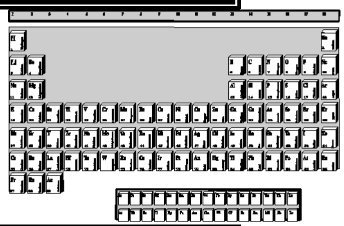
Agri-science Resources
for High School Sciences

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

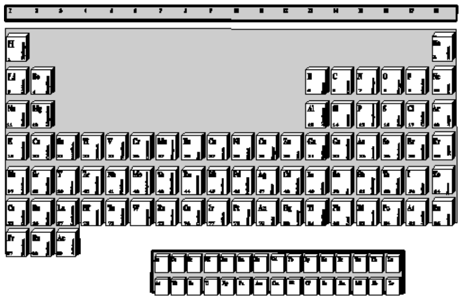
Students should:

- 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?

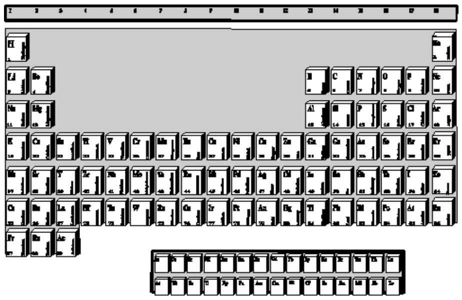
Iron oxides are responsible for the red soil on Prince Edward Island. It is possible to trace the reactions of iron from the time it is released from rock. Iron olivine is a good example of a rock which contains iron. This iron can be released due to environmental conditions. Weathering of iron olivine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