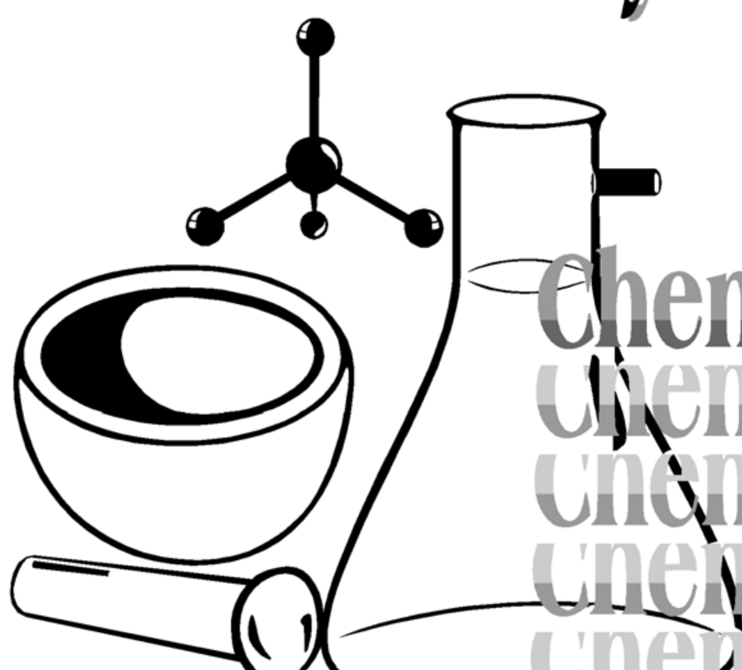
Agri-science Resources for High School Chemistry



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www.gov.pe.ca/educ/resources/agriculture

Acknowledgments

The first edition of *Agri-science Resources for High School Chemistry* was designed as an agriculture learning resource for teachers and students. Through a funding partnership between the agricultural industry, federal and provincial governments, this handbook will be made available to teachers and students in high schools across Prince Edward Island.

The Agricultural Human Resources Council is indebted to student researcher, Ian Johnson B.Sc., for his competence, dedication and creativity.

Appreciation is extended to all our consultants and resource persons. Special thanks are extended to Martha Burka and Shawn Alexander of the Department of Education and Ann McMicken of Text Support Services who was an essential resource to the final preparation of the documents. Sharing of resource materials by faculty members of the Nova Scotia Agricultural College assisted in ensuring that the learning resources were in direct application to the agricultural industry.

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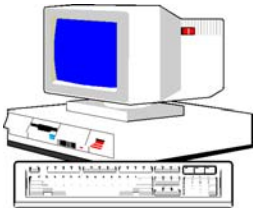


Chemistry

Science

Grade 10-12

Chemistry Classroom
Computer Lab

Teams of 2 or 3

DESCRIPTION

Soil is the top layer of the earth's crust in which organic matter grows. There are many components which determine a soil type such as pH, nutrient level and organic content. These factors can vary depending on the type of plant or crop which grows in the soil and also on geographic location. The best way to determine soil quality is by conducting a soil test. In this exercise, students will learn about soil and some of its components. Groups will collect soil to be analyzed and students will use the Internet to view their results.

READINESS ACTIVITIES

Students should:

- see what types of compounds their family uses to care for their lawn or garden

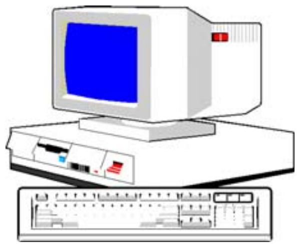
LEARNING OUTCOMES

Students will:

- learn various techniques that are used to modify the quality of soil
- develop computer skills in a soil analysis program
- examine the chemistry involved in soil science

MATERIALS

- Soil sampling bags
- Soil probe or shovel
- Bucket or container
- Sample information sheet



Soil

Gardeners know that you can not grow vegetables just anywhere. The quality of vegetables grown depends on the condition of the **soil**. Soil is the top layer of the Earth's surface that is suitable for plant growth. Soil quality is a major concern for Prince Edward Island farmers because of it's importance to agriculture. Although it is often referred to as dirt or ground, there is a lot more to soil than meets the eye.

pH

One of the most important components of soil is the **pH**. The pH of soil can be modified by adding different chemicals. Soil pH indicates how **acid** or **alkaline** the soil is. The pH scale ranges from 0 to 14. Any substance with a pH near the lower end of the scale is very acidic. Substances in the upper range of the scale have a high alkalinity or are very basic. The pH of a soil is crucial because crops grow best in a narrow pH range which can vary among crops. For example, blueberries and a few types of flowers grow best when the pH is 5.5 or less. Potatoes, a more familiar crop, grow best with a soil pH range of 5.5 to 6.0. Most garden vegetables, shrubs, trees and lawns grow best when the soil pH is over 6.0 or 6.5. The range between 5.5 and 7.5 is favorable for two reasons. It allows sufficient microorganisms to break down **organic matter**. It is also the best range for **nutrient** availability. Organic matter and nutrients will be discussed later. Areas that were formerly covered by trees, such as Prince Edward Island, develop acidic soils. This helps explain how Prince Edward Island farmers can grow the best potatoes in the world.

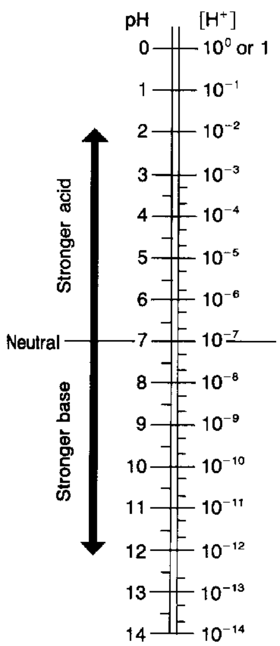
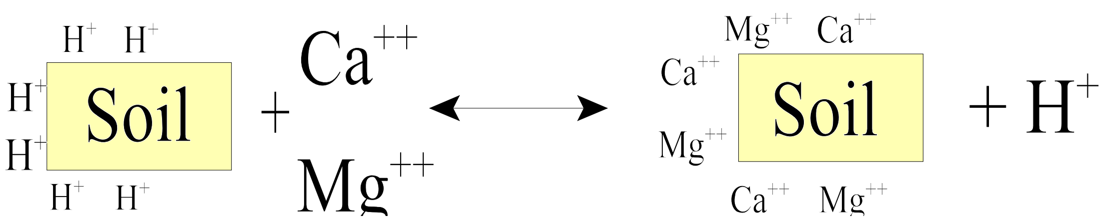


Figure 1. pH scale

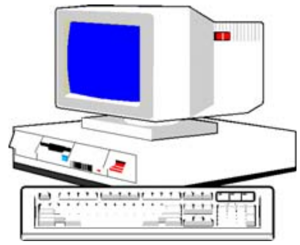
source: Chemistry: International System of Units Edition

Liming

When farmers originally cleared the lands on the Island, the soil quality was adequate for growing potatoes. However, potatoes were not the only crop at that time. Therefore, farmers needed a way to increase the pH of the soil to make it suitable for other crops. The pH of soil can be increased by liming. This is why people sometimes spread white powder on their lawns or gardens. This white powder is **lime**. Calcitic limestone ($CaCO_3$) provides a good source of Calcium (Ca) and helps neutralize soil acidity. Dolomitic limestone functions similarly but also adds Magnesium (Mg). The best limestone will have the greatest calcium and magnesium content and will be ground into very tiny particles. The smaller particles allow the limestone to correct soil acidity more rapidly. The chemistry to liming is quite simple. Hydrogen ions (H^+) are attracted to soil and organic material which have a negative charge. When lime is applied, these hydrogen ions are exchanged for calcium or magnesium (Ca^{2+} or Mg^{2+}) ions which have a greater positive charge. This helps to neutralize the acidity of the soil. The free hydrogen ions are taken out of solution. This also helps to increase the pH. This reaction demonstrates the process of liming:



In some cases, the soil may have very high pH and need to be made more acidic. This can be done by using sulfur, aluminum sulfate, or ammonium sulfate.



Nutrients

Each year the soil undergoes a series of cycles in which materials are added and then taken away. Organic matter and nutrients, in various forms, are constantly being added to the soil. Nutrients are the minerals required by plants to survive. It is very important that plants receive all the required nutrients. There are a total of sixteen elements required for plant growth. Each is required in different amounts. The most important nutrients are called **macronutrients**. Nutrients which are essential, but only needed in small quantities are called **micronutrients**. Carbon, Hydrogen, and Oxygen are the big three macronutrients. These are obtained in almost unlimited amounts from the atmosphere and from the water around the plant. The other macronutrients are nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S). These nutrients should be available for plant uptake from the soil. Micronutrients are obtained from the soil. They are boron (B), copper (Cu), chlorine (Cl), iron (Fe), manganese (Mn), molybdenum (Mo), and zinc (Zn). They are all essential because the absence of any one of these will cause the plant to grow poorly or develop disease.

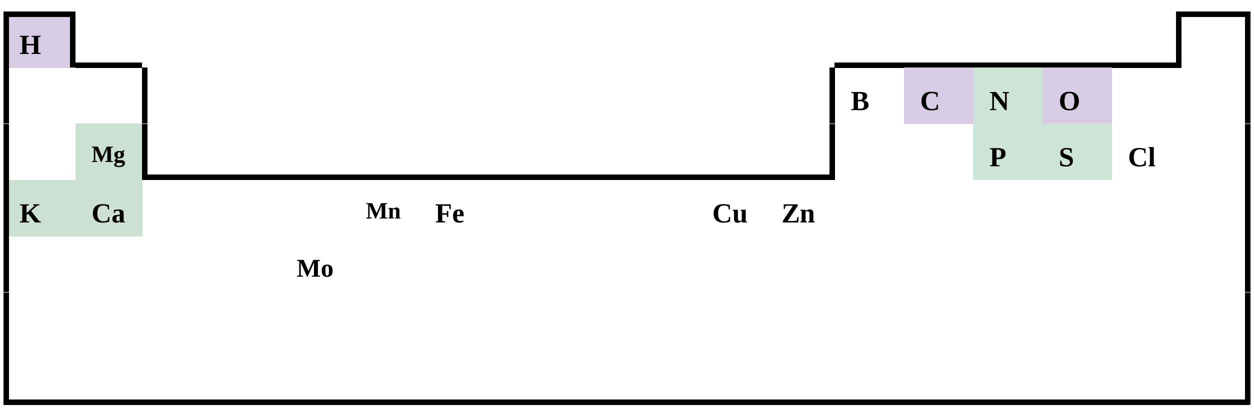
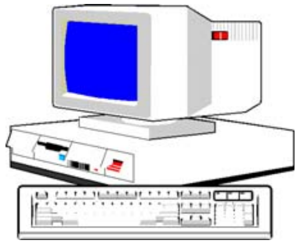


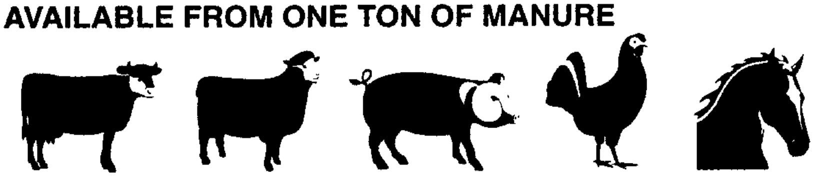
Figure 2. The sixteen essential nutrients indicating their position on the periodic table. The macronutrients are highlighted.



Organic Matter

Many pleasant drives in the country have been affected when the passengers of a car are hit with an unpleasant, but familiar odor. Many people complain about the smell without questioning why it exists. There is actually a very good reason for this practice. Although they are often given more unpleasant names, these animal wastes are known as organic fertilizers. These fertilizers have a very high content of organic matter. Organic matter is simply dead decaying matter that originated from a living source. It prevents nutrients from being lost from the soil by binding these nutrients. Therefore, the best soil for crop production will have a very high organic content. Most organic fertilizer originates from livestock such as cows, pigs, and poultry. Compost is also an organic fertilizer. Compost can be made up of grass clippings, table scraps, ashes, seaweed, and many other types of food products. Organic fertilizers contain high levels of Nitrogen and moderate levels of Phosphorus and Potassium. The nutrient content of organic fertilizer can vary according to the animal that produced it (agriscience text). The process of spreading organic fertilizers gives farmers the opportunity to rid themselves of accumulated livestock waste. It also provides farmers with a free source of fertilizer which is sometimes sufficient to meet the needs of the desired crop. Organic fertilizers are also less harmful to the environment. This may be one of the first recycling practices that ever developed.

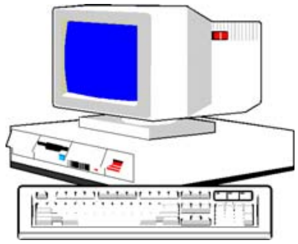
APPROXIMATE AMOUNTS OF PLANT NUTRIENTS AVAILABLE FROM ONE TON OF MANURE



	Cattle	Sheep	Swine	Poultry	Horse
Nitrogen (lb)	10	28	10	30	14
Phosphorus (lb)	5	10	5	20	5
Potassium (lb)	10	25	10	10	14

Figure 3. The nutrients present in manure of different livestock animals.
(Source: Agriscience: Fundamentals & Applications)

Soil Chemistry



Cation Exchange Capacity (CEC)

The **CEC** measures the extent to which soil can hold and exchange plant nutrient cations. The ability of soil to hold positively charged nutrients from being leached and lost from soil is important to maintaining soil fertility. Clay and organic matter have a negative charge. They allow the soil to hold these nutrient cations due to the attraction of charges. Soils with high clay or organic matter content will have a higher CEC. Sandy soils tend to have a lower CEC.

Buffering Capacity

This is the ability to withstand rapid pH fluctuation. The greater the **buffering capacity**, the greater the quantity of acid or base which must be used to alter the pH. Soil types having low buffering capacities include sandy soils with little clay or organic matter. Soils with a higher buffering capacity would have large quantities of mineral clay and organic matter. Therefore, a thick rich soil with a high buffering capacity would require more lime in order to raise the pH.

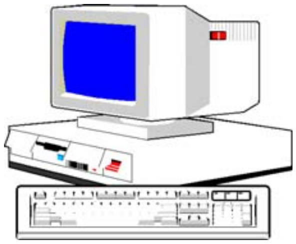
Fertilizer

Fertilizers can replenish the mineral nutrients depleted from the soil by natural means or during crop removal. Most fertilizers contain nitrogen (N), phosphorus (P), and potassium (K). The proportions of these elements are called the fertilizer grade. The fertilizer grade on a bag gives the percentages of each mineral by weight. For example, a bag of fertilizer labeled 10-10-10 contains 10 percent N, 10 percent P, and 10 percent K. In the common 80 pound bag of this grade, you would have 8 pounds of each nutrient. There are a variety of different grades of fertilizer. The cost varies according to the contents. The most appropriate grade of fertilizer depends on the desired crop, and the condition of the soil where the crop will be planted.

Exercise 1

In the following exercise you will need to know the names and formulas of several compounds used in soil chemistry. To determine the formula for the compound, use the following cations and anions:

Soil Chemistry



Agri-science Resources
for High School Sciences

Chemistry

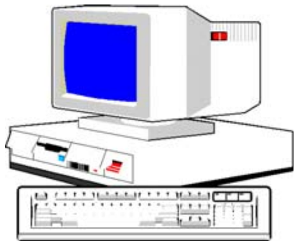
Cations:	NO_3^- nitrate	Anions:	NH_4^+ ammonium
	PO_4^{3-} phosphate		Ca^{2+} calcium
	SO_4^{2-} sulfate		Na^+ sodium
	O^{2-} oxide		K^+ potassium
	CO_3^{2-} carbonate		Mg^{2+} magnesium

Mix and Match

Write the letter next to the statement number which matches it.

__ 1. Calcium sulfate
__ 2. compound that is a good source of nitrogen and increases soil pH
__ 3. because the ions have opposite effects, this compound does not change soil pH
__ 4. contains two of the three nutrients in fertilizer
__ 5. a macronutrient obtained from the soil often often associated with an unpleasant odor
__ 6. a micronutrient which has an atomic number of 29
__ 7. used when soil has a very high pH and needs to be made more acidic
__ 8. macronutrient with an atomic mass of 24.305
__ 9. this compound contains three macronutrients which can be obtained from the atmosphere
__ 10. sometimes referred to as a metalloid
__ 11. potassium sulfate
__ 12. A micronutrient with a charge of - 1
__ 13. magnesium oxide
__ 14. contains both a macronutrient and a micronutrient
__ 15. used to lime acidic fields

a. $CaCO_3$
b. $K_2(SO_4)_2$
c. $Al_2(SO_4)_3$
d. Cu
e. Ca_2SO_4
f. S
g. chlorine
h. MgO_2
i. urea
J. KNO_3
k. Mn
l. calcium nitrate
m. $CaSO_4$
n. B
o. K_2SO_4
p. sodium sulfide
q. potassium fluoride
r. MgO
s. KSO_4
t. Mg
u. KCl
v. $MgSO_4$

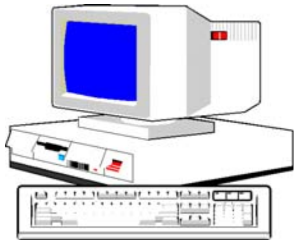


Exercise 2

Soil Test

The best way to learn if your soil needs to be limed or fertilized is by conducting a soil test. A soil test will give you an accurate description of many soil factors, including pH and nutrient levels. For example, if the pH of the soil is low, lime should be used. The amount needed can be estimated by considering the type of soil, the desired pH, and the form of lime that will be used. A soil test will also indicate how much fertilizer to use and the best grade for your soil.

In this lab exercise students will divide into groups of three or four. Each group will take a soil sample either from a group members backyard or a nearby field. The soil will be analyzed at the Soil and Feed Laboratory in Charlottetown. The Provincial Department of Agriculture and Forestry has an Internet program which will each group to examine their results. There are a few questions designed to help understand the program. If there any terms in the program that are unfamiliar, double click the term, and a clear explanation is given.



Taking a Soil Sample

- ✔ You need a pail or ice cream container, a small shovel or spade, and a sample bag.

- ✔ Choose a few uniform spots in the field or yard and take a few small samples from each one. This will give a good representative sample of the test area.

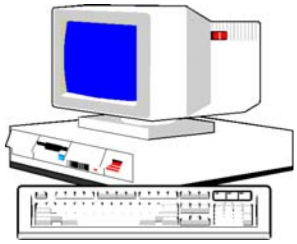
- ✔ The soil should be sampled to a depth of about 6 inches (15cm). You need to dig enough soil for a 500 gram sample (roughly). Try not to include too much grass.

- ✔ Put all the soil samples in the container and mix it thoroughly.

- ✔ Use the soil sample bags provided by the Soils and Feeds Lab of the Department of Agriculture and Forestry. Fill the bag to the indicated level. The instructor will take this bag to the Soil and Feed testing lab in the bottom floor of the Research Station at 440 University Avenue, Charlottetown, Prince Edward Island.

- ✔ The sample will take about three or four working days to analyze. Then you can obtain your results on the Internet by using the username and password issued to you by the Soils and Feeds Lab.

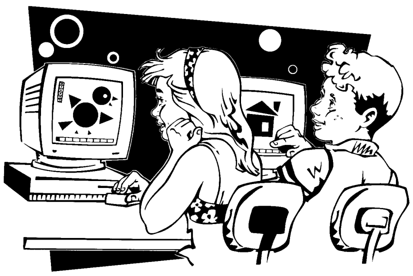
Soil Chemistry



Agri-science Resources
for High School Sciences

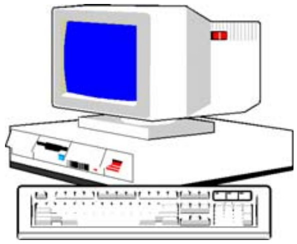
Chemistry

To Gain Access to the Soil Analysis Program:



- ☞ get on the world wide web by connecting to your server
- ☞ Find the Open Location command in the file menu
- ☞ Access the provincial government web site by typing **www.gov.pe.ca/daff/soilfeed**
- ☞ Open the site and the home page should appear. It is titled Soil and Feed Testing Laboratory

The page gives a brief description of the lab itself along with a great deal of useful information. Feel free to click on any subject that interests you. We will be focusing on Soil Testing. To see the results from your own soil sample go to Click here to view your results in the upper right hand corner of the page. Use the username and password that has been given to you to gain access to your file. Remember, we are focusing on soil testing, so you do not have to change anything on the next page, simply click View under Soil Test. Next a table labeled Soil Analysis will appear. This table lists the Date Sampled, an Accession Number, and the Number of Samples. Next you get a choice to click for your data. Begin by clicking View.



Questions

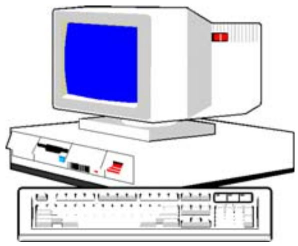
Use the results from your soil sample and the section "How to Interpret your soil test report" on the Homepage to answer the following questions.

1. What is the pH of your sample? Based on the pH value, would the sample area be suitable for growing potatoes?
2. Describe the soil ratings (H,M,L) for P, K, Ca, and Mg. Are any of these nutrients found in higher or lower amounts than the others?
3. Comment on the amount of N, P, and K that the program suggests is required. Based on what you have learned about fertilizer grades, what types of grades do you think would be most appropriate for your sample area?

Part II

The next set of questions apply to the demonstration samples which the Department of Agriculture and Forestry has made available to the public. Access this file with username:1383 and password: warps2stoop. Go to the example with five samples. Enter the View function.

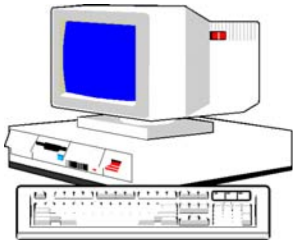
4. Of the five micronutrients shown in the analysis, which is the most abundant in ppm? Which is the least abundant?
5. What is the Cation Exchange Capacity (CEC) of the soil? What does this value indicate in terms of the organic content and texture of the soil? Consult the program if you are not sure.
6. Compare the Percent Base Saturation values to those presented in Table 2; "Ideal % Base Saturation". What values fall into the "ideal" bracket and which ones do not? What else does the % H indicate about the soil?



Next we will use the Fertilizer Fit Function. First, you need to change the crop in the first table to Lawn. This will give a more realistic comparison to your samples. Underneath the table, the ratio of N,P, and K required is given. Skip down to the section Summary of Individual Field Requirements.

7. Of all the listed fertilizer grades listed, which grade has the largest application mass? Which grade has the smallest mass of application?
8. What grade is the most expensive? Which is the least expensive? Are there any trends in the price of fertilizer?
9. You have figured out the fertilizer you need, but when you go to the store, they only have the 10-10-10 grade. How much of this fertilizer will you need and how much will it cost? Use the force fit function.
10. Your parents decide they want to change this lawn into a potato field. You wonder if they have any idea how to do this. You decide to give them some help. Copy the nutrient requirements for an Established Lawn. Now change the crop to potatoes. How have the nutrient requirements changed? What will your parents have to do to the soil if they want to grow potatoes?
11. You decide that if your parents are growing potatoes, you are going to have your own pumpkin patch. What are the different nutrient requirements for pumpkins? Is there much work ahead of you to obtain a prize pumpkin?

This ends the lab on soil. Feel free to play around with the Internet program some more if you would like. Remember, it's free. When you do get your own lawn, hopefully now you've learned how to care for it properly.



Glossary of Terms

acid — material with a pH of less than 6.9

alkaline — material with a pH of more than 7.1

buffering capacity — the ability of the soil to withstand pH fluctuation

CEC — cation exchange capacity is the ability of a soil to hold and exchange plant nutrient cations

fertilizer — material that supplies nutrients for plants

lime — material that reduces the acid content of soil and supplies nutrients such as calcium and magnesium to improve plant growth

macronutrients — elements used in relatively large quantities

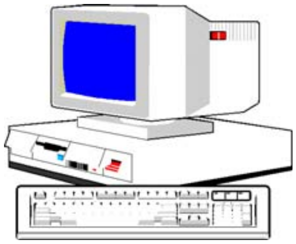
micronutrients — elements used in very small quantities

nutrients — substances necessary for the functioning of an organism

organic matter — dead plant and animal tissue that originates from living sources such as plants, animals, insects, and microbes

pH — measurement of alkalinity from 1 to 14

soil — top layer of the earth's surface suitable for plant life



Answer Key

Mix and Match:

1. m	6. d	11. o
2. l	7. c	12. g
3. n	8. t	13. r
4. j	9. i	14. u
5. f	10. n	15. a

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Agri-science Resources
for High School Sciences

Science

Grade 10-12

Silicate Garden

Chemistry Lab

Chemistry

Individual or teams of 2

DESCRIPTION

Small colorful gardens can be created by adding crystals of various salts to a sodium silicate solution. In this exercise, students will have an opportunity to create these tiny gardens.

LEARNING OUTCOMES

Students will:
- learn the chemistry involved in stalagmite formation

READINESS ACTIVITIES

Teachers should:
- check the availability of the salt crystals required for the exercise

MATERIALS

- commercial sodium silicate solution (water glass)
- distilled water
- crystals of hydrated forms (see instructions)
- small jars or vials, covered or uncovered

Silicate Garden

Agri-science Resources
for High School Sciences

Chemistry

Science involved

When crystals of various salts are added to a sodium silicate solution, colorful plant-like extensions grow from the surface of each crystal. There is actually a lot of chemistry involved in the process. As the salts dissolve, the metal ions combine with silicate ions and form membranes of **insoluble** silicates around the crystals. The inside of the membranes contains lower water concentrations and higher salt concentrations than the outside, so water passes inward by **osmosis**. This causes breaks in the membrane and formation of more membrane surface. The metal dissolves in the water and expands forming **stalagmites**. Growth occurs in an upward direction.

Salt Crystals

These are the best crystals for silicate gardens. Beside the name of each crystal is the color of extension that grows from it.

aluminum(III) chloride ($AlCl_3$) - white
cobalt(II) chloride ($CoCl_2$) - dark blue
chromium(III) chloride ($CrCl_3$) - dark green
copper(II) chloride ($CuCl_2$) - light blue-green
iron(III) chloride ($FeCl_3$) - yellow
tin chloride ($SnCl_4$) - white
dark

iron(II) sulfate ($FeSO_4$) - grayish white
nickel(II) sulfate ($NiSO_4$) - green
aluminum(III) nitrate $[Al(NO_3)_3]$ - white
cobalt(II) nitrate $[Co(NO_3)_2]$ - dark blue
nickel(II) chloride ($NiCl_2$) - light green
chromium(III) nitrate $[Cr(NO_3)_3]$ -
green

Silicate Garden

Agri-science Resources for High School Sciences

Chemistry

Caution

Some of the compounds in this lab are very dangerous when not handled properly. For example:

Aluminum chloride is caustic and can cause burns to the skin
Chromium nitrate is a cancer-suspect agent. Avoid contact or inhalation
Copper compounds are harmful if taken internally. Dust from these compounds can irritate mucous membranes
Nickel salts or solutions can irritate the eyes upon contact. The compounds are toxic if ingested. Nickel salts are suspected carcinogens
Tin(IV) chloride is corrosive and can cause burns to the skin on prolonged contact
Water glass is a strongly alkaline solution and is caustic to skin and mucous membranes

Please handle all materials with care

Procedure

1. Pour the sodium silicate into the vials or jars. It might be a good idea to dilute with distilled water.

2. Choose a variety of different types of crystals to allow the garden to be as colorful as possible. ***Handle all compounds with care***.

3. Drop the crystals of the salts into the solution and distribute them evenly on the bottom of the beaker.

4. The reaction should start to occur almost immediately. Allow it to continue for several days without disturbing the vial.

5. The color of each column is determined by the identity of the salt crystal. Once the garden has grown, the cap can be taken off, allowing the solution to evaporate leaving the crystal garden.

6. Dispose of the garden by flushing down the drain with water.

Glossary of Terms

insoluble	not capable of being dissolved in some liquid
osmosis	tendency of liquids to pass through a porous membrane or partition that separates them
stalagmites	a cone of carbonate of lime which gradually forms a column

Information from

Dr. Nancy Crowe and Dr. Jeff Hoyle
Nova Scotia Agricultural College, Truro, Nova Scotia.

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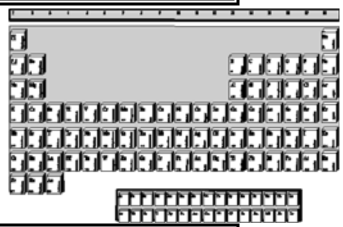
Agri-science Resources for High School Sciences

Corrosion



Chemistry

Science

Grade 10-12

Chemistry Classroom

Individual reading

DESCRIPTION

The characteristic red color of Prince Edward Island soil can be explained by a chemical reaction. The process is known as corrosion or rusting. Just like a car or nails will rust when exposed to the elements, the iron in soil will also rust. This article explains all of the chemical reactions involved.

LEARNING OUTCOMES

Students will:

- examine the great amount of chemistry involved in something as obvious as the color of soil
- discover some methods which are used to protect against rusting

READINESS ACTIVITIES

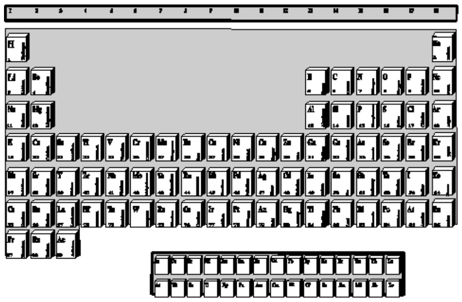
Students should:

- find some objects around home which corrode easily
- find some metal objects which are able to resist rusting

MATERIALS

- copy of article

Corrosion



Agri-science Resources
for High School Sciences

Chemistry

Introduction

Prince Edward Island soil is famous for its red color. Remember “Bud the Spud from the Bright Red Mud”? A well-known chemical reaction is actually responsible for this characteristic color. The actual process is known as **corrosion**. The spontaneous destructive **oxidation** of metals is called corrosion. Corrosion occurs whenever a metal surface is destroyed by being converted to a metal compound. The reaction is actually more complicated than most people think.

Elements of the Earth

Roughly 92 chemical **elements** are known to exist in earth’s crust. Most of these elements have combined with one or more other elements to form compounds known as **minerals**. There are numerous possible combinations of elements and up to 2000 minerals have been discovered. These minerals exist in mixtures which form the rocks of the earth. Relatively few of these elements and minerals are of real importance in soils. Approximately 98% of the earth is composed of only eight chemical elements, most of which is oxygen (O) or Silicon (Si). The most abundant minerals in soils are light in color. If all soils were composed of crushed minerals that had undergone little chemical change they would be light gray. It is obvious that not all soils are gray. The brown, red, and yellow colors of soils are caused by chemical changes in the elements that make up these minerals. Iron(Fe) is the element responsible for the chemical changes that occur in Prince Edward Island soil.

Reactions that cause Rusting

To understand what happens in a field or backyard, the events of corrosion must first be explained. Iron rusts only when there is water and oxygen present. Rust is a complicated material that contains various types of **hydrated** iron (III) oxide, $Fe_2O_3 \bullet xH_2O$. Iron begins to rust at places on its surface where there is an impurity, or where the iron **lattice** has imperfections. At these points some of the iron atoms produce iron (II) ions in the solution:

$$Fe\ (s) \rightarrow Fe^{2+}\ (aq) + 2e^-$$

Here the iron has undergone oxidation. Oxidation is the loss of electrons by ions. As the iron(II) ions move away they meet hydroxide ions and produce iron (II) hydroxide:

$$Fe^{2+}\ (aq) + 2OH^-\ (aq) \rightarrow Fe(OH)_2\ (s)$$

Dissolved oxygen will then oxidize the iron (II) hydroxide producing the substance called rust:

$$Fe(OH)_2(s) + \text{dissolved oxygen} \rightarrow \text{rust}\ (Fe_2O_3)$$

The electrons liberated from the process are taken up by hydrogen ions in the water producing gas. This is a reduction reaction:

$$2H^+\ (aq) + 2e^- \rightarrow H_2(g)$$

For a drop of water on an iron surface, rusting will occur near the edges of the drop. This is because there is more oxygen dissolved from the air near the edges of the drop.

Iron

Iron is the fourth most common element in soil, comprising 5% of the earth's crust. The iron in soil is usually found in the soluble cation form (Fe^{2+}). This reduced form is more common because of the lower levels of oxygen in soil. This ion can be readily absorbed by plants. When high levels of oxygen are present in the air surrounding soil particles, oxidation occurs and the Fe^{3+} form of iron prevails. This form of iron is **insoluble** and therefore not available to plants. Usually in acid soil sufficient Fe^{2+} exists in the soil to meet the needs of plants. However, iron deficiencies are common in **alkaline** soil. The greater concentration of hydroxyl causes the oxidation of iron.

Why the Red Soil?

Iron oxides are responsible for the red soil on Prince Edward Island. It is possible to trace the reactions of iron from the time it is released from rock. Iron olivine is a good example of a rock which contains iron. This iron can be released due to environmental conditions. Weathering of iron olivine leads to hydrolysis yielding iron oxide and silicic acid:

$$Fe_2SiO_4 \quad + \quad 2HOH \quad \rightarrow \quad 2FeO \quad + \quad H_4SiO_4$$

Both of these products are somewhat **soluble** and can be lost be **leaching**. However, in the presence of free oxygen, and when moisture and temperature conditions are favorable for chemical activity, the iron in the soil minerals is oxidized and hydrated into red and yellow compounds. The iron oxide (FeO) is oxidized to only slightly soluble iron oxides such as Fe_2O_3 or its hydrated counterpart $Fe_2O_3 \bullet xH_2O$ (the x indicates that the quantity of associated water can vary). This is oxidation reaction:

$$4FeO \quad + \quad O_2 \quad \rightarrow \quad 2Fe_2O_3$$

Because of the extremely low solubility of these iron oxides, very little of the iron is lost. This results in a characteristic red color of the soil where the reaction occurs.

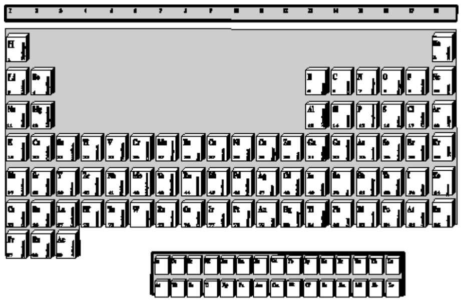
Protection from Rusting

There are a few basic methods for protecting metals from corrosion:

One is to slow down the process. Slowing down the corrosion process is done with protective coatings such as paint or tar. These help to keep out oxygen, water, and **electrolyte** salts. The presence of small salt crystals in the air is the major reason why metal corrodes more rapidly at seacoasts.

Cathodic protection from corrosion occurs when a metal to be protected is coupled with a metal more easily oxidized than itself. Metal fences, sheets, and nails made of iron can be protected by galvanizing them. These materials are coated with zinc and said to be **galvanized**. The galvanized metal will not corrode until after the zinc coating does because zinc corrodes more readily than iron. Instead of Fe^{2+} ions going into solution, Zn^{2+} ions are lost from the zinc. The iron remains unaffected. Tin is also very good at protecting iron and steel. This is especially evident with tin cans. It is more difficult to plate steel with a thin layer of zinc than tin. Also, tin is less reactive than zinc and is less likely to dissolve in the liquids stored in cans. However, tin is not as effective in protection and it will rust if it is holed.

In anodic protection, the metal to be protected is briefly made positive to form a stable oxide film on its surface. The stable **oxide** film then protects the underlying metal from corrosion. Stainless steels form a protective film of nickel/chromium oxides since they have a high content of these metals



Glossary of Terms

alkaline	a basic environment where the pH is greater than 7.
corrosion	the spontaneous destructive oxidation of metals
electrolyte	a compound that conducts an electric current in aqueous solution
element	a substance that cannot be changed into a simpler substance under normal laboratory conditions
galvanized	coated by an electric process with zinc to keep it from rusting
hydrated	a substance that is joined with water to give a compound
insoluble	not capable, or hard to be dissolved in some liquid
lattice	crossed or interlaced network of metal atoms
leaching	a substance is lost from a location due to movement by water
minerals	compound formed from one or more elements
oxidation	a process that involves a complete or partial loss of electrons
oxide	a compound of oxygen with another element
soluble	capable of being dissolved in a fluid

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Agri-science Resources
for High School Sciences

Iron in Cereals

Food Chemistry

Science

Grade 10-12

Chemistry Lab

Teams of 2 or 3

DESCRIPTION

Iron is essential for healthy living and must be obtained from our diets. There are various forms of iron, some of which are more important than others. Because iron is so important for good nutrition, it is often added to some foods. This lab examines the iron content of breakfast cereals.

LEARNING OUTCOMES

Students will:

- actually see an important component of breakfast cereal
- discover the role of iron in the body
- learn several good sources of iron

READINESS ACTIVITIES

Students should:

- read the labels on the boxes of cereal to see the actual iron content

MATERIALS

- about 50 g of ordinary cereal
- mortar and pestle
- plastic coated magnet
- stirrer apparatus
- hand-held magnifying device
- 1000 ml beaker

Iron in Cereals

Agri-science Resources
for High School Sciences

Food Chemistry

Iron

Iron is a very important component of our diets. Humans must obtain the iron they require for growth, maintenance, and cellular division from dietary sources. Heme iron from meat can be absorbed by humans to a greater extent than non-heme iron from inorganic salts or plant sources. Therefore, meats such as beef, pork, and poultry are all excellent sources of iron. Some foods are **enriched** with iron to enable people to get an adequate supply for good health.

World Status

Most Canadians have a good supply of meat in their diets. This is why Canadians have higher iron stores in the body than other more impoverished nations. The World Health Organization (WHO) estimate that 30% of the world's population are **anemic**, of whom 500 to 600 million people suffer from iron deficiency.

Iron Balance

Humans are the only mammals capable of developing iron overload to the point of causing tissue damage. There is a very delicate balance in the body. If more iron is eaten in foods than is **excreted** from the body, iron overload may occur. If not enough iron is consumed in comparison with the amount that is excreted, iron deficiency may result. Therefore, it is very important to eat a well-balanced diet.

Iron in Cereals

Agri-science Resources
for High School Sciences

Food Chemistry

Why we need Iron

The most important roles of iron in the body are in **oxygen transport** and **electron transfer** in **respiration**. Iron binds Oxygen in the blood, allowing an adequate supply of Oxygen to be carried throughout the body from the lungs. Iron is also involved in Immune reactions of the body. If the body does not receive an adequate supply of iron, red blood cells in the body are not as effective at transporting oxygen.

Forms

The form of iron determines the ability of the body to absorb and use the mineral. Some foods have iron in the form of ferrous sulfate ($FeSO_4$) added. The reduced form of iron (Fe^{2+}) is more readily absorbed into our bodies than is the oxidized form (Fe^{3+}). The completely reduced form of iron, elemental iron (Fe_s), is often added to foods and is absorbed from our intestinal tracts. This form of iron is often added to breads and cereals. However, the amount and size of reduced iron that is added is carefully monitored to ensure safety.

In this lab exercise, we will use common household cereal to demonstrate iron content in foods.

Iron in Cereals

Agri-science Resources
for High School Sciences

Food Chemistry

Procedure

1. Before the lab, look at some of the cereals you have in your cupboards at home. The ingredients should indicate that the cereal has reduced iron added. Take about 50 grams of one of these cereals to the lab with you. Remember the name of the cereal because they will be compared later.

2. In the lab, crush the cereal using a mortar and pestle. Place the ground material in a large beaker and add 400 ml of water.

3. Use a plastic coated magnet and stirrer apparatus. The mixture needs to be stirred continuously for several hours.

4. During this time, the iron in the crushed cereal will be attracted to the magnet. Remember, the amount of iron will be very small.

5. After the time has passed, observe the magnet. You should be able to see some small iron filings on the surface. A magnifying device may help if you are having problems seeing them.

Questions

1. You know that 50 grams of cereal were used in the experiment. Based on this, give a very rough estimate of how much iron the sample contained?
2. Compare your beaker with that of your classmates. What cereal appears to contain the most iron?
3. What do you think would happen if the body did not receive an adequate supply of iron?

Agri-science Resources
for High School Sciences

Science

Grade 10-12

Vitamin C

Chemistry Lab

Food Chemistry

Teams of 2 or 3

DESCRIPTION

Humans are one of the few organisms which are not able to synthesize their own Vitamin C. Therefore, we must obtain it in our diets, mainly from fruits and vegetables. Vitamin C is easily oxidized and is therefore a valuable preservative. It has several very important roles in the human body. This exercise will measure the vitamin C content of several fruit and vegetable products.

LEARNING OUTCOMES

Students will:

- practice their titration techniques
- learn the essential roles of Vitamin C in the body
- learn about several good sources of Vitamin C

READINESS ACTIVITIES

Students should:

- go through the cupboards at home and see which foods have Vitamin C naturally and which ones have added Vitamin C

MATERIALS

- burette
- pipettes
- graduated cylinders
- Samples: - various fruit juices such as apple, orange, five alive, etc.
  - water from boiled potato or broccoli
  - juice form fruit or vegetables which have been sitting in the refrigerator for a long time

  (Anything that will give 4 - 5 ml)
- Ascorbic acid standard or vitamin C pill
- Dichloroindophenol dye solution
- Sample preparation solution

Vitamin C

Agri-science Resources
for High School Sciences

Food Chemistry

Vitamin C

Vitamins are complex chemicals essential for normal body functions. There are many complex reactions that occur in the body with vitamins. One essential vitamin that is fairly well known is Vitamin C. Most plants and animals have the ability to synthesize their own Vitamin C from glucose and galactose. Unfortunately, there are species which lack the **enzyme** L-gulonolactone oxidase, which is necessary for the conversion. Guinea pigs, apes, rainbow trout, coho salmon, as well as humans are among this group. These species must obtain the vitamin in their diet.

Sources

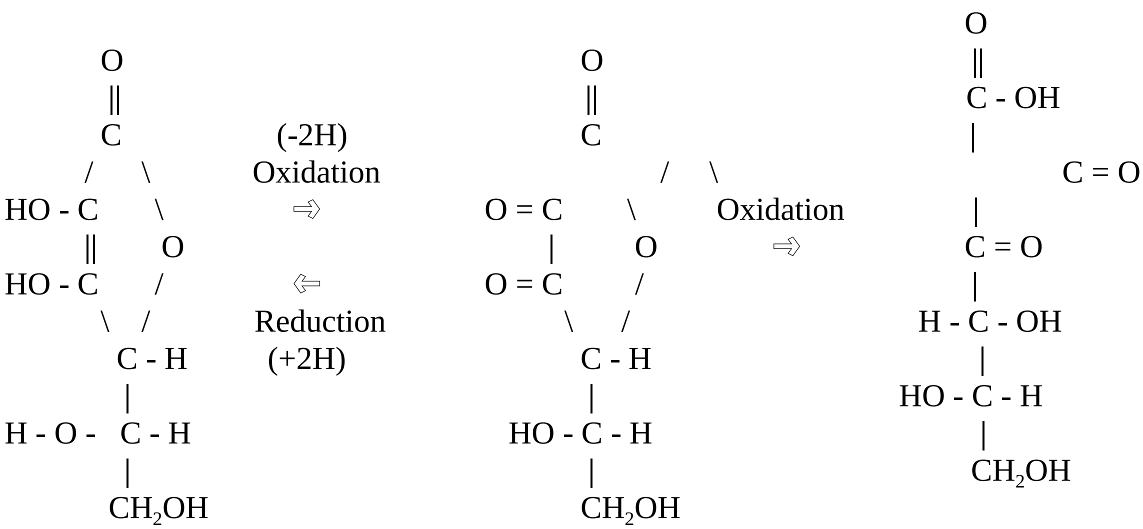
Vitamin C occurs naturally in several foods. Foods of plant origin are rich sources of the vitamin. These include black currants, oranges, lemons, strawberries, kiwi fruit, most green leafy vegetables, and potatoes. The amount of Vitamin C naturally present in plant foods is determined by factors such the part of the plant consumed, and the stage of maturity at the time of consumption. One form of Vitamin C, ascorbic acid, is used as a dietary supplement and chemical preservative. These enriched products often provide an adequate source of Vitamin C in the diet. It is added to soft drinks, meats, flours, fish, cereals, and other fruit beverages to prevent **oxidation** of these foods.

Table 1. The Vitamin C content of some common fruits and vegetables (mg per 100 g). source: Vitamin C: Its Chemistry and Biochemistry

Fruit or vegetable	**Ascorbic acid content**
Blackcurrant	200
Green pepper	128
Brocolli	113
Brussels sprouts	109
Strawberry	59
Oranges/lemons	50
New potato	30
Old potato	8
Apple	6

Oxidation Reaction

Vitamin C prevents oxidation because it is itself readily oxidized. This occurs in a two step reaction:



Ascorbic acid (reduced form)	Dehydroascorbic acid (oxidized form)	Diketogulonic acid (inactive)

Ascorbic acid and Dehydroascorbic acid are the two active forms of vitamin C and are interconvertable. Once converted to its inactive form, Dekitogulonic acid, it can no longer be converted into an active form and the body is not able to use it. Because of its vulnerability to oxidation, vitamin C can be destroyed or altered in many different ways. It is water soluble and can easily be **leached** out during washing or cooking. Storage of fresh food will gradually deplete the level of vitamin C. Therefore, the availability of this vitamin is higher in fresh raw plant foods.

Vitamin C

Agri-science Resources
for High School Sciences

Food Chemistry

Why we need Vitamin C

Vitamin C plays an important role in the body. It is used in the synthesis of **collagen**, the protein used to repair damaged tissue. The vitamin is responsible for the post-translational hydroxylation of the **amino acids** proline and lysine, the major components of collagen. It is also used in the synthesis of **neurotransmitters**, which are essential for the nervous system to function. Vitamin C plays a major role in protecting the body from many foreign harmful compounds. It is an important factor for the use of other nutrients, such as iron and folacin. Vitamin C is also important in the function of the Immune System.

Health Conditions

When the body is without a source of Vitamin C for 100-160 days, a condition known as **scurvy** develops. Some signs of scurvy include teeth which loosen and fall out, and severe pain and immobility. These conditions develop because collagen can no longer be properly synthesized. This leads to an inability to maintain some of the cellular structures of the body such as bone, **dentine**, **cartilage**, and connective tissues. A daily intake of 40-60 mg of vitamin C is recommended for adults. A minimum of 10 mg/day is sufficient to prevent scurvy. There is also a potential hazard associated with prolonged and regular ingestion of large amounts of vitamin C.

Vitamin C

Measurement

The vitamin C content of food can be measured using several methods. In this lab exercise, we will measure the vitamin C content of several familiar food items by using the Dye Titration method. This method is based on the official method of the Association of Official Analytical Chemists (AOAC). It has been simplified and does not require any sophisticated equipment or dangerous chemicals. The titration involves the oxidation reaction between ascorbic acid and sodium 2,6 dichloroindophenol:

```
      O                  O                          O                  OH
      ||             Cl  ||  Cl                     ||             Cl   |   Cl
      C---             \ /   \ /                    C---             \ /  \\ /
       |   |            ||    ||                     |    |           ||    |
  HO-C     |             \    /                  O=C      |            \   //
      ||   O     +        ||             ➔           |    O             ||
  HO-C     |               N                     O=C      |             NH
       |   |               |                         |    |              |
    H-C---                /   \\                  H-C---                //    \
       |                 ||     |                    |                  |     ||
  HO-C-H                  \    //                HO-C-H                 \\    /
       |                   |                         |                    |
      CH2OH                OH                        CH2OH                OH
```

L-ascorbic acid   2,6-Dichloroindophenol   L-dehydro ascorbic acid

Vitamin C

Instructions

These are the instructions for preparing the dye and sample solutions. These materials may not be available at every school and may have to be ordered by the instructor.

- Dichloroindophenol dye solution: Dissolve 50 mg of sodium dichloroindophenol in 50 ml of water. Add 42 mg of sodium bicarbonate ($NaHCO_2$ or baking soda). Shake vigorously. The dye will take several hours to dissolve. Dilute to 200 ml with water. Filter using Whatman #1 or #4. Store in a dark bottle protected from the light.

- Sample preparation solution: Add 40 ml of glacial acetic acid to 500 ml of water. The AOAC method calls for 15 g metaphosphoric acid pellets dissolved in 40 ml acetic acid and 200 ml of water. This solution is then diluted to 500 ml. It can be kept in the fridge for 7 days.

Procedure

1. To begin, the dye must be standardized against a standard ascorbic acid solution. Do this by dissolving 50 mg of ascorbic acid standard (in chemical or pill form) and dilute to 50 ml using the acetic acid solution.

2. Using a graduated cylinder, put 25-30 ml of the acetic acid solution in 125 or 250 ml Erlenmeyer flasks. Pipette a 2.0 ml aliquot of the ascorbic standard into the flask. Swirl and start the titration. Be sure to watch the meniscus on the burette closely. It may be difficult to read because of the color of the dye. Continue adding dye from the burette until the solution in the flask remains pink for 10 seconds. Record the volume of titrant that was needed to reach this end point.

3. Now titrate a blank by using 2 ml of water and 25 ml of acetic acid. Again, record the volume by reading the burette when the flask remains pink for at least 10 seconds. The concentration of the dye is calculated by using the formula:

$$\frac{\text{2.0 ml ascorbic acid solution} \times \text{50.0mg/ml}}{\text{Volume of titrant for standard - volume of titrant for blank}}$$

This gives the concentration of the dye in mg ascorbic acid per ml of dye.

4. Now get the samples which are to be tested. Since Vitamin C is water soluble, different liquids will be tested. Fruit juices make good samples. The liquid from ground up vegetables could also be used. The titration requires 4-5 ml of each sample. Try to use liquids with a light color to enable the color change to be detected more easily at the endpoint. Use as many different types of samples as possible for later comparison.

5. Pipette 4 or 5 ml of the juice into an Erlenmeyer flask. Add 30 ml acetic acid solution. Titrate until the color lasts for 10 seconds. The consistency of the endpoint is more important than the exact point or color obtained.

6. For accurate results, this analysis should be done in duplicate or triplicate. Also do sample blanks as was done to determine the standard.

7. To calculate the amount of vitamin C in your sample:

$$\frac{\text{(ml sample - ml blank) x conc of dye (mg ascorbic acid/ml dye)}}{\text{ml juice used}}$$

This gives the mg ascorbic acid per ml of fruit juice.

8. Compare these results with the other samples.

Questions

1. Why do you think scurvy was a common problem among sailors many years ago?
2. Based on the class results, if you could take one type of fruit or vegetable with you to sea, which would you chose as the best source of vitamin C?

Agri-science Resources for High School Sciences

Science

Flavor Reactions

Chemistry Lab

Food Chemistry

Teams of 2 or 3

DESCRIPTION

Many of foods on the market have artificial flavor added. Esters are commonly used as these types of food additives. An ester can be formed by reacting an alcohol and an acid. In this exercise, several ester reactions will be performed. Students will try to identify the odor that is given off from each reaction.

LEARNING OUTCOMES

Students will:

- learn the source of several artificial flavors in foods

READINESS ACTIVITIES

Students should:

- choose some familiar food items and see if they have any artificial flavorings

MATERIALS

- droppers
- test tubes
- concentrated sulfuric acid
- aspirin
- Alcohol:
  - isoamyl alcohol
  - benzyl alcohol
  - n-propyl alcohol
  - octanol
  - ethanol
  - methanol
  - isobutyl alcohol
- Acids:
  - acetic acid
  - butanoic acid
  - propionic acid
  - 2-amino-benzoic acid

Flavor Reactions

Agri-science Resources for High School Sciences

Food Chemistry

Esters

Many of today's foods contain artificial flavors. Most people have no idea what these compounds are or where they come from. Many artificial flavors are caused by the organic compounds called esters. Esters are a combination of alcohols and acids. These two combine to form an ester:

$$CH_3CH_2OH + HO\text{-}\overset{\overset{\displaystyle O}{\|}}{C}\text{-}(CH_2)_2CH_3 \xrightarrow{H^+} CH_3CH_2\text{-}O\text{-}\overset{\overset{\displaystyle O}{\|}}{C}\text{-}(CH_2)_2CH_3 + H_2O$$

ethanol — butanoic acid — ethyl butyrate

Many of these esters have odors and flavors that are very similar to those found in natural foods. In this lab, the students will create a series of ester reactions and try to distinguish the type of smell given off.

Caution

- **Handle all of these compounds with extreme care**
- **When attempting to distinguish the odor of an ester, wafte the odor towards yourself with your hand. Do not inhale the mixtures directly.**

Flavor Reactions

Agri-science Resources for High School Sciences

Food Chemistry

Procedure

1. Obtain several test tubes. Divide into partners. Each group should create a few esters.

2. Using the dropper, place a dropper full of the alcohol into the test tube.

3. Add a dropper full of the acid to the alcohol.

4. Now add 2 - 4 drops of concentrated sulfuric acid (H_2SO_4). PLEASE HANDLE WITH CARE. Concentrated sulfuric acid is extremely corrosive.

5. Allow the test tubes to become warm as heat is released by the sulfuric acid. If this does not work, use a warm water bath to heat the test tubes and start the ester reaction.

6. When the tubes are warm to the touch, the odor should be recognizable. If there is no odor, try pouring the mixture over ice.

7. Now try the reaction with Aspirin. Grind up several Aspirin and add about 0.5 grams to the bottom of a test tube. Add 2 ml of methanol and 2 drops of concentrated H_2SO_4. When the tube is warm to the touch, pour it over the ice. Try and distinguish the odor.

Questions

1. What is the odor produced in the Aspirin reaction? Based on the reaction, what type of compound is Aspirin?

2. Describe the reaction that is occurring when the acid is added to the alcohol.

Flavor Reactions

Agri-science Resources
for High School Sciences

Food Chemistry

Notes

- Warn the students about the concentrated sulfuric acid
- These are all the ester reactions. Try and give each group of students two or three examples to try. See if they can guess the odor that is produced. You should also give them the names of the reactants and try to figure out the name of the product. They could also try drawing the reactions.

isoamyl alcohol	+	acetic acid	=	isoamyl acetate (banana)
benzyl alcohol	+	acetic acid	=	benzyl acetate (peaches)
n-propyl alcohol	+	acetic acid	=	n-propyl acetate (pears)
octanol	+	acetic acid	=	octyl acetate (oranges)
ethanol	+	butanoic acid	=	ethyl butyrate (pineapple)
benzyl alcohol	+	butanoic acid	=	benzyl butyrate (flowers)
methanol	+	butanoic acid	=	methyl butyrate (apples)
isobutyl alcohol	+	propionic acid	=	isobutyl propionate (rum)
methanol	+	2-amino-benzoic acid	=	methyl anthranilate (grape)

Answers

1. The odor should be recognized as wintergreen. For this reaction to occur, Asprin must be an acid. It is called salicylic acid.

2. In this reaction, a hydrogen and an oxygen are lost when the two compounds combine. Hydrogen and Oxygen combine with Hydrogen ions to give water.

Glossary of Terms

amino acids	an organic compound having amino and carboxylic acid groups in the same molecule. Proteins are made up of the 20 naturally occuring amino acids
anemic	a diseased condition caused by loss of blood or defective red blood cells
collagen	chief component of connective tissue
cartilage	an elastic tissue of the body that develops into bone
dentine	the hard, dense tissue which forms the main part of a tooth
electron transfer	key step in life processes such as respiration and photosynthesis
enriched	products which have vitamins or minerals added to improve nutrition
enzyme	a complex organic substance that promotes chemical or catalytic changes in other substances
excreted	waste matter that is rid of by the body is excreted
leached	when a substance is lost due to movement by water
neurotransmitters	chemicals in the body that are involved in relaying signals along nerves
oxidation	a process that involves a complete or partial loss of electrons
oxygen transport	transport of oxygen molecules from the lungs to the rest of the body by red blood cells
respiration	a process in which living cells take in oxygen and give off carbon dioxide
scurvy	vitamin C deficiency disease

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