE WET CELL

The wet cell or other type of primary cell is very similar to the dry cell. The electrolyte instead of being a paste, as in the dry cell, is a solution. The positive and negative

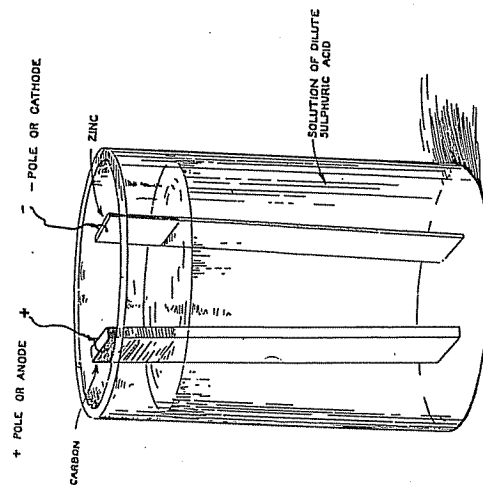


Fig. 39

electrodes are of carbon and zinc or of copper and zinc. (Figure 39.) The principles involved in the formation of a current due to chemical action in the wet cell is the same as that in the dry cell, although there are several types of wet cells.

THE STORAGE BATTERY

The second type of electric cell or storage battery is a little more complicated than the dry or wet cell. The storage battery consists of a number of secondary cells (Figure 40). It is used largely for running electric power plants, electric automobiles, telephone and telegraph work, etc.

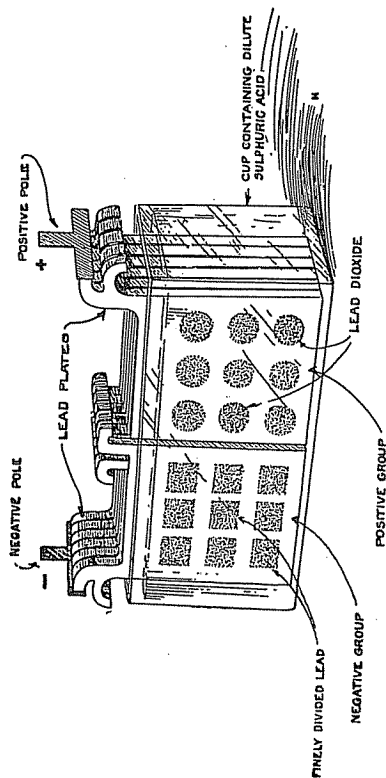


Fig. 40

The storage battery does not generate a current of electricity like a primary cell by a direct chemical action. It is charged by a current of electricity, after which it will deliver a current until the cell is run down. The chemical action taking place when the electricity is discharged is much more complex in this type of cell, so that we will not go into a discussion of it.

EXPERIMENT 621—How to test a battery of dry cells

If you have two or three dry cells around the house and wish to test their strength, perform the following experiment with them:

Connect the cells together in series as shown in Figure 41 by attaching small pieces of copper wire to the carbon binding post of one cell and zinc binding post of the other cell. (Figure 41.) Now connect a longer piece of wire to the free carbon post and another long piece to the free zinc post. Clean the ends of all the copper wires by scraping with a knife blade.

Now dissolve two teaspoonfuls of sodium chloride (table salt) in a tumbler two-thirds full of water and put the ends of the copper wires, which should be clean, in this solution. Notice whether bubbles of gas appear on the ends of the wires in the solution. By setting up the same number of new cells in the same manner and comparing the amount of gas produced with that produced from the old cells you can tell whether the old cells are of sufficient strength to be of value in performing the following experiments.

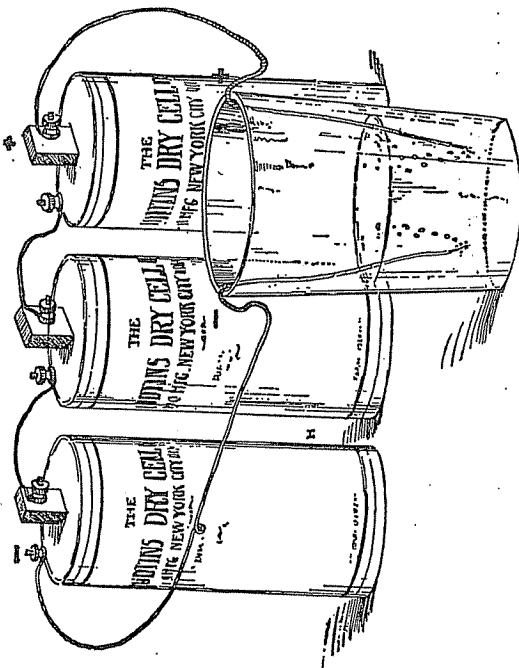


Fig. 41

If no gas is formed from the old cells when the preceding experiment is accurately performed, the cells are worn out and you will have to obtain some new cells. Two or three dry cells connected in series will give you sufficient current for performing most of the experiments as outlined.

EXPERIMENT 622—How to determine the positive or negative wire

Connect two or three dry cells together in series as in Experiment 621. Now moisten a piece of filter paper with a little sodium iodide solution and place the ends of the wires from the battery about one-quarter inch apart on the paper (Figure 42). Notice that the spot where one of the wires touches the paper becomes reddish brown. Also notice that this is the wire connected to the positive or carbon pole.

What really happened was this: When you touched the ends of the wires from the battery to the paper containing sodium iodide solution you simply closed the circuit and a current of electricity flowed from the positive carbon electrode to the negative zinc electrode, at the same time decomposing the sodium iodide. The iodine of the sodium iodide being in the form of negative ions is attracted to the positive wire, where they lose their charge and become atomic iodine, thereby producing a reddish brown spot. This is a very convenient way of telling what is the positive and negative wire of any source of electricity.

EXPERIMENT 623—Another way to tell the positive and negative wires

Put two measures of potassium nitrate and two drops of phenolphthalein in a test tube one-quarter full of water. Shake thoroughly until all the solid is dissolved.

Now moisten a piece of filter paper about one inch square with some of this solution and test the paper the same way you did in the preceding experiment. Notice this

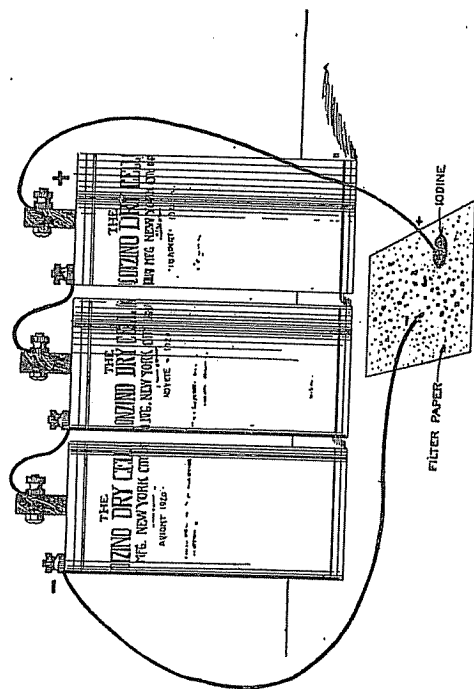


Fig. 42

time that the spot where one of the wires touches the paper becomes red. Also notice that this wire is the wire connected to the negative zinc binding post and is therefore the negative wire.

The potassium ions of the potassium nitrate being positively charged are attracted to the negative copper wire, where they lose their charges and become atomic potassium. Atomic potassium, being a very active substance, instantly unites with the water present to form a base potassium hydroxide, which turns the phenolphthalein red.

EXPERIMENT 624—How to show the direction of a current

Dissolve eight measures of nickel ammonium sulphate in a tumbler one-third full of water.

Now connect two or three dry cells in series as shown in Experiment 621 and put the ends of the wires leading from the positive and negative poles of the battery into the nickel solution. Notice that very soon the wire attached to the negative pole or zinc electrode is coated with metallic nickel or is being nickel-plated.

Now disconnect the two wires from the battery and attach the wire which was plated with nickel to the positive carbon pole and the other wire to the negative zinc pole. Put the ends of the wires again in the solution. Notice that the nickel is soon dissolved from the plated wire and is deposited on the other wire which is attached to the negative pole.

This proves that the current always flows from the positive pole to the negative pole and that the metal deposited always follows the direction of the current.

ELECTROPLATING

The very simple process of transferring metal from one object to another by chemical and electrical means is called electroplating. All of the silverware in use is plated