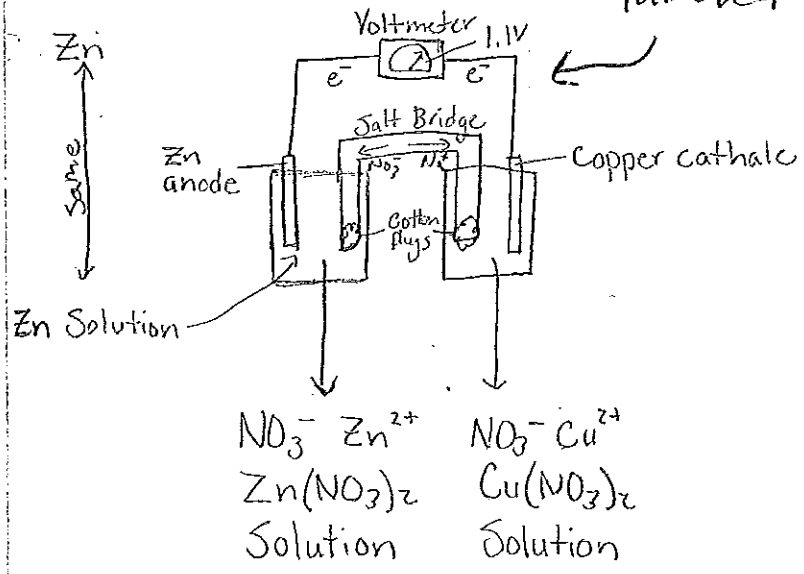
battery drawing labeled



Loss Gain
Electrons says Electrons
Oxidation Reduction

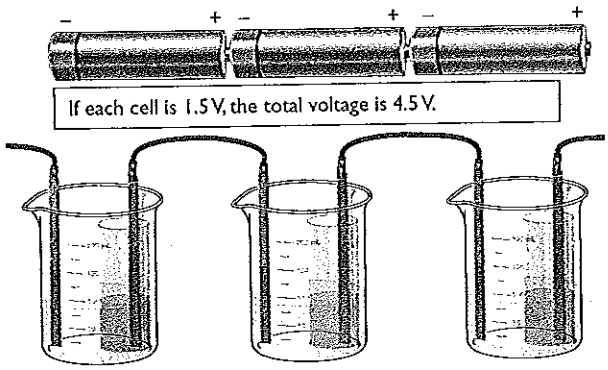
p.357
The "decreaseing tendency to release electrons" is going from;
Top: loss
Bottom: Gain

Activity Series

Li
K
Ba
Ca
Na
Mg
Al
Mn
Zn
Cr
Fe
Cd
Co
Ni
Sn
Pd
Cu
Ag
Hg
Au

If the elements are far away, you will get a stronger voltage, if they are closer together; the voltage will be small.

An ion is an element that gains or losses electron(s).



3. Use alligator clips to hook the electrode from one electrochemical cell to the different metal electrode of the next electrochemical cell. Continue in this fashion until you have enough voltage to power your toy. You will have to share your cell with other teams to get enough voltage to run some toys.

4. Compare your setup to the battery arrangement in the toy.
   a) How many electrochemical cells were required?
   b) How long do you think it will take for your battery to die?

Wash your hands and arms thoroughly after the activity.

ChemTalk

OXIDATION-REDUCTION REACTIONS AND ELECTROCHEMICAL CELLS

Electrochemical Cell

An **electrochemical cell** is a cell or a battery that uses chemical reactions to generate electricity. When two metals of differing electron-releasing tendencies are connected, an electrical potential is created between the two metals. The electrical potential (**voltage**) is measured in **volts** (V) and represents the energy that drives electrons through the wire connecting the two metals. A 9-V battery has a larger electrical potential than a 1.5-V battery. **Current** describes the rate of flow of electric charge. Larger batteries can generate larger currents than smaller batteries.

Some metals tend to lose electrons (become oxidized) more readily than other metals. Examine the Metal Activity Series shown on the next page. A metal that is higher in the activity series will "give up," or release, electrons more readily than one that is lower. You can make use of these differing tendencies to convert chemical energy to electrical energy. As you may have found in the activity, metals that are furthest apart in the activity series will produce the largest voltages.

Metal Activity Series

A **battery** is a system that directly converts chemical energy to electrical energy. The Consumer Electronics Association claims that there

Chem Words

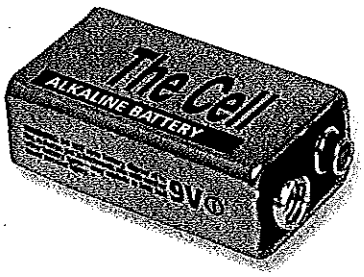
electrochemical cell: a cell or a battery that uses chemical reactions to generate electricity.

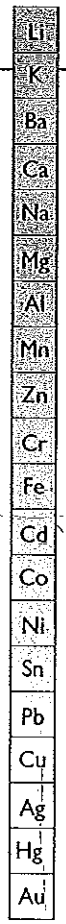
voltage: a measure of the difference in electrochemical potential between two electrodes.

volts: the electrical potential of an electrochemical cell. They represent the "push" that drives electrons through the wire connecting the two metals.

current: the rate of flow of electric charge.

battery: a system that directly converts chemical energy to electrical energy.





were over 4.9 billion dollars worth of batteries sold in the U.S. in 2002. The typical batteries used in toys are more correctly called electrochemical cells.

If you examine any commercial battery you will see two terminals. One terminal is marked (+), or positive, while the other is marked (−), or negative. These are typically located at the ends of the battery.

Electrons (which are negative) flow from the negative terminal of the battery. If connected to the positive terminal, the electrons will flow toward the positive. Wires and a **load** provide the path for the electrons. The load may be a motor or a light or something else that runs on electricity (the flow of electrons).

Before considering how your chemical batteries worked, look at a simpler system.

Consider the following reactions:

$$Zn_{(s)} \rightarrow Zn^{2+}_{(aq)} + 2e^-$$

In certain situations, neutral zinc (Zn) loses two electrons. When that happens, a Zn **ion** and two free electrons are formed. Since the zinc has lost two electrons, the charge on the Zn ion is +2.

$$Cu^{2+}_{(aq)} + 2e^- \rightarrow Cu_{(s)}$$

In certain situations, a copper (Cu^{2+}) ion tends to gain two electrons. When that happens, a neutral copper atom is formed. The Cu ion had a charge of +2 so it needed two electrons to become electronically neutral.

When the neutral zinc and the copper ion interact, as shown by these reactions, the neutral zinc supplies electrons to the copper ion. This flow of electrons is produced by the potential difference (voltage) and the result is a battery.

The zinc reaction of *losing* electrons is called **oxidation**. The copper reaction of *gaining* electrons is **reduction**. Each of the two reactions are called **half-reactions**.

$$Zn_{(s)} \rightarrow Zn^{2+}_{(aq)} + 2e^-$$
(loss of electrons = oxidation, occurs at the anode)

$$Cu^{2+}_{(aq)} + 2e^- \rightarrow Cu_{(s)}$$
(gain of electrons = reduction, occurs at the cathode)

A mnemonic device to remind you of these two processes is:

LEO the lion says **GER**
Lose **E**lectrons **O**xidation **G**ain **E**lectrons **R**eduction

Chem Words

load: a motor, light bulb, or other device that runs on electricity (the flow of electric charge).

ion: an atom or molecule that has acquired a charge by either gaining or losing electron(s).

oxidation: the process of a substance losing one or more electrons.

reduction: the process of a substance gaining one or more electrons.

half-reactions: two separated parts of a redox reaction. One part is the oxidation reaction and the other part is the reduction reaction.

oxidized: the acquiring of a positive charge on an atom or molecule by losing electron(s).

reduced: the acquiring of a negative charge on an atom or molecule by gaining electron(s).

oxidation-reduction (redox) reaction: a chemical reaction in which the valence electrons of one substance are transferred to the valence shell of the second substance.

spectator ions: ions that do not chemically react in the overall reaction.

dry cell: an electrochemical cell in which the electrolyte is a paste instead of a solution.

Checking Up

1. Which metal will lose electrons more easily, Ca or Mg?
2. Which combination of metals will produce the greater voltage, Ca and Al or Ca and Cu?
3. What units are used to measure electrical potential?
4. Why is the NO_3^- ion in an electrochemical cell called a spectator ion?
5. Define reduction and oxidation.
6. Another memory "trick" for remembering oxidation and reduction is "OIL RIG." What do the letters in this device stand for?
7. What is the difference between a dry cell and the one you built in this activity?

The pair of reactions occurring at the same time is called an **oxidation-reduction** (often called **redox**) **reaction**.

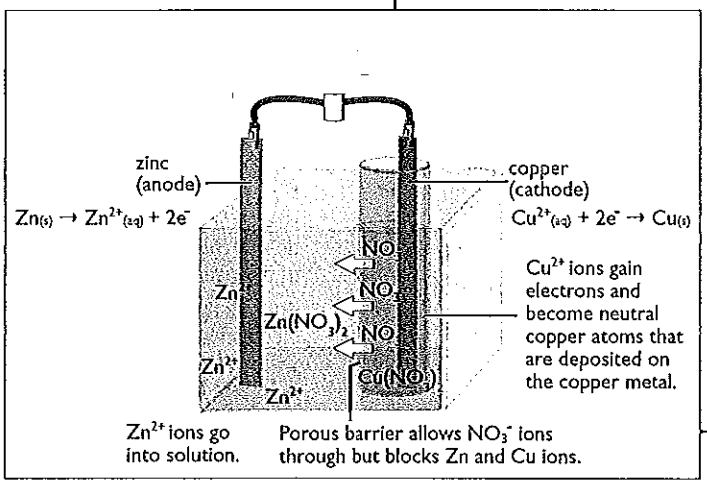
$$Zn_{(s)} + Cu^{2+}_{(aq)} \rightarrow Zn^{2+}_{(aq)} + Cu_{(s)}$$

One of the characteristic properties of metals is that they tend to lose or "give up" electrons more easily compared to nonmetal atoms. When an atom has lost electrons, it has been **oxidized**. No atom or particle can be oxidized unless some other particle is simultaneously reduced. An atom is **reduced** when it gains electrons.

In the activity, the Zn metal and the Cu^{2+} ions were kept separated by using a porous barrier. This separation forces the electrons to flow through the wire and the load from the anode (Zn) to reach the cathode (Cu). In this way electricity is produced that can do useful work. The Zn anode is bathed in a solution of $Zn(NO_3^-)_2$ while the Cu cathode sits in a solution of $Cu(NO_3^-)_2$ in the porous cup. Because the nitrate ions (NO_3^-) do not participate in the reaction, they are referred to as **spectator ions**. Typically, they are not written into the equation.

When the wire is connected, the zinc metal is oxidized to Zn^{2+} ions, which dissolve into the solution. The Cu^{2+} ions are converted to neutral copper atoms that come out of the solution as copper metal.

As the reaction takes place, the zinc half-cell becomes positive and the copper half-cell becomes negative. This would slow and eventually stop the reaction unless the two sides can become electrically neutral. The porous cup allows for the negative NO_3^- ions to move from the copper half-cell to the zinc half-cell. This keeps both sides neutral and the reaction continues.



Your car battery is a wet cell battery that functions similarly to the electrochemical cells that you created. However, most toy batteries are **dry cell** batteries. They operate on exactly the same principles as your electrochemical cells, but the electrolytic substances are in a paste form.

What Do You Think Now?

At the beginning of this activity you were asked:

- What is a battery and how does it work?

Take a look at your original thoughts on the nature of batteries. How have they changed? How would you answer the question now?

Chem to Go

1. For the highest electrical potential, should an electrochemical cell's two metals be close together or far apart on the activity series? Explain.
2. Predict whether the electrical potential of cells composed of these metal pairings will be higher or lower than that of the pairs you tested:

   a) Zn and Cr b) Zn and Ag c) Sn and Cu
3. Notice that silver, platinum, and gold have good reduction potential. Why are these elements not generally found in batteries?
4. Predict the direction of electron flow in an electrochemical cell made from each pair of metals in solutions of their ions.

   a) Mg and Cu b) Zn and Cu c) Ag and Mg
5. a) Identify the anode and the cathode for the metal pairs in *Question 4*.

   b) Write the half-reactions for each metal pair in *Question 4*.
6. List some of the pros and cons of batteries. Consider cost, size, and disposal issues, among others.
7. Which half-reaction correctly represents reduction?

   a) $Ag \rightarrow Ag^+ + e^-$ b) $Au^{3+} + 3e^- \rightarrow Au$

   c) $F_2 \rightarrow 2F^- + 2e^-$ d) $Fe^{2+} \rightarrow Fe^{3+} + e^-$
8. Which reaction is an example of an oxidation-reduction reaction?

   a) $AgNO_3 + KI \rightarrow AgI + KNO_3$

   b) $Cu + 2AgNO_3 \rightarrow Cu(NO_3)_2 + 2Ag$

   c) $2KOH + H_2SO_4 \rightarrow K_2SO_4 + 2H_2O$

   d) $Ba(OH)_2 + 2HCl \rightarrow BaCl_2 + 2H_2O$
9. Where does oxidation occur in an electrochemical cell?

   a) at the cathode

   b) at the cathode and the anode in the electrolytic cell

   c) at the anode

   d) neither the cathode nor the anode

Inquiring Further

Storing batteries

Design and conduct a test for determining the best way to store batteries in order to extend their life.