#2000 CHEMICAL COMPOSTION OF THE SOIL

Science First

The objective of this kit is to introduce students to the chemical composition of soil. Using local samples of soil, students can perform a series of tests to detect the presence of the major chemical components of interest to geologists and biologists. The following tests can be performed using the materials provided: (1) the moisture content of the soil; (2) the organic content of the soil; (3) the pH of the soil; (4) tests to detect the presence of nitrates, carbonates, sulfates, phosphates, ammonium, calcium, potassium, magnesium and iron. Enough materials are included in the kit for a class of 30 students working in pairs. At least three classroom periods are required to complete the suggested studies.

Contents:

- LabForms (15)
- Metal Cups (15-30 ml cups)
- Plastic Cups (15-30 ml cups)
- Pipettes (eyedroppers) (15)
- Plastic Spoons (15)
- Forceps (2)
- Labels (48)
- Acetic Acid Solution, 25% (1-30 ml bottle)
- Ammonium Oxalate Solution (1-30 ml bottle)
- Hydrochloric Acid Solution 1M (1-30 ml bottle)
- Sodium Hydroxide Solution (2-60 ml bottle)
- Magnesium Reagent (1-30 ml bottle)
  - Titan Yellow
  - Ethanol
- Phosphorus Reagents (2-30 ml bottle):
  - Ascorbic Acid (dehydrated)
  - Ammonium Molybdate
- Test Papers:
  - Universal pH (1 vial)
  - Nitrate (15 strips)
  - Ammonium (4 strips)
  - Iron (4 strips)
  - Potassium (4 strips)
  - Sulfate(15 strips)

- Teacher Manual (1)
- Student Instructions Master (1)

Additional Required Materials:

- Soil samples or equipment for soil collection
- Test tubes and racks
- Stoppers for test tubes
- Source of tap water
- Distilled water
- Scissors
- Oven or Hot Plate
- Balance
- Safety Glasses
- Protective Gloves
- Magnesium Reagent (1-30 ml bottle)

REFILLS:

Solutions: TSS part no. 2000-SOL
"Solutions for 2000 Kit"

Test papers: TSS part no. 700089G-2000
"HDW, TEST PAPER"

Chemical Composition of the Soil #2000 Teacher Manual

Introduction:

All life on earth depends on a thin layer of soil, a complex mixture of organic and inorganic components. It is the mixture of these components in the right proportions that makes soil fertile and useful. The absence of certain materials can be corrected by using fertilizers and soil additives. An understanding of soil chemistry is very important to the fields of forestry and agriculture. Soil offers a unique opportunity to examine the interaction between living things and their environment. Soil supports an incredible variety of microbial, animal and plant life. All of the organisms that live in or on the soil interact with the chemical components of the soil. Organisms are influenced by their chemical environment, and they also determine to some extent what that environment will be.

The activities in this kit present a comprehensive, qualitative analysis of the chemical composition of soil. Using local samples of soil, the student performs a series of tests to detect the presence of the major chemical components of interest to geologists and biologists. Students may compare the results obtained from different types of soils found in their area.

The kit illustrates well the concept of soil as a complex medium, thus making it suitable for supporting a variety of life forms. While no previous exposure to geology is needed, the student should have some experience with the names of various elements and their symbols.

Background Information

Soil can be defined as a mixture of inorganic and organic material - rock fragments and organic debris. Rock particles range in size from microscopic (clay) to large stones; organic debris is the result of the decomposition of plant, animal and microbial material. The relative proportions of these components determine the properties of the soil.

Because of its porous nature, soil can retain water. Each type of soil has a maximum amount of water that it can hold called its "field of capacity". At any given time, except after a heavy rain storm, most soils contain less than the field capacity amount of water. The interactions of sunlight, vegetation, temperature, and wind, greatly influence the soil's water content at any given time. If a sample of soil is air dried at room temperature, its physical appearance changes. The soil may be crumbled easily and appears lighter than it did when moist. There is still a fair amount of water contained in the apparently dry soil, however, most of it as waters of "hydration" surrounding individual soil particles.

Under normal circumstances, there is a distinct film of water surrounding each soil particle. Dissolved in this water are various molecules and ions. These materials can undergo chemical reactions with each other, or they may be absorbed by the roots of plants. Listed below are some of the more important materials found in the soil, and in the film of water that is so essential to the properties of the soil.

Organic Materials

The organic materials in the soil are derived from the wastes and remains of plants, animals and microbes that live in and on the soil. These compounds are listed first, simply because there are so many different types of materials in this category. Simple molecules such as sugars and amino acids may be found along with extremely complex and large molecules, such as cellulose and various proteins. These organic nutrients serve as raw materials for the decomposers that live in the soil, and are also used by plants. The larger molecules are important to the drainage and aeration of the soil.
Organic materials bind rock fragments together into various types of aggregate particles. The general properties of these aggregations are referred to as the "crumb structure" of the soil.

Hydrogen Ions (H^+)

The acidity of soil is determined by the relative amounts of hydrogen ions and hydroxide ions. The most common way of expressing this is the pH of the soil, defined as the negative logarithm of hydrogen ion concentration. Thus, the lower the pH number, the higher the concentration of hydrogen ions, and the more acidic the soil is.

Many factors determine the soil's hydrogen ion concentration. Some of these factors included the concentrations of other materials in the water, and the amount of water present in the soil. The concentration of hydrogen ions is important to the overall chemistry of the soil. Plants are very sensitive to pH, especially because it affects their enzymes and their transport of materials into and out of the roots. Other materials found in the soil are also greatly affected by the pH. Solubility, ionic equilibria, and the formation of ion complexes are all strongly influenced by pH.

Carbonates $(CO_3)^{-2}$

Carbonates in the soil are derived both from mineral and organic sources. Carbonates are formed by the activity of plants and animals as they release carbon dioxide into the environment. Carbonates also come from limestone and related minerals. Carbon dioxide dissolves in water to form carbonic acid, which, along with bicarbonate ions, establishes a complex equilibrium system with carbonate ions. Because they interact with hydrogen ions, carbonates are important in determining the acidity of soil.

Nitrates (NO_3), Nitrites $(NO_2)^-$, and Ammonium Ions $(NH_4)^+$

The nitrogen cycle is one of the most critical aspects of soil ecology and chemistry. Nitrogen is essential to the formation of all nucleic acids and proteins, the bases of life as we know it. All usable nitrogen is absorbed by plants through their roots. The nitrates, nitrites, and ammonium ions are involved in complex cycles of chemical interconversions performed by various soil microorganisms. The essential ions for plants are the nitrates, which are made through the conversion of atmospheric nitrogen or nitrites by the reaction of various nitrifying bacteria. The ammonium ions represent an intermediate in the cycle, but may also be used by plants.

Nitrates are very soluble in water, and so may be leached out of extremely porous soil. Nitrogen is one of the three principle components of fertilizers, indicated by the first of the three "analysis numbers". Thus a 5-10-5 fertilizer would contain 5% nitrogen (in the form of nitrates and ammonium compounds). The other two numbers refer to the percentage by weight of phosphates and potassium, respectively.

Phosphates $(PO_4)^{-3}$

Phosphates are formed through the breakdown of organic material and various minerals. Phosphorous is essential to the formation of many organic molecules, particularly the nucleic acids. Like nitrogen, phosphorous undergoes a cyclic transport through the ecosystem. Phosphorous, unlike nitrogen, is washed into the sea where it is non recoverable. One of the great problems facing the agriculture of the future will be regenerating the supply of phosphates.

Sulfates $(SO_4)^{-2}$

Sulfates are derived from various minerals, and from the breakdown of organic material. Sulfates are often involved in the formation of complex molecules involving several different ions.
Sulfates are required by plants in the formation of proteins. Because of their usual abundance in the soil, they are not usually of major concern in soil management.

Magnesium Mg^{+2}

Magnesium ions are important to many enzyme systems in both plants and animals, especially the chlorophyll on which all life depends. Magnesium deficiencies are often indicated by yellowish leaves on the plants.

Magnesium is derived primarily from minerals. The level of magnesium in the soil water is very sensitive to pH changes. Alkaline soil prevents the dissolving of sufficient magnesium for the plants, which is why brackish or alkaline soil causes yellowing in plants.

Potassium K^{+}

This ion is required by plant root systems to maintain their transport mechanisms. Potassium is important to many systems in animals as well, especially the nervous system. Potassium is a major component of most fertilizers, since it is easily leached from the soil.

Calcium Ca^{+2}

Calcium, like magnesium, iron, and other ions, is involved in a number of enzymatic systems. Calcium usually acts as a co-enzyme. Many minerals contain calcium, so it is usually found in sufficient concentration in the soil. Calcium, sulfate, phosphate, and carbonate ions act together in a complex equilibrium system.

Iron Fe^{+2}, Fe^{+3}

Iron, manganese, boron, and cobalt are several of the so-called trace elements. These elements are derived from minerals in the soil and underlying rocks. Usually, they act as co-enzymes in various organic reactions. Most plants require certain minimum concentrations of these materials, but if the soil is properly managed, and is not subject to extensive erosion or leaching, these elements will recycle themselves.

Analysis of soil chemistry is an important aspect of agricultural science. The ability of the soil to support particular crops depends on the correct balance of chemicals in the soil. Many areas have access to field stations of the U.S. Department of Agriculture, which will provide information about local soil conditions, and will often perform detailed chemical analysis of soil samples.

Using the Kit in the Classroom:

This kit is designed to be used by secondary level students in biology, earth science, ecology, and physical science courses. It allows the student to perform a chemical analysis of soil. While performing this analysis, the student learns something of the importance of the various chemical components of soil.

The specific objectives for this kit are:

1. The student will determine the percentage of water in a soil sample. The student shall be able to summarize the importance of water content in the soil, and the limitations of the procedure used to determine water content.

2. The student will determine qualitatively the content of organic material in a soil sample. The student will be able to state the importance and origin of this material.

3. The student will determine the pH of the soil sample, and will be able to classify the soil as acid, neutral, or alkaline. The student shall be able to summarize the importance of pH to the properties of the soil.

4. The student will carry out qualitative measurements for the following compounds: carbonates, nitrates, phosphates, sulfates, ammonium ions, magnesium, potassium, calcium, and iron. The student shall be able to state briefly the probable origin and importance of each of these materials.

5. The student shall be able to compare various soil samples as far as their chemical composition is concerned.

Before using this kit, the student should have some experience with the naming of chemical compounds, and the use of chemical symbols. While not essential, some discussion of the formation of soil is useful prior to the use of this kit. The instructor may wish to consider The Science Source Kit "How Soil is Formed #2600".

Preparing the Materials:

Besides the materials contained in this kit, the following additional equipment is needed:

Samples of soil, or equipment for taking soil samples (coffee cans, bags etc)

Oven or hot plate	Several test tube racks
Pan balances	2 test tubes per team
Distilled water	Stoppers
A source of tap water	Safety glasses & Protective gloves

The ascorbic acid must be prepared before the phosphate test. Add 30 mL of distilled water to the bottle of ascorbate powder and shake until completely dissolved.

Collecting the Soil Samples:

The samples of soil should be taken by mixing together about a cup of soil from each of three or four locations within a one meter radius. The samples should include material from the surface down to about 15 cm deep. Provide your students with coffee cans, bags, or empty milk cartons if you want them to collect their own samples. If you collect the samples yourself, label each container with its location before the students test them.

Several balances, capable of measurements to 0.1 gram, and an oven of some type, are needed for the water determination test. If you do not have access to a drying oven, the school cafeteria may be willing to let you use their oven. Heat the material overnight at a temperature of about 110_C (225_F) or for about one hour at 175C (350_F). As an alternative to this, you may wish to have the students heat the dishes gently on a hot plate for about 5 to 10 minutes. **Be sure to supply safety goggles and suitable tongs for handling the metal cups if you use this method.**

Before using the kit, cut up the pieces of test paper so that each section is about 1x2 cm.

Guide to the Student Materials:

The following schedule allows for completion of the activities in 3 days.

Day 1:
- Prepare water analysis
- Prepare organic analysis
- pH measurements

Day 2:
- Analyze water content
- Analyze organic content
- Prepare soil extract
- Carbonate test

Day 3:
- Perform other chemical tests
- Discussion questions

The student begins the activity by collecting a sample for use by his team. Discuss the origin of the soil samples. Encourage your students to speculate on the potential differences between the different soil samples being tested. Indicate the storage location for the samples and for the various materials that will be needed.

The ***water content*** of a soil sample is measured by weighing out a sample of fresh soil, subjecting the soil to intense drying, and then weighing again. The difference in the weights is used to determine water composition as a percentage of the total original weight. Some students should comment that the condition of the soil at the time of the sampling will affect the results. Suggest that students develop a standard procedure, such as saturating the soil first, or air drying the soil at room temperature, then heating it.

The test for ***organic material*** depends on the fact such materials dissolve in alkaline solution. Large organic molecules appear dark in color when dissolved. The color of the supernatant liquid will vary from a light yellow with low organic matter to a dark brown for high organic matter. You may wish to have samples of "rich" and "poor" soils to compare their reactions to this test. Encourage the students to compare their reactions to this test. Encourage the students to check each other's results to develop the rating system called for in the written materials.

The test for ***soil pH*** involves the use of universal indicator paper. Soil pH is usually tested with fluid reagents on a white porcelain plate, but the method used here gives a reading of soil pH accurate to within a single pH unit. Obviously, analysis of soil for agricultural purposes requires more precise readings than provided by this method. The purpose of this kit, however, is to give the students a general view of soil chemistry. In discussing soil pH, mention different environments that have variations in soil pH, such as bogs, which are very acidic.

The test for carbonates may be done any time, since it doesn't require the preparation of soil extract. The test is based on the reaction between carbonate ions and hydrogen ions:

$$(CO_3)^{-2} + 2H^+ \ \_ \ CO_2(gas) + H_2O$$

If you have a sample of limestone available, demonstrate the bubbling reaction to the students. Limestone is calcium carbonate, and so will give a vigorous reaction. Alternatively, give students a sample of "soil" known to contain carbonates. Prepare this by adding a small amount of baking soda to a soil sample, and mixing thoroughly.

In the next section the student then prepares a ***soil extract*** to use with the various chemical tests. The presence of the acetic acid will not interfere with the tests themselves. Be sure that the students pour off only the supernatant liquid from the tube, and that the solid material remains in the tube. If you wish, make up test solutions of each of the chemical groups being tested for in the kit to demonstrate the positive reaction.

The ***phosphate*** test involves a complex reaction with molybdate that produces a blue color in solution.
The presence of ***nitrates*** is determined using the specially prepared testing paper. In the presence of nitrate the lower test paper reagent zone turns red. The upper test paper reagent zone (nearer to the holding of the strip) will turn red if the concentration of nitrite(NO_2^-) is high in the sample.

The test for ***sulfates*** is determined using the specially prepared testing paper. There are four reagent zones on each test strip. An orange color indicates the presence of sulfate(SO_4^{2-}) in the sample. This is a semi-quantitative measurement since the more reagent zones (from 1 to 4) that turn orange represent a higher concentration of sulfates. If all four test paper reagent zones turn orange, a concentration of >1600mg/L sulfate is indicated.

A testing paper is also used to detect the presence of ***ammonium ions***. In this case, the soil extract is used as is. A brownish yellow color indicates the presence of ammonium.

The ***magnesium*** reaction may be used as a semi-quantitative measurement of magnesium concentration in the soil. The brownish color, which indicates a moderate amount of magnesium, represents a minimum acceptable magnesium level in the soil. Reactions that produce light tan or yellow colors indicate magnesium deficiency.

Potassium is detected using a testing paper. A positive test is indicated by an orange or reddish spot on the paper.

Calcium ions are detected by the formation of a precipitate with oxalate ions. Again, the test is semiquantitative, since the amount of precipitate formed reflects the amount of calcium ion present in the soil extract. This reaction is:

$$Ca^{+2} + (C_2O_4)^{-2} \ \_ \ Ca(C_2O_4) \ \text{(precipitate)}$$

The presence of ***iron,*** both Fe^{+2} and Fe^{+3} ions, is detected with a testing paper. A brownish-red color confirms the presence of iron in the soil. Point out to the students that there are several different trace elements needed by the plants and animals in the soil. Iron is only one of these elements. It is included in the analysis as representative of the trace element's group.

As a final activity, the student is asked to **summarize the results** of his analysis, and to compare those results with the others. You may wish to prepare and hand out a table similar to the one on page 7 of the student materials. Have several columns for the students to record the results from different soil samples. Alternatively, draw the summary table on the chalkboard.

Further Topics for Discussion:

After completing the activities in this kit, you may want to pursue some of the following topics:

1. Have the students investigate soil management. Contact field stations of the U.S. Department of Agriculture, nearby nurseries, or local colleges. Discuss topics such as soil testing, sampling procedures, the use of fertilizers, and relationship between vegetation and soil chemistry.

2. Have the students study ways in which soil is formed. Stress the relationship between these processes, and the presence of various materials in the soil. The Science Source Kit, "How Soil is Formed #2300" may be useful here.

3. Discuss the various nutrient cycles, and their relationship to the soil's chemistry, particularly, the water, carbon, and nitrogen cycles.

4. Analyze several different types of soils. Expand the analysis to include particle size distribution and soil profiles. Have the students prepare summaries of differences in soil types in your area.

5. Discuss various aspects of life in the soil. Many microorganisms, particularly bacteria that produce and consume nitrogen, are critical to the balance of soil chemistry. Discuss the involvement of plants in utilizing, depleting and replenishing various materials.

Chemical Composition of Soil #2000 Student Instructions (Annotated)

If you look at handful of soil, you'll find that it's a very complex material. Within the soil are many different types of rocks and mineral fragments, as well as material from living things. The combination of all these materials gives the soil its properties. You are going to analyze a sample of soil to determine what materials it contains, and why they are important.

Obtain a metal cup and a plastic spoon. Use a pencil or a marker to label the cup with your name and your partner's name. Get a sample of soil to use in the activities. Your teacher may have already collected the sample for you. If not, collect the sample yourself. Store the sample in a can, bag, or box. Select an area for sampling, then collect scoops of soil from several different points in the area. Don't include large rocks or pieces of plants in your sample. Be sure to take soil from the surface and from several inches below the surface. When you have about two cups of soil, mix it well with your hands or a stick.

Water Content

Choose a metal cup and weigh it. Record this weight on your data sheet. Partially fill the small metal cup with soil and bring it to your lab station. Using a balance, weigh the metal cup and soil. Record those values on the data sheet below. Place the cup and soil in an oven overnight to dry the soil thoroughly. Be extremely careful that you do not spill any of your sample from the cup. Your teacher may tell you to heat the metal cup on a hot plate for 5 minutes. Weigh the cup and soil again and record this weight on your data sheet.

Data Sheet: Water content of soil

1. Weight of empty cup ____________________ grams
2. Weight of cup + fresh soil ____________________ grams
3. Weight of cup + dried soil ____________________ grams
4. Weight of fresh soil (#2 - # 1) ____________________ grams
5. Weight of dry soil (#3 - #1) ____________________ grams
6. Weight of water lost (#4- #5) ____________________ grams
7. % of water in soil (#6/#4x100) ____________________ % (percent)

What are some factors that might change the results of this experiment?

(Whether or not the soil sample had completely dried with the heating, and how dry the soil was at the beginning of the experiment. If it had just rained, the soil would be wetter and would contain more water.)

Organic Matter:

Mark your name and your partner's name on the side of a test tube. Add one level scoopful of fresh soil to the tube. Save the rest of the soil for later use. Add 3ml (~ 75 drops) of sodium hydroxide solution to the tube and 3ml (~ 75 drops) of water. Stopper the tube and shake well. then leave it in a test tube rack overnight.

On the following day, observe the tube, and notice that the solid material has settled to the bottom. Describe the color of the liquid above the solid:

(Reddish brown, but transparent)

Organic molecules, like proteins, fats, and sugars dissolve in sodium hydroxide solution, and cause the color to darken. A pale yellow color indicates a small amount of organic material, while an orange or brown color shows the presence of large amounts of these materials. Try to rate the color of your test solution and indicate the relative amount of organic material present. Use a number from 0 to 5, and compare your results with those of other lab groups. Rinse out the test tubes and save them for later use.

pH (acidity)

Scientists measure the acidity of the soil in terms of pH. A sample of soil can have a pH value from 1 to 14. The lower the number, the more acidic the soil is. A pH of 7 is considered neutral. pH is very important to plants and animals that live in the soil, since most of the cells in living things are very sensitive to pH. A small change in the pH of the soil can make a big difference in the ways that the plants and animals will behave. For example, if the pH changes from 7 to 8, a plant will have a great deal of difficulty in absorbing enough magnesium through its roots.

To test pH, take a strip of pH indicator paper from the vial, place one scoopful of soil in the center cup of the Lab Form, and add water with the pipette until the soil is just saturated. Add 5 drops more and let the water sit for 20 seconds. Tilt the Lab Form so the excess water runs into one of the small tubes near the edge of the Lab Form. Dip the piece of test paper into the water, and compare its color with the colors on the package that the test paper came in. Record the pH number that corresponds to the color on your piece of test paper.

Preparing a Soil Extract:

You now need to prepare what is called a soil extract. Add one level scoopful of dried soil to a clean test tube. Add distilled water to the tube until it is 2/3 full. Add 2 drops of the 25 % acetic acid solution to the soil extract. **(CAUTION: Do not allow this material to contact your skin. Rinse immediately with water.)** Stopper the tube and shake well for about a minute, then let it sit in a test tube rack overnight. Be sure it's labeled with your name!

After the soil extract has set overnight, carefully pour off the liquid in the tube into plastic sample cups. This liquid contains the various minerals that were present in the soil. The acetic acid helped to dissolve some of the minerals, but it won't interfere with any of your tests.

Nitrates:

Nitrates are needed by living things to make proteins, and other important parts of cells. They dissolve in water and are easily washed away by rain. Therefore, fertilizers are used to replace the lost nitrates in the soil.

Obtain a piece of nitrate testing paper. Add ten drops of soil extract to one of the tubes of the Lab Form. Dip the reagent end of the test strip briefly (1-2 seconds) into the soil extract sample. Remove and after 60 seconds observe and record your results. In the presence of nitrate the lower reagent zone turns red. The upper reagent zone may turn red indicating the presence of nitrite.

(The lower zone of the test paper does show a red color, so nitrates are present. The upper zone shows a red color, so nitrites are also present.)

Carbonates:

These ions are found in many minerals, and are also produced from carbon dioxide gas. Add one half scoop of dried soil to one of the tubes in the Lab Form. Add 10 drops of hydrochloric acid solution to this. **(CAUTION: Do not allow this material to contact your skin. Rinse immediately with water.)**
The formation of bubbles indicates that carbonates are present in the soil. Record your observations.

(A very small amount of bubbling activity was present. Other groups seemed to get more. Our soil had a low concentration of carbonates.)

Phosphates:

Phosphates are very important to plants and animals. They're part of many important molecules in all cells. Phosphates are often lacking from soil, and must be added with fertilizer.

Add 100 drops of the soil extract to a clean tube of the Lab Form. Add 20 drops of each phosphorous reagent; first the ammonium molybdate solution, then the ascorbic acid. Swirl the solution gently and wait 5 to 15 minutes. A bluish color indicates the presence of phosphorous in the soil extract; the darker the blue, the higher the amount of phosphate. Record your observations.

(Compared to other groups, we seem to have about an average amount of blue color. It is a medium blue, which indicates a moderate amount of phosphate ions.)

Sulfates:

These are important to the manufacture of proteins by plants. Sulfates are formed from minerals in the soil and from dead plant and animal material. To test for the presence of sulfates, add 20 drops of the soil extract from the plastic cup to a clean tube of the Lab Form. Dip the reagent end of the test strip into the soil extract sample for one second. Shake off the excess liquid from the strip. After two minutes, observe and record your results. A positive indication of sulfates results in 1 or more reagent zones turning orange.

(Compared to other groups, we had all four reagent zones turn orange with this test. Our soil sample contains a high concentration of sulfates.)

Ammonium:

Ammonium ions represent another form of nitrogen in the soil. Some plants and bacteria use ammonium as their source of nitrogen rather than nitrates. Ammonium is another material found in many fertilizers.

To test for the presence of ammonium, add 3 drops of soil extract to one of the tubes of the Lab Form. Add 10 drops of sodium hydroxide solution to this extract. Dip a piece of ammonium test paper into this mixture and note any color change. A brownish yellow color shows that ammonium is present. Record your results.

(Ammonium ions are present since the paper did turn brownish yellow in color.)

Magnesium:

One of the key components of the green pigment of plants is the element magnesium. The pigment, called chlorophyll, allows the plants to capture sunlight and to, make energy for themselves. Plants that do not receive enough magnesium will usually appear yellowish. This is because the chlorophyll cannot form without the magnesium.

To test for magnesium ions, add 20 drops of soil extract to a clean tube of the Lab Form. Add one drop of sodium hydroxide solution and one drop of magnesium reagent solution to the extract. Observe the mixture after 30 seconds. A pinkish cloudy appearance indicates a large amount of magnesium.

A brownish color means that there is a moderate amount of magnesium present. A yellow or a very pale tan color means that the soil lacks sufficient amounts of magnesium. Record your results.

(The color of the solution was pale yellow. This indicates that there is very little magnesium in this soil.)

Calcium:

Calcium ions are needed by many enzymes in plant and animal cells. Calcium is found in many different types of minerals. It is usually present in sufficient amounts in the soil. Minerals such as limestone and marble contain large amounts of calcium.

To test for the presence of calcium in the soil, place 20 drops of soil extract in a clean tube of the Lab Form. Add 2 drops of ammonium oxalate solution to the extract. A white, cloudy appearance indicates that calcium is present. Record your results.

(There is a small amount of cloudiness with this test. This indicates a small amount of calcium in the soil.)

Potassium:

Potassium is another material required by plants, but, like the nitrates, is often washed away by rain. It is a common ingredient in fertilizers. Potassium and sodium are involved in the transport of materials inside the plant. In animals they are important to the activity of nerves.

Obtain a piece of potassium testing paper. Using a pipette, place one drop of the soil extract on the center of the testing paper. Add two drops of the phosphorous reagent to the same spot on the paper. If potassium were present in the soil extract, an orange or red spot will remain on the test paper where the soil extract was Placed. The paper surrounding this spot will turn yellow (an indication of no potassium.) Record your results.

(Potassium was present in the soil. A reddish spot remained on the test paper.)

Iron:

Iron, and several other metal ions as well, are needed by plants in very small amounts. These ions help the plants to carry out certain reactions needed for life and growth. Each type of ion may take part in only one or two reactions in the whole plant. Iron is a typical "trace" element in most soils.

With a pipette, add one drop of soil extract to a piece of iron testing paper. A brownish-red spot indicates the presence of iron. Record your results.

(Reddish-brown spots appeared. This indicates that iron is present in the soil sample.)

Soil Analysis Table:

Summarize the results of your tests by filling in the chart below for your soil sample.

Material	**Results**
Percent water content	______________
Organic material (0-5)	______________
pH(1-14)	______________
Nitrates (present or absent)	______________
Carbonates (high, med, low, none)	______________
Phosphates (high, med, low, none)	______________
Sulfates (high, med, low, none)	______________
Ammonium (present or absent)	______________
Magnesium (high, med, low, none)	______________
Calcium (high, med, low, none)	______________
Potassium (present or absent)	______________
Iron (present or absent)	______________

Questions for Discussion:

Compare your results with those of the other lab teams.

(There are differences in the amounts of various materials that are present in the different soil samples. Some soils have more or less organic matter, magnesium, and phosphates. All of the soils have nitrates, ammonium and potassium.)

What are factors that would determine the total amount of water that a given amount of soil can hold? Why is water content important?

(The size and shape of the soil particles would influence the amount of water that the soil could hold. The greater the amount of porous organic material present in the soil, the more water it can hold. The amount of water which soil can hold is very important to the types of plants and animals that can live on and in the soil. If a soil cannot hold very much water, then plants will need very deep roots to capture enough water.)

Why would a farmer want to know the chemical composition of the soil? Be as specific as you can with your answer.

(Each crop that a farmer would grow has its own set of requirements for chemical nutrients. To provide optimum conditions for each type of plant, the farmer should adjust the chemistry of the soil appropriately. Eventually, the farmer will need to know what crops to plant in sequence to replenish to chemical supplies of the soil.)

What factors might cause the chemical composition of the soil in a particular area to change?

(Man can change soil chemistry, both intentionally with fertilizers and insecticides, and unintentionally industrial runoffs and air pollution. Changes in climate may affect the soil chemistry. Heavy rains will wash away the soluble materials in the soil. This process is called leaching. Erosion and wind storms may also affect the chemistry of the soil, especially by removing critical upper layers of the soil. Plants and animals also affect the chemistry of the soil. New plants and animals in an area add different types of materials to the soil, and will remove others. This may change the balance of the different components in the soil. In the same way, microorganisms may alter the composition of the soil.)

NOTICE TO TEACHERS REGARDING LABORATORY REAGENTS

Perhaps the best general rule regarding the safe handling of laboratory chemicals is to treat all of them as being potentially dangerous. This means that none of them should be taken internally, and that any external contact should be washed thoroughly. In fact, most of the chemicals provided in The Science Source kits are diluted enough that they are not hazardous. The following lists indicate appropriate antidotes for the hazardous chemicals. Check this list for the chemicals provided in the kit:

I. **Concentrated Acids & Bases** - **Do not** induce vomiting, dilute with water, then milk or egg white, call a physician immediately.

1. 25 % Acetic Acid
2. 3M Hydrochloric Acid
3. Concentrated Sulfuric Acid

II **Dilute Acids & Bases** - **Dilute** with water, then milk.

1. 1 M, 0.5M, 0.1 M Hydrochloric Acid
2. Oxalic Acid
3. Sodium Hydroxide
4. Ammonium Hydroxide

III **Miscellaneous Chemicals** - Dilute immediately with water. Induce vomiting with warm salt water, or warm baking soda solution.

1. Ammonium Chloride
2. Ammonium Oxalate
3. Barium Chloride
4. Biuret Reagent
5. Bromthymol Blue
6. Calcium Chloride
7. Ethanol (Denatured Alcohol)
8. Ferric Ammonium Sulfate
9. Hydrogen Peroxide
10. Janus Green B
11. Lead Nitrate
12. Lugol's Solution
13. Magnesium Reagent (Titan Yellow, Alcohol)
14. Mercuric Nitrate
15. Methylene Blue
16. Ninhydrin
17. Phosphorus Reagent (Ammonium Mo1ybdate, Ascorbic Acid)
18. Potassium Ferricyanide
19. Potassium Permanganate
20. Silver Nitrate
21. Sodium Carbonate
22. Sodium Thiosulfate
23. Sudan IV

IV. **Organic Solvents** - **Do not** induce vomiting. Dilute with water and milk. Call a physician immediately.

Chemical Composition of Soil #2000 Student Instructions

If you look at handful of soil, you'll find that it's a very complex material. Within the soil are many different types of rocks and mineral fragments, as well as material from living things. The various combination of all these materials create the unique properties of the different soil types. You will analyze a soil sample to determine the material it contains. You will record your observations and experimental results on a data sheet.

Preparation

Collecting the Soil Sample:

- (Skip this step if your teacher is providing the sample). Get a can, bag or box. Select an area for sampling, then collect scoops of soil from several different points within a one meter diameter. Don't include large rocks or pieces of plants in your sample. Be sure to take soil from the surface and from several inches below the surface. Collect about three cups of soil, mix it well with your hands or a stick
- Observe your sample; squeeze some in your hand. Describe it. Is it damp, dry, grainy, fine, spongy, stiff, slippery, crumbly, etc? Record your observations on your data sheet.

Day 1

Water Content

- Get a metal cup and a plastic spoon from the kit. Use a pencil or a marker to label the cup with your name and your partner's name.
- Weigh the empty metal cup on a triple beam balance and record this weight on your data sheet.
- Add four to five spoonfuls of your soil to the cup, then weigh again and record the value.
- Place the cup and soil in an oven for about an hour at 175_C(350_F) to dry the soil thoroughly. Instead, your teacher may tell you to heat the metal cup on a hot plate for 10-15 minutes.
- Weigh the cup and dry soil, record this weight, then calculate the percent of water in your sample.

<u>What are some factors which might change the results of this experiment?</u>

Organic Matter:

- Label a test tube with your name(s). Add one level spoonful of **fresh soil** to the test tube.
- Add 3ml (~ 75 drops) of sodium hydroxide solution to the sample in the test tube.
- Add 3ml (~ 75 drops) of distilled water to the sample in the test tube.
- Stopper the test tube and, with your thumb over the stopper, shake well. Place it in a test tube rack overnight.

Day 2

Organic Matter (continued):

Organic molecules, like proteins, fats, and sugars, dissolve in sodium hydroxide, resulting in a color change.

- Observe the contents of your test tube and notice that the solid material has settled to the bottom. The liquid layer may be colored. A pale yellow color indicates a small amount of organic material, orange, a moderate amount an d brown a large amount. Try to rate the color of your test solution using a number from 0 to 5. Record your observations.

Compare your results with those of other lab groups. Is there any relation between the amount of organic matter and the water content of the different samples?

pH (acidity)

Scientists measure the acidity of the soil in terms of pH (pH is the negative logarithm of the hydrogen ion content). The pH scale ranges from very acidic (1) to very alkaline (14) with 7 considered neutral. pH is very important to plants and animals that live in the soil. Small changes in pH can make a big difference in the ways that plants and animals behave. For example, if the pH changes from 7 to 8, a plant will have a great deal of difficulty absorbing enough magnesium through its roots to create chlorophyll.

- Place one heaping spoonful of dried soil into the center cup of the Labform.
- Pipet enough distilled water to just saturate the soil, then add 5 more drops. Let the soil sit for 30 seconds.
- Use the spoon to press the soil to the side of the Labform and release the water.
- Take a strip of pH indicator paper from the vial and dip it into the water. Compare its color with the color chart on the indicator paper container. Record the number that corresponds with the color you obtained.

Carbonates:

These ions are found in many minerals, the most common is calcite. Carbonates are also produced from carbon dioxide gas.

- Add ½ spoonful of **dried soil** into a clean tube in the Labform
- Add 10 drops of hydrochloric acid solution to the tube. **CAUTION: Do NOT let this acid touch your skin. Rinse immediately with water.**

- The formation of bubbles indicates that carbonates are present in your soil. Record your observations.

- Clean your Labform and use distilled water for the final rinse.

Preparing a Soil Extract:

You now need to prepare a soil extract. This acid extract will contain the dissolved nutrients and minerals that are in your soil sample.

- Label a test tube with your name(s). Add one level scoopful of dried soil to the test tube.

- Pipet 8ml of distilled water into the test tube.

- Add 2 drops of the acetic acid solution to the test tube. **CAUTION: Do NOT allow this material to contact your skin. Rinse immediately with water.**

- Stopper the tube and, keeping your thumb on the stopper, shake well for about a minute. Place the test tube in test tube rack overnight. Be sure it's labeled with your name(s)!

Day 3

Soil Extract (continued):

Carefully pour off the liquid in your test tube into a plastic sample cup. This is your soil extract.

Nitrates:

Nitrates are needed by living things to make proteins, and other important parts of cells. They dissolve in water and are easily washed away by rain. For this reason, fertilizers are used to replace the lost nitrates in the soil.

- Pipet 20 drops of soil extract into a clean tube of the Labform.

- Obtain a nitrate testing strip and dip reagent end of test strip briefly (1-2 seconds) into soil extract in tube.

- Remove, and after 60 seconds observe and record results.

- Nitrates are present if lower reagent strip turns red. Nitrites are present if the upper reagent strip turns red.

Phosphates:

Phosphates are very important to plants and animals. They are part of many important molecules in all cells. Phosphates are often lacking from soil, and must be added with fertilizer.

- Pipet 100 drops of the soil extract to a clean tube of the Lab Form.

- Add 20 drops of ammonium molybdate solution, then 20 drops of the ascorbic acid solution. **CAUTION: Do NOT let these reagents touch your skin. Rinse immediately with water.**
- Wait at least 5 minutes for the reaction to occur, but no longer than 15 minutes.
- A blue color indicates the presence of phosphates; the darker the blue, the higher the amount of phosphate. Record your results.

Sulfates:

Sulfates are important to the manufacture of proteins by plants. They are formed from minerals in the soil and from dead plant and animal material.

- Pipet 20 drops of the soil extract into a clean tube in the Labform.
- Obtain sulfate testing strip. Dip reagent end of test strip into the soil extract tube for one second.
- After 2 minutes, observe and record results.
- One or more reagent pads turning yellow/orange indicates the presence of sulfates. The more reagent pads that react positively indicates a higher amount of sulfates present.

Ammonium:

Ammonium ions are another form of nitrogen in the soil. Some plants and bacteria use ammonium as their source of nitrogen rather than nitrates. Ammonium is also found in many fertilizers.

- Place a piece of ammonium test paper into a clean depression in the Labform.
- Pipet 2 drops of soil extract onto the ammonium test paper.
- Add 7 drops of sodium hydroxide solution.
- A brownish yellow color shows the presence of ammonium ions. Record your results.

Magnesium:

Magnesium is the key component of chlorophyll, the green pigment produced by plants. This pigment allows the plant to capture sunlight and to convert it into energy for themselves. Plants which do not receive enough magnesium appear yellowish because they cannot make chlorophyll.

- Pipet 20 drops of soil extract into a clean tube in the Labforn.
- Add 1 drop of sodium hydroxide solution to the extract.
- Add 1 drop of magnesium reagent to the extract.
- Observe the mixture after 30 seconds. A pinkish cloudy appearance indicates a large amount of magnesium. A brownish color indicates a medium amount, and a very pale tan or yellow color means that the soil lacks sufficient magnesium to grow healthy plants. Record your results.

Calcium:

Calcium ions are used by many enzymes in plant and animal cells. Since calcium is found in a number of different minerals, such as limestone and marble, it is usually present in sufficient amounts in the soil.

- Pipet 20 drops of soil extract into a clean tube in the Labform.
- Add 2 drops of ammonium oxalate solution to the extract.
- A white, cloudy appearance indicates that calcium is present. Record your results.

Potassium:

Potassium is another material required by plants. Since potassium, like nitrates, is often washed away by rain, it is also a common ingredient in fertilizers. Potassium and sodium are involved in the transport of materials inside the plant. In animals they are important to the activity of the nervous system

- Obtain a piece of potassium testing paper. Place it in the center well of the Labform.
- Pipet one drop of soil extract onto the testing paper.
- Add 2 drops of the phosphorous reagent to the same spot on the paper.
- An orange or red spot remaining on the test paper where the extract was placed indicates the presence of potassium ions. The paper surrounding this spot will turn yellow, an indication of no potassium. Record your results.

Iron:

Iron, manganese, boron, and cobalt are some of the trace elements needed by plants in very small amounts. Each type of ion may take part in only one or two reactions in the whole plant. Iron is a typical trace element found in most soils.

- Place a piece of iron test paper in a clean depression in the Labform.
- Pipet 1 drop of soil extract onto the test paper.
- A brownish-red spot indicates the presence of iron. Record your results.

Soil Analysis Table:

Summarize the results of your tests by filling in the chart below for your soil sample.

Material	Results
Percent water content	____________
Organic material (0-5)	____________
pH(1-14)	____________
Nitrates (present or absent)	____________
Carbonates (high, med, low, none)	____________
Phosphates (high, med, low, none)	____________
Sulfates (high, med, low, none)	____________
Ammonium (present or absent)	____________
Magnesium (high, med, low, none)	____________
Calcium (high, med, low, none)	____________
Potassium (present or absent)	____________
Iron (present or absent)	____________

Summary and Discussion:

Compare your results with those of the other lab teams.

What are factors which would determine the total amount of water that a given amount of soil can hold?

Why would a farmer want to know the chemical composition of the soil? Be as specific as you can with your answer.

What factors might cause the chemical composition of the soil in a particular area to change?