GOALS
In this activity you will:
• Cause different metals to rust by oxidation-reduction (redox) reactions.
• Determine what materials can react with metals, causing the metals to corrode.
• Write the word equations and chemical equations for redox reactions.
• Identify the materials that react, and the materials that are simply spectators, in a redox reaction.
• Learn how to impede corrosion.

What Do You Think?
A scratch on a car that is not repaired will rust. The same thing will happen to metal barbecue tools that get left out in the rain for a few weeks.

What is rust and what causes it?
Record your ideas about these questions in your Active Chemistry log. Be prepared to discuss your responses with your group and the class.

Investigate
1. Half-fill a test tube with copper (II) sulfate solution (CuSO₄(aq)). Add a small amount of zinc powder to the test tube. Stopper the test tube, and shake carefully. Then remove the stopper.
   a) Record your observations. Dispose of the products as directed by your teacher.
   b) The reaction you just observed was a single-replacement reaction. The zinc replaced the copper. Use this information and your observations to complete the following equations:
      zinc + copper (II) sulfate → ______ + ______
c) Write the word equation as a sentence. Also, explain why this would be classified as a single-replacement reaction. (Refer back to Activity 4.)

d) Write the equation using the chemical formulas of the products.

\[
\text{Zn}(s) + \text{CuSO}_4(aq) \rightarrow \underline{\text{____}} + \underline{\text{____}}
\]

Because the sulfate ion shows on both sides of the equation, it is considered a spectator ion and the equation can be written as shown below:

\[
\text{Zn}(s) + \text{Cu}^{2+}(aq) \rightarrow \text{Cu}(s) + \text{Zn}^{2+}(aq)
\]

e) Write a sentence or two describing what happened in the test tube in terms of the zinc and copper.

2. Cut a design or a strip of aluminum from a pie plate or tray. If you cut a strip of aluminum, twist it into an interesting shape.

Place the aluminum in a solution that contains copper (II) ions (\text{Cu}^{2+}(aq)). Possible solutions include: copper (II) nitrate (\text{Cu(NO}_3)_2(aq)) or copper (II) chloride (\text{CuCl}_2(aq)).

a) Observe and record your results. Dispose of the products as directed by your teacher.

b) What evidence do you have that a chemical reaction occurs? What changes have taken place with the aluminum? With the copper ions?

c) Complete this equation:

\[
\text{Al}(s) + \text{Cu}^{2+}(aq) \rightarrow \underline{\text{____}} + \underline{\text{____}}
\]

3. Repeat Step 2 using a different metal such as zinc.

a) Record your observations.

b) Write a chemical equation for the reaction that takes place.

4. Repeat Step 2 again, this time using a strip of copper in a solution of aluminum nitrate (\text{Al(NO}_3)_3(aq)).

a) Record your observations.

b) Write a chemical equation for the reaction that takes place.

5. Dispose of the materials as directed by your teacher. Clean up your workstation.
Chem Words

oxidation: the process of a substance losing one or more electrons.
reduction: the process of a substance gaining one or more electrons.
redox reaction: a chemical reaction where both oxidation and reduction occur simultaneously.

REDOX REACTIONS

When zinc solid reacts with copper ions in solution, a change occurs. Atoms of zinc lose electrons to form zinc ions (Zn²⁺) that dissolve in the solution. Copper ions (Cu²⁺) gain the electrons from the zinc atoms to form copper atoms that plate out as a solid. Whenever an atom or ion becomes more positively charged in a chemical reaction, as in the case of zinc atoms forming positive zinc ions, the process is called oxidation. Oxidation is the process of losing electrons. Whenever an atom or ion becomes less positively charged in a chemical reaction, as in the case of the copper ions forming copper atoms, the process is called reduction. Reduction involves a gain of electrons. The processes of oxidation and reduction happen together and as such are commonly referred to as “redox” reactions. An easy way to remember which is oxidation and which is reduction is by remembering “LEO the lion says GERrr;” — Lose Electrons Oxidation; Gain Electrons Reduction.

The formation of rust is a redox process. Water and oxygen are necessary for the iron metal to corrode (rust). Iron atoms lose electrons to form mostly Fe³⁺ ions with the help of the moisture in the air and the heat of the Sun. Because the atoms have given up electrons to become more positively charged, oxidation of iron has taken place. Molecules of oxygen gain electrons to form O₂⁻ ions. The oxygen has accepted electrons and is said to have been reduced. Corrosion can be prevented by painting a surface of iron to prevent moisture and air from coming in contact with the metal. Let’s summarize what you have learned about atoms and ions:
The term atom means that the element is neutral; this means that it has the same number of protons and electrons. Ions mean that the atom (or ion) has gained or lost electron(s). When an atom gains or loses one or more electrons, an ion results.

Examples are:

\[
Na \rightarrow Na^+ + e^- \quad \text{(Sodium atom loses one electron and now has a net charge of +1.)}
\]

\[
Cl_2 + 2e^- \rightarrow 2Cl^- \quad \text{(The two chlorine atoms gain one electron each and the net charge is –1 for each chloride ion.)}
\]

Polyatomic ions like the sulfate ion (SO₄²⁻) imply that there are two more electrons than protons in the entire structure.

In some cases you will find that an ion can gain or lose an electron and form a new ion. An example of this type is: Fe²⁺ \rightarrow Fe³⁺ + e⁻ (The iron in the +2 state loses 1 more electron and now will be in a +3 state.)

What Do You Think Now?

At the beginning of this activity you were asked:

• What is rust and what causes it?

How has your understanding of rusting changed from when you first answered this question?

How do you think you could slow down the oxidation process involved in the corrosion and destruction of things made from metal?

Checking Up

1. What charge does an ion have when it is oxidized?
2. What charge does an ion have when it is reduced?
3. Explain what happens in a redox reaction.
Reflecting on the Activity and the Challenge

Although many colorful chemical reactions involve the use of acids and bases with indicators, there is an entire group of chemical reactions that produce colorful results through the transfer of electrons. In this activity you became familiar with some of the simple concepts behind redox reactions, and you saw several examples of the color changes they can produce. You and/or your classmates may decide to include some redox reactions in the Cool Chemistry Show.
1. Aluminum metal can react to form an ion with a charge of +3. Does the aluminum atom gain or lose electrons to form the Al$^{3+}$ ion?

2. A copper ion with a charge of +2 can react to form an atom of copper. Does the copper ion have to gain or lose electrons in this reaction?

3. The element iron can form two different ions. The iron (II) ion (Fe$^{2+}$) is commonly called a ferrous ion while the iron (III) ion (Fe$^{3+}$) is called a ferric ion. When ferrous ions undergo a chemical change to become ferric ions, what process has taken place, oxidation or reduction? Explain your answer.

4. In the reaction you did with zinc metal reacting with copper ions, which substance gains electrons? Which loses electrons?

5. What must take place for copper metal to be oxidized?

6. Galvanized iron nails are used to fasten materials that will be exposed to the outdoors. A galvanized nail is a regular iron nail that is coated with zinc.
   a) Why would a zinc coating be an advantage here? What do you think is the purpose of the zinc?
   b) What two reactants could you use to test this in the laboratory? What results would you expect if you were right about the purpose of the zinc?

7. When a zinc metal strip is placed in a blue copper (II) nitrate solution we observe that the blue solution disappears. Explain why this is happening.

8. Which reaction is an example of an oxidation-reduction reaction?
   a) $\text{AgNO}_3 + \text{KI} \rightarrow \text{AgI} + \text{KNO}_3$
   b) $\text{Cu} + 2\text{AgNO}_3 \rightarrow \text{Cu(NO}_3)_2 + 2\text{Ag}$
   c) $2\text{KOH} + \text{H}_2\text{SO}_4 \rightarrow \text{K}_2\text{SO}_4 + 2\text{H}_2\text{O}$
   d) $\text{Ba(OH)}_2 + 2\text{HCl} \rightarrow \text{BaCl}_2 + 2\text{H}_2\text{O}$

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Inquiring Further

The Statue of Liberty

In the 1980s the Statue of Liberty in New York harbor underwent extensive renovation. Research the involvement of oxidation-reduction reactions in this renovation. Identify what the problem was and its solution.