1042

Issued January 17, 1908.

U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS—BULLETIN 195.

A. C. TRUE, Director.

SIMPLE EXERCISES ILLUSTRATING SOME APPLICATIONS OF CHEMISTRY TO AGRICULTURE.

BY

K. L. HATCH,

Principal of the Winnebago County School of Agriculture and Domestic Economy, Winneconne, Wis.

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THE OFFICE OF EXPERIMENT STATIONS.

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[Bull. 195.]

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., November 20, 1907.

Sir: I have the honor to transmit herewith, and to recommend for publication as Bulletin 195 of this Office, a series of exercises showing how rural school teachers can make simple and inexpensive demonstrations illustrating some of the applications of chemistry to agriculture. The bulletin is intended to supplement Bulletin 186 of this Office, Exercises in Elementary Agriculture, and was prepared under the direction of Mr. Dick J. Crosby, of this Office, by Mr. K. L. Hatch, principal of the Winnebago County School of Agriculture and Domestic Economy, Winneconne, Wis.

Respectfully,
A. C. True, *Director.*

Hon. James Wilson,
Secretary of Agriculture.

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SIMPLE EXERCISES ILLUSTRATING SOME APPLICATIONS OF CHEMISTRY TO AGRICULTURE.

INTRODUCTION.

Many people have come to think of chemistry as a laboratory science, the workings of which are shrouded in mystery, and of chemicals as liquids, powders, and crystals confined in bottles and safely stowed away on the shelves of the apothecary shop. The science has been regarded too difficult for ordinary comprehension and the materials too illusive for our grasp.

Such, however, is not the case. Chemistry is indeed a wonderful science, but its processes are taking place all around us and its compounds exist everywhere. The air we breathe is a mixture of chemical elements and compounds, the water we drink is a chemical compound, the solid earth beneath us but a conglomerate mass of many chemicals. The plants which grow upon the surface of the earth are composed of only a few chemical substances, and the animals which feed upon the plants (and upon other animals) are but chemical compounds wrought in nature's laboratory by that mysterious process called life.

PURPOSE OF THE BULLETIN.

It is the purpose of this bulletin to aid the teacher in working out a series of simple exercises which will acquaint the pupils with a few chemical elements of great importance in agriculture—those entering into the structure of the plant and those composing plant-made compounds.

The exercises are not intended for children studying the science of chemistry or the science of agriculture, but for children unfamiliar with scientific methods and terms. For this reason the exercises are made very simple and the fewest possible technical terms are used. Where it has been necessary to choose between accurate technical language which might be a little confusing to the pupils and a less technical statement expressed in language familiar to them, the latter has been chosen. The aim is simply to show the intimate relation between the plant, the air, and the soil, and to familiarize the farmers' children with a few chemical terms which must become household words if the principles underlying agriculture are to be taught successfully in the common schools.

SCOPE OF THE BULLETIN.

The following topics are covered by the exercises outlined herein:

(1) Those elements and compounds, called plant foods, which are essential to the growth and development of the plant.

(2) Those compounds, called plant products, which are formed by the plant out of the food which it consumes.

(3) The three sources of plant food, viz, the soil, the air, and the water.

(4) The meaning and the importance of the terms "Acids" and "Alkalis."

(5) Methods of treating soils which are abnormally acid or alkali.

NECESSARY MATERIALS.

The necessary materials are of the simplest kind and can be procured in any locality at very slight expense. The school children may be asked to provide the following items:

1. Four or five old bottles.
2. Two tin cans.
3. A tin plate.
4. A tin pan.
5. Two tumblers.
6. A glass fruit jar.
7. Two or three feet of broom wire.
8. A thimble.
9. Splinters of wood.
10. Matches.
11. Straws or woodbine or pipestems.
12. Small pieces of waste zinc.
13. A few pieces of charcoal.
14. Two or three rusty nails.
15. Two or three heavy white pie plates or sauce dishes.
16. A teaspoonful of sulphur.
17. A handful of fresh unslaked lime.
18. A small bottle of vinegar.
19. A handful of cotton.
20. A small bottle of sulphuric acid from the creamery or cheese factory. (The acid used in testing milk.)[a]

To the above list must be added the following, which can be purchased at any drug store (see fig. 1):

Alcohol (denatured)[b]	$0.10
Potassium chlorate	.05
Iodin	.05
Saltpeter	.05
Soda (saleratus)	.05
Ammonia	.05
Caustic potash	.05
Copper sulphate	.05
Cochineal or litmus paper	.05
Total	.50

[a] *Great care must be exercised in working with sulphuric or other strong acids, as they are strongly corrosive. They must not come in contact with the flesh or clothes of the operator nor with ordinary metallic vessels and must be greatly diluted with water before being poured into the sink.*

[b] Wood alcohol or ordinary alcohol may be used if denatured alcohol is not easily obtained.

The teacher will need an alcohol lamp, which can be made from an ink bottle, as follows: Drive an empty cartridge shell through the cork, file off the closed end, and punch out the cork inside the shell.

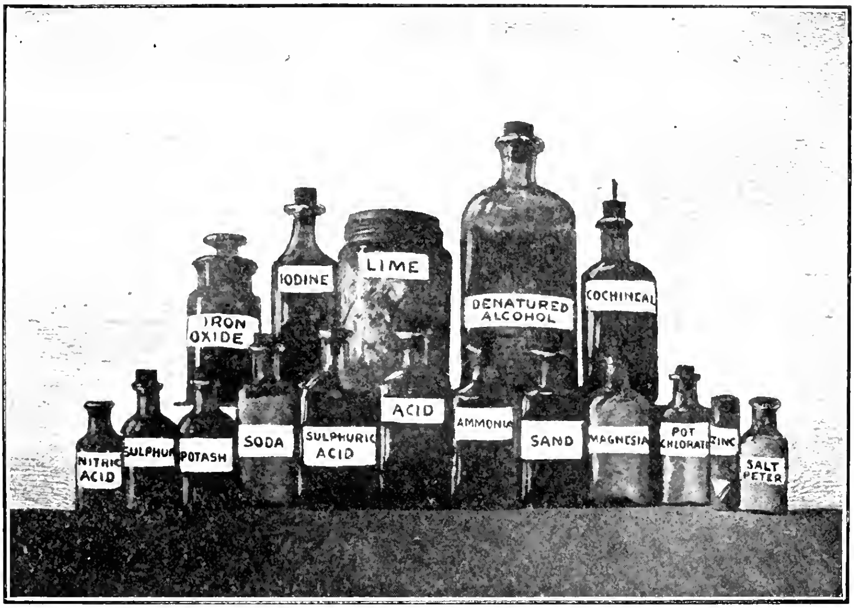

FIG. 1.—Chemicals needed for the exercises in this bulletin.

Twist a string into a wick, draw it through the shell, and fill the bottle half full of alcohol (fig. 2). Evaporation of the alcohol may be prevented by covering the wick with a thimble. Either wood alcohol, denatured alcohol, or kerosene may be used, though the latter smokes badly and blackens the dishes heated by the flame.

A lamp can also be made from a small tin box. Punch a hole through the cover from the under side, fill the box with cotton, and pull a wisp of it through the hole in the top for a wick. Moisten the cotton with two or three teaspoonfuls of alcohol, light, and you will have a lamp that will burn nicely for ten or fifteen minutes.

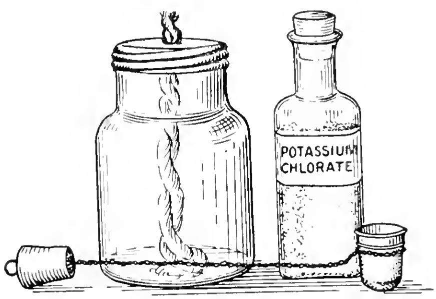

FIG. 2.—Apparatus used in preparing oxygen.

The entire cost of the apparatus and supplies is a trifling outlay for any school. With this material at hand the earnest teacher will be able to work out the exercises outlined below in an interesting and an instructive manner.

Part I.—The Plant.

PLANT FOODS.

It is well known that a little plant is to be found in every perfect seed. When the seed germinates this plant lives principally on the food material stored in the seed until it develops roots and leaves. It is then able to take in food from the air through its leaves, while its roots absorb from the soil other food materials dissolved in water. Large quantities of this water are incorporated into the tissues of the plant, but by far the greater portion of it passes off again into the air through the breathing pores of the leaves. Water, then, is important to the plant for three reasons, viz:

(1) It dissolves the plant foods in the soil.

(2) It transports the plant foods upward from the roots toward the leaves.

(3) It serves as a plant food itself.

Out of its food materials the plant manufactures starch, sugar, oil, protein, fiber, and cellulose, compounds which go to make up the plant structure. Starch, sugar, oil, and protein are digestible and furnish food for men and animals. Fiber and cellulose are the indigestible parts of the plant.

As has already been stated, there are three sources of plant food—the soil, the air, and the water. From the air the plant takes in oxygen and carbonic-acid gas through the breathing pores of the leaves. The leaves do not use the nitrogen of the air. This essential and most expensive of plant foods is taken in by the roots of plants. Small quantities of nitrogen exist in soils in a form known as nitrates, which dissolve readily in water and enter the plant through its roots, in company with the other plant foods. The roots of leguminous plants, such as clovers, alfalfa, peas, and beans, are able also, with the aid of minute organisms known as bacteria, to use the uncombined nitrogen in the soil air.

Most of the plant foods are available in the soil in great abundance, but it is sometimes necessary to supply nitrogen (in the form of nitrates), phosphoric acid, and potash. These are called fertilizers and are the only plant foods which the plant ever has difficulty in getting. The other plant foods are lime, oxid of iron (iron rust), soda, magnesia, silica (largely sand), hydrochloric acid, and sulphuric acid. Alumina and several other mineral compounds are frequently found in plants, but are not considered essential to their perfect development. Lime is sometimes applied to the soil to "sweeten" it or make it more friable, but not as a plant food.

When the plant is burned the carbonic acid, water, oxygen, and nitrogen pass off again into the air. The mineral matter is left behind in the ash. When the chemist makes a complete analysis of a plant he first dries it at the temperature of boiling water. The loss in weight is water. He next burns the plant, "traps" the escaping gases, and weighs them. Finally he analyzes the remaining ash. In this way it is easy for him to learn just what substances are used by the plant in its growth.

The first fifteen of the following exercises are intended to illustrate plant foods and simple tests for them.

Exercise 1.—To Prepare Carbonic-acid Gas.

Carbonic-acid gas is found in small quantities in the air. It is a product of the breathing of animals, the burning of wood and coal, and the decay of vegetation.

To prepare it place a teaspoonful of soda in a glass half full of water and add to this a few teaspoonfuls of vinegar. Stir the mixture and gas will be given off in little bubbles. This is carbonic-acid gas, the same as that given off from the lungs, as will be shown by a later experiment.

Exercise 2.—To Prepare Limewater.

To test for carbonic-acid gas limewater may be used. It may be easily prepared as follows:

Place a small handful of unslaked lime in a clean quart bottle, fill the bottle nearly full of water and allow it to stand for several hours, shake well and set aside until the undissolved lime settles and the water above it is perfectly clear. Pour off this clear liquid into another clean bottle. This clear liquid is limewater. Taste it to satisfy yourself. Cork the bottle tightly and set aside for testing carbonic-acid gas. If the bottle is kept corked the limewater will remain clear for a long time. When the lime separates out the solution should be thrown away and a fresh supply prepared.

Exercise 3.—To Test for Carbonic-acid Gas.

Make some carbonic-acid gas from vinegar and soda, as in Exercise 1. Pour some of this gas into a glass containing a little limewater. The gas is heavier than air and can be poured from one vessel into another. Place your hand over the glass and shake it. The limewater becomes milky, due to the action of the carbonic-acid gas.

Pour some freshly prepared limewater into a tumbler and blow bubbles through it with a straw or pipestem. The limewater turns milky. This shows that carbonic-acid gas is given off by the lungs.

Pour a little limewater into a bottle, place your hand over the mouth of the bottle, and shake it. If the air in the bottle is comparatively free from carbonic-acid gas, the limewater will not be affected. Set the bottle down and introduce into it a burning splinter. Leave it there until the flame goes out. Withdraw the splinter, place your hand again over the mouth of the bottle, and shake it. The limewater is now milky, showing that carbonic-acid gas is formed when wood burns. In the preceding test the presence of carbonic-acid gas in the air coming from the lungs is an evidence of combustion within the body.

Place a little limewater in a saucer and set it on the floor of the schoolroom. In a little while it will become milky, showing the presence of carbonic-acid gas near the floor of our living rooms. Why not near the ceiling?

Exercise 4.—To Illustrate Carbon.

All kinds of coal are composed largely of carbon. Stove blacking is carbon. The "lead" in our pencils is carbon and not lead at all. When wood begins to burn it turns black, forming charcoal. This charcoal is almost pure carbon. When any form of carbon burns carbonic-acid gas is formed. This gas is a compound of the hard, black, solid carbon and the oxygen of the air.

Exercise 5.—To Prepare Oxygen.

Double a piece of broom wire into a loop and twist it around a thimble. Push the free ends of the wire through a cork for a handle (fig. 2). Fill the thimble half full of chlorate of potassium and hold it in the flame of the alcohol lamp. When the chlorate melts oxygen will come off. It is a good plan to mix equal parts of clean, fine sand with the chlorate. This causes the oxygen to come off more rapidly. An empty brass cartridge shell can be used instead of the thimble.

Exercise 6.—To Test for Oxygen.

When the chlorate of potassium in the above experiment becomes heated light a splinter in the blaze of the lamp and blow it out, leaving a bright red coal. Hold this glowing coal close over the thimble and it will burst into a brilliant flame. This is a test for oxygen. Oxygen is a very active element, and in a pure state it combines very readily with many other elements even at low temperatures. This combination is commonly called combustion.

Bend a piece of fine wire into a loop, heat it, and dip this loop into some sulphur. Light the sulphur and hold it over the thimble, in which the oxygen is being prepared, as before. The sulphur, and perhaps the wire, will burn with great brilliancy.

Exercise 7.—To Prepare Nitrogen.

The air is composed of three gases—nitrogen, oxygen, and carbonic-acid gas. Four-fifths of it is nitrogen, nearly one-fifth is oxygen, and a very small part of it is carbonic-acid gas. If the oxygen and carbonic-acid gas can be taken out of the air, nothing will then remain but the nitrogen. This may be accomplished by burning out the oxygen, i. e., converting it into carbonic-acid gas, and then dissolving the carbonic-acid gas in limewater in the following manner:

Twist a piece of wire about a foot in length around a very small bit of cotton and bend it sharply about 3 inches from the end nearly, but not quite, double. Dip the cotton in alcohol, light the little torch, rest the loop with the torch standing upright on the bottom of a dish containing some limewater. Now invert an empty bottle over the torch and rest it on the bottom of the dish so that the neck will be immersed in the limewater (fig. 3). The oxygen will soon burn out of the bottle and water will rush in to take its place. The oxygen is now converted into carbonic-acid gas. Place your hand over the mouth of the bottle, still held beneath the water, invert it quickly, and shake. The limewater immediately becomes milky, showing that the carbonic-acid gas has been taken up by it. Practically everything except the nitrogen and the limewater have been taken out of the bottle. Set the bottle right side up on the table, remove your hand, and cover the bottle quickly with a piece of glass or a small board, and proceed immediately with the following tests:

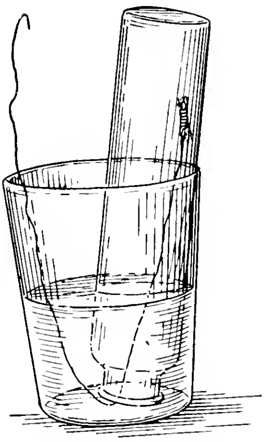

Fig. 3.—Apparatus used in preparing nitrogen.

Exercise 8.—To Test for Nitrogen.

First note the color and odor of the gas. Light a long splinter and while still burning brightly thrust it into the bottle nearly to the limewater. It immediately goes out. This is a test for nitrogen. It is the exact opposite of oxygen. Like oxygen, it is colorless, odorless, and invisible, but it will not burn and it will not support combustion. Thrust the burning sulphur into the bottle of nitrogen. The bottle must be kept covered as much as possible, as the oxygen of the air, being somewhat heavier than nitrogen, will soon get into the bottle and spoil the experiment.

EXERCISE 9.—TO PREPARE HYDROGEN.

Water is composed of two gases—hydrogen and oxygen. Oxygen has already been discussed. Hydrogen may be prepared by using some sulphuric acid and some waste zinc cut in small enough pieces to be put into a bottle. A scrap from an old stove board or the top of an old fruit can will answer. Place a small handful of the zinc pieces in an empty bottle and cover with water (fig. 4). Now add about one-fifth as much sulphuric acid as water used and hydrogen will come off rapidly in little bubbles.

Precautions which must be observed.—(1) Do not spill the acid on the floor, hands, or clothing. If by accident any should be spilled, it must be washed off immediately with an abundance of water and, if possible, a little liquid ammonia applied.

FIG. 4.—Apparatus used in preparing hydrogen.

(2) Do not hold the bottle in which the hydrogen is being prepared in the hands during the experiment.

(3) Never pour water into the acid. Always pour the acid into the water.

(4) Always stand back when you light the hydrogen. It sometimes explodes so violently as to break the bottle.

(5) Even when all of these precautions are observed the bottle may break, because it becomes so highly heated. Better set it in an earthen dish to catch contents, should it break. Never put acid in an ordinary metal dish. It will destroy most metals.

EXERCISE 10.—TO TEST FOR HYDROGEN.

Light a match and hold it close over the mouth of the bottle in which the hydrogen is being prepared. The hydrogen explodes with a puff and may take fire and burn with a nearly colorless flame at the mouth of the bottle. This is a test for hydrogen. Like oxygen and nitrogen, it is colorless, tasteless, and invisible.

Should the gas take fire at the mouth of the bottle, hold a piece of cold glass over the flame. Little drops of water will soon appear on the glass, showing that when hydrogen burns (i. e., unites with oxygen under the influence of heat) water is formed. The observation should be made before the flame has had time to heat the glass, otherwise there will be no condensation of moisture on the glass.

Exercise 11.—To Prepare Potash.

Potash is easily prepared from wood ashes. Pour 2 or 3 quarts of water over a pan half filled with wood ashes and stir water and ashes together thoroughly. Set aside for a time and stir again. Repeat this several times, in order completely to dissolve the potash contained in the ashes. When the ashes have finally settled, pour off the clear liquid on the top into another vessel, set it on the stove, and evaporate to dryness. The dry, white substance found on the bottom of this dish is potash. A little of it dissolved in water will make the water feel soapy. This "soapy feel" is a test for alkalis, to which group potash belongs. Repeat this exercise after Exercise 24 has been performed, and test the potash with litmus paper.

Exercise 12.—To Prepare Phosphoric Acid.

Phosphoric acid, uncombined with other elements, is very difficult to obtain. For illustrative purposes, crude phosphoric acid may be easily prepared from bones by burning them to whiteness. Burned bone is practically a combination of phosphoric acid and lime. The lime may be removed by placing the burned bone, finely pulverized, in a bottle, covering it with water, and adding a small quantity of sulphuric acid. The lime will combine with the sulphuric acid and settle to the bottom and the clear liquid above it will contain the phosphoric acid. This is a very simple way to prepare it, and the liquid is sufficiently pure for illustrative purposes.

Exercise 13.—To Test Stone for Lime.

Break off a piece of stone as large as a hickory nut and pulverize it by pounding it with a hammer. Make a very fine powder, put the powder in a glass, cover it with water, and add a small quantity of sulphuric acid.[a] If the stone is a limestone, little bubbles of carbonic-acid gas will come off. Test it with limewater. If no gas comes off, the stone contains little or no lime.

Exercise 14.—To Prepare Lime.

When a stone is known to contain lime it may be converted into the kind of lime used by builders by burning it in a stove for a day or two. When thoroughly burned take it out and make some limewater from

[a] Observe the precautions noted on page 8 regarding the use of acids.

it as directed in Exercise 2. Test this limewater by tasting it and by blowing carbonic-acid gas through it from the lungs.

EXERCISE 15.—TO MAKE A COLLECTION OF PLANT FOODS.

It is a good plan to illustrate all plant foods by making a collection of them. Each substance should be placed in a separate bottle and properly labeled. Lime, oxid of iron (iron rust), soda, and silica (sand) are very easily obtained. Magnesia and ammonia can be purchased at any drug store. A few cents' worth of each will suffice. Vinegar is the commonest kind of acid. A small vial of this will serve to illustrate acid. Carbonic-acid gas has been studied and sulphuric acid is to be found with your supplies. The three essential fertilizers—nitrogen, phosphoric acid, and potash—have already been pre-

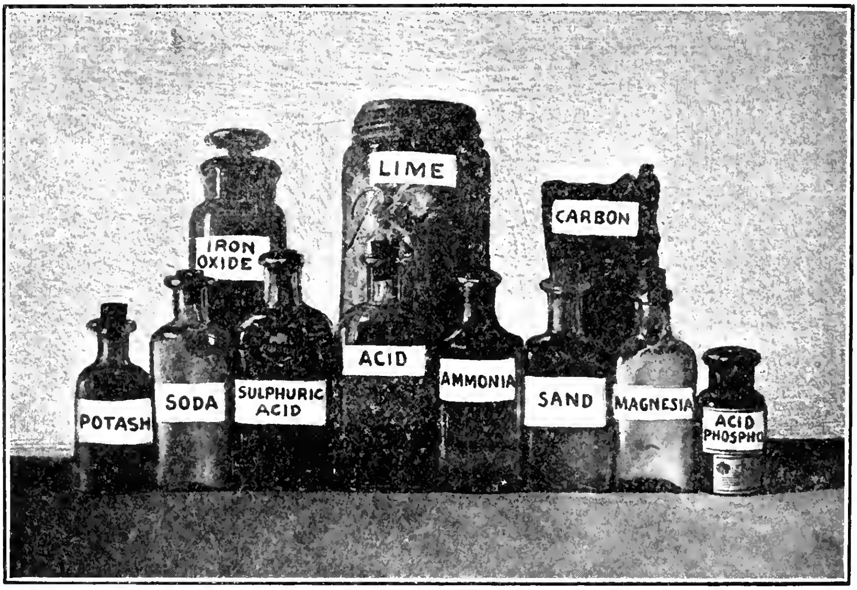

FIG. 5.—A collection of plant foods.

pared. Saltpeter (potassium nitrate) is a good example of soluble nitrates (see fig. 5).

Pupils should be encouraged to handle the plant foods until they become perfectly familiar with them and can readily recognize each at sight.

PLANT PRODUCTS.

From 10 to 90 per cent of the entire weight of the plant is water and from 1 to 10 per cent is ash. These amounts vary so widely that it is hardly possible to find an average. In a very general way we may say that plants contain about 50 per cent of water and about 2 per cent of ash. The remainder is composed of a variety of plant products, chief of which are starch, sugar, oil, protein, fiber, and cellulose. All of these except protein are composed of exactly the same elements—carbon, oxygen, and hydrogen—combined in different proportions.

Protein contains (in addition to hydrogen, oxygen, and carbon) nitrogen, sulphur, phosphoric acid, and sometimes other soil elements. It will be observed from their composition that none of the plant products named, except protein, make any demands upon the soil. The plant gets its carbon from the carbonic-acid gas of the air and its hydrogen and oxygen from water. Out of these three elements it makes starch, sugar, oil, cellulose, and plant fiber.

The difference between fiber and cellulose is very slight. By plant fiber we usually mean those threadlike tissues, like cotton and flax, which are easily separated from the plant in fibrous threads. Cellulose constitutes the essential part of the solid framework of the plant.

If the plant be dried, pulverized, and boiled in water to which a little acid is added and then in water to which potash is added, the starch, sugar, oil, and protein will be dissolved out and only the indigestible fiber and cellulose will remain.

By making use of the exercises which follow, the teacher may show that the products named above are to be found in plants.

Exercise 16.—To Test for Starch.

Stir a pinch of starch into a little hot water. Dip a clean splinter into the iodin bottle, and a drop of this substance will adhere to the end of the splinter. Stir the starch water with the moistened splinter and it immediately turns blue. This is a test for starch. Iodin always turns starch blue, the intensity of the color varying with the amount of starch present.

If seeds be pulverized and boiled in water the starch in them will be separated out. If the water in which the seeds have been boiled be treated with iodin in the way in which the starch water was treated, the presence of starch will be shown by the blue color. It is a good plan to use a white earthen dish for this experiment, as the white background makes it easy to see the slightest blue color.

Another test for starch is made by dipping a cloth into the water in which the pulverized seeds have been boiled, afterwards drying and ironing it. The presence of starch is indicated by the increased stiffness of the cloth.

Test potatoes, corn, beans, oats, and other seeds for starch.

Exercise 17.—To Test for Sugar.

There is no easy chemical test for sugar, though its presence in seeds and other parts of the plant is easily detected by the taste. The slightest sweet taste indicates the presence of sugar in some form.

Test rye, wheat, sweet corn, pumpkin seeds, and root crops for sugar.

Exercise 18.—To Test for Oil.

If seeds containing oil be crushed on a piece of clean white paper, a grease spot will appear. Should this test fail to show oil, place the crushed seeds and paper on a tin plate in a moderately warm oven. Care must be taken not to scorch the paper. The high temperature will drive out the oil, and its presence will be indicated by a grease spot on the paper.

Test nuts and small seeds for oil.

Exercise 19.—To Test for Protein.

The white of egg is the best example of protein that can be easily obtained. The test for this compound is somewhat complicated, but if the directions here given are carefully followed there should be little difficulty in securing the characteristic reaction. Prepare first a 10 per cent solution of caustic potash by dissolving a stick of caustic potash (about $\frac{1}{5}$ ounce) in a 2-ounce bottle of warm water. Care should be taken in handling caustic potash not to touch it to the fingers or clothes, as it is very strongly alkaline and will eat through the skin or the clothing. Secondly, dissolve a piece of copper sulphate (bluestone), about $\frac{1}{2}$ inch in diameter, in a 2-ounce bottle of warm water.

Pour a small quantity of white of egg on a white pie plate or sauce dish and cover it with a portion of the caustic potash solution. Warm the dish, but be careful not to cook the egg. Over this pour a little of the copper sulphate solution and stir with a clean splinter. At first the only color perceptible will be the greenish-blue of the copper sulphate, but after ten or fifteen minutes a bright violet color will begin to appear and spread through the solution wherever there is white of egg.

Test wheat, rye, bran, flaxseed, corn, and other grains for protein. The kernels should be crushed or ground fine and heated for some time in the caustic potash solution before adding the copper sulphate solution. It sometimes takes several hours for the purple color, indicating the presence of protein, to appear. If it does not show during the class period, set aside and examine it at intervals for several hours.

Exercise 20.—To Illustrate Plant Fiber.

Cotton is a good illustration of plant fiber. Flax is another. The fibrous bark of trees like the elm, hickory, and basswood are other good examples.

Pupils should be encouraged to make a collection of various kinds of plant fiber.

PART 2.—THE SOIL.

Soil is sometimes defined as the storehouse for plant food. It is derived mainly from rocks which have been broken down into fine particles by the action of water, air, heat, cold, and other natural agencies. It contains numerous substances which serve as plant food, and numerous minerals which are not considered essential to plant growth, but the composition of different soils varies as widely as the composition of the rocks from which they came. It would be useless, therefore, to attempt to give the composition of an average soil. There is no such thing as an average soil. But there are many substances which chemists have found in nearly all soils, and by taking the average of many chemical analyses we can get a pretty good notion of what we might expect to find in a fertile soil. A table of such averages is given below:

Composition of soils.

	Per cent.
Silica (largely sand)	80.00
Oxid of iron (iron rust)	4.00
Lime	1.00
Magnesia	1.00
Acids (not including phosphoric acid)	.75
Soda	.50
Potash	.50
Phosphoric acid	.15
Nitrogen, in the form of nitrates, seldom exceeding	.10
Other matter sometimes found in plants, but not considered essential to plant growth	12.00
Total	100.00

From this it will be seen that nearly all soil substances are plant foods and that the three essential fertilizers—nitrogen in the form of nitrates, phosphoric acid, and potash—constitute only a very small percentage of the soil.

There are three classes of soluble compounds in the soil—acids, alkalis, and salts. The acids are characterized by their sour taste, and by other properties which will be discussed later. They have already been named. Lime, magnesia, soda, and potash are the principal soil alkalis. The other soluble compounds are called salts. An alkali is a substance having power to combine with an acid, and the product of this combination is a salt. For example, potash is an alkali. If potash be added to a dilute solution of nitric acid, the salt known as saltpeter is formed. If the potash be added in the right amount to exactly neutralize the acid (see "Neutral soils," Exercise 25), the saltpeter may be collected by the evaporation of the solution to dryness in exactly the same manner as in the preparation of potash. Because it is formed from the union of potash and nitric acid chemists have given to saltpeter the chemical name of potassium nitrate. Plants will not grow well in a soil that has too great an excess of either acid or alkali.

Numerous and complex chemical changes, due to the liberation and recombination of acids and alkalis, are continually taking place in the soil.

EXERCISE 21.—TO ILLUSTRATE PLANT FOODS WHICH MUST BE DERIVED FROM THE SOIL.

Select from your collection of plant foods all those to be found in the soil (see Composition of Soils, above). You will observe that this collection includes the entire list with the exception of carbon and the oxygen and hydrogen to be found in water. You will remember that these last three substances go to make up starch, sugar, oil, cellulose, and vegetable fiber. You will also note that the additional substances required to make protein—i. e., nitrogen, sulphur, and phosphorus—are derived from the soil.

EXERCISE 22.—TO ILLUSTRATE ACIDS.

Vinegar is an acid. It is sour. Add a few drops of sulphuric acid to a glass of water. Taste it. It, too, is sour. Add a few drops of nitric acid to a glass of water. Taste it. It is sour. (Be very careful not to use much acid in these tests, as strong acids are very injurious.) The sour taste is an acid characteristic.

EXERCISE 23.—TO ILLUSTRATE ALKALIS.

Lime is an alkali. So, too, are magnesia, soda, ammonia, and potash. Their chief characteristic is that they destroy the properties of an acid by combining with it. To illustrate this fill a glass half full of weak vinegar and slowly add to it limewater, about a teaspoonful at a time, tasting the mixture after each addition of limewater. The sour taste of the vinegar soon disappears—i. e., the solution becomes neutral, or, if more limewater be added, alkaline. The same result will be obtained if soda, ammonia, or potash be added to the vinegar instead of limewater.

EXERCISE 24.—TO TEST FOR ACIDS AND ALKALIS.

Cochineal, a dyestuff made from insects, may be purchased at any drug store. If a teaspoonful of cochineal be pulverized and dissolved in a small bottle partly full of alcohol, it forms a colored liquid called by chemists an "indicator," from the fact that its color depends on the character of the substance in which it is placed. This cochineal indicator is reddish-brown in the presence of an acid, and purplish-blue in the presence of an alkali.

If a few drops of cochineal be added to weak vinegar or any other acid the liquid will assume a reddish-brown color. If the same indicator be added to any of the alkalis—limewater, ammonia, or the like—these liquids will assume a purplish-blue color.

There is a kind of paper called litmus paper, which is red in acids and blue in alkalis. If a slip of this paper be dipped in vinegar or any other acid it turns red. Now, if it be transferred to lye, ammonia, or any alkali, it immediately turns blue.

These are the tests for acids and alkalis. Test lye, soapy water, cream of tartar, saleratus, baking powder, sour milk, lemon juice, or any fruit juice for acids and alkalis by the use of litmus paper or the cochineal indicator.

Exercise 25.—To Test for Acidity and Alkalinity of Soils.

Boil a sample of the soil to be tested in a small quantity of water, allow it to settle and, when perfectly clear, pour off the clear water into a white dish and test it with both blue and red litmus paper. If the soil was acid blue litmus paper will turn red; if it was alkaline red litmus paper will turn blue. Allow a little time, 5 or 10 minutes, if necessary, for the litmus paper to change color. If litmus paper is not at hand test with cochineal.

Neutral soils—that is, those which are neither acid nor alkaline—will have no effect upon the color of either indicator, the paper or the cochineal.

Exercise 26.—To Show that Lime will "Sweeten" a Sour Soil.

Take a can partly full of moist soil known to be acid. Test it to make sure. Stir into the soil a small handful of slaked lime and test as in Exercise 25. If it still shows acid repeat the addition of lime until the litmus or cochineal shows by the blue color that the soil is alkaline.

Exercise 27.—To Show that Wood Ashes will "Sweeten" a Sour Soil.

Secure an acid soil, test, and add to it wood ashes instead of lime, conducting this experiment exactly as in the preceding exercise. When the soil is "sweet"—that is, when the acid has been completely neutralized by the alkali—both litmus and cochineal will show blue color.

EXERCISE 28.—TO SHOW THAT IRRIGATION WITH UNDERDRAINAGE WILL REMOVE ALKALI FROM THE SOIL.

The alkali soils of the West are made fertile by running water on them from the top and draining it off from the bottom through tile drains. To show that this method removes alkali, prepare an alkali soil by mixing soda or potash with dry, sandy soil. Place this alkali soil in a tin can with holes in the bottom, through which the water may escape. Set this can in another dish, pour water on to the soil from the top, and test that which drains through by the use of litmus or cochineal. A blue color of the indicator produced by this drainage water shows that the alkali is being washed out of the soil.

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