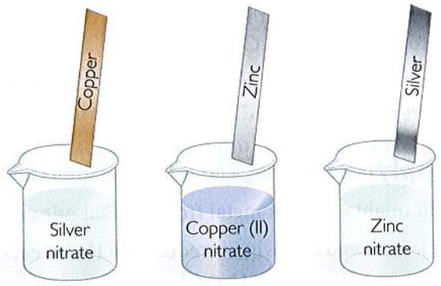
LESSON

18 The Active Life

Activity of Metals

Think About It

Imagine you set up three experiments. In one, a strip of copper is placed in a solution of silver nitrate. In the second, a strip of zinc is placed in a solution of copper (II) nitrate. In the third, a strip of silver is placed in a solution of zinc nitrate. Only two of these setups will result in reactions. How can you predict which reactions will occur?



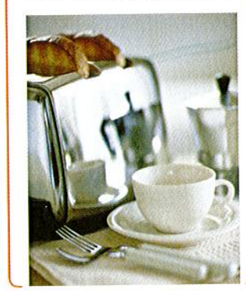
Which metal atoms are most easily oxidized?

To answer this question, you will explore

1. Comparing Metals
2. Activity Series

INDUSTRY CONNECTION

Redox reactions have been used for decades to coat metals with chromium. Chrome plating improves appearance and durability. Chromium sulfate, or chromium chloride, are often used in industrial plating solutions.



Exploring the Topic

1 Comparing Metals

When metal atoms are combined with metal ions in solution, you may or may not end up with a reaction. Some combinations of metals and metal salts result in redox reactions and others don't. It all depends on which combinations of metals are used.

Consider the three solutions shown on the next page. Each solution contains metal cations and a strip of elemental metal. If the metal atoms on the strip transfer electrons to the metal cations in solution, a reaction will occur.

In the first beaker, the copper atoms transfer electrons to the silver ions. Copper atoms are oxidized and silver cations are reduced. As a result, silver metal can be seen as a coating on the copper strip. In the second beaker, zinc atoms transfer electrons to the copper ions in solution. Zinc atoms are oxidized and copper is reduced. Copper metal coats the zinc strip. However, nothing happens in the third beaker.

$$\text{Beaker 1: } Cu(s) + 2AgNO_3(aq) \longrightarrow Cu(NO_3)_2(aq) + 2Ag(s)$$

$$Cu(s) + 2Ag^+(aq) \longrightarrow Cu^{2+}(aq) + 2Ag(s)$$

$$\text{Beaker 2: } Zn(s) + Cu(NO_3)_2(aq) \longrightarrow Zn(NO_3)_2(aq) + Cu(s)$$

$$Zn(s) + Cu^{2+}(aq) \longrightarrow Zn^{2+}(aq) + Cu(s)$$

$$\text{Beaker 3: } Ag(s) + Zn(NO_3)_2(aq) \longrightarrow \text{no reaction}$$

In the third beaker there is no reaction. Silver does not give up its electrons in the presence of zinc ions. Chemists say that silver is not as active as zinc.

2 Activity Series

By combining different metals and metal ions, you can determine experimentally which metals are more active than other metals. The result is called an **activity series.** Working with the data we have so far, zinc, copper, and silver can be placed in order of their activity.

Zinc
gives up electrons to
Copper
which gives up electrons to
Silver

More active ↕ Less active

Where would magnesium fit on this list? In the classroom you combined magnesium with zinc nitrate. The magnesium was oxidized and formed Mg^{2+} ions.

$$Mg(s) + Zn(NO_3)_2(aq) \longrightarrow Mg(NO_3)_2(aq) + Zn(s)$$

So, magnesium belongs above zinc on the list.

Magnesium
gives up electrons to
Zinc
which gives up electrons to
Copper
which gives up electrons to
Silver

More active ↕ Less active

CONSUMER CONNECTION

Lithium is the most active metal on the periodic table and would potentially be listed above potassium on the activity series table. Your cell phone may contain a lithium battery. A redox reaction in the battery supplies electrical energy to power your phone.

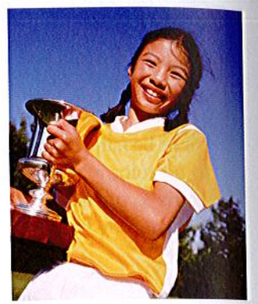
Activity Series

Potassium	More active
Barium	Easily oxidized
Calcium	
Sodium	
Magnesium	
Aluminum	
Zinc	
Chromium	
Iron	
Nickel	
Copper	
Silver	
Mercury	Less active
Gold	Easily reduced

You may have noticed that all the reactions in this section have been single exchange reactions where the more easily oxidized metal displaces the other metal. In this way, the more active metal forms cations while the less active metal is reduced to a solid.

A series of experiments can reveal where other metals belong on the list. The more active atoms at the top of the list will always displace the less active ones below.

On this list, gold is at the bottom. Gold atoms are very difficult to oxidize, and gold cations are very easy to reduce. This is one reason why gold is rarely found in compounds combined with other atoms.



Because silver is easily reduced, it is relatively easy to plate metals with silver for ornamentation.

A metal high in the activity series

- reacts vigorously and quickly with compounds
- readily gives up electrons in reactions to form positive ions
- is corroded easily

A metal low in the activity series

- does not react vigorously and quickly with chemicals
- does not readily give up electrons in reactions to form positive ions
- is not corroded easily

Example

Use the provided equations to determine where aluminum falls in the order of activity with zinc, copper, and silver that have been looked at so far.

$Al_{(s)} + Zn(NO_3)_{2\,(aq)} \rightarrow$ No reaction

$Al_{(s)} + CuNO_{3\,(aq)} \rightarrow Cu_{(s)} + Al(NO_3)_{3\,(aq)}$

Solution

a.) Aluminum does not react with zinc nitrate, so aluminum is less active than the zinc ions that are in the solution of the first equation. This means aluminum is below zinc on the activity series. We need to look at the second equation to determine where below zinc aluminum should be placed.

b.) Aluminum does react with copper(I) nitrate, so aluminum is more active than the copper ions that are in the solution of the second equation. This means aluminum is above copper on the activity series. So the order, so far, should be zinc, aluminum, copper, and then silver (most to least active).

All of the metals on the periodic table can be placed in an activity series table. Chemists are interested in the activity of metals, because this allows them to control the outcome of different reactions. Metal compounds can be combined in different ways to form other compounds. Also, the most easily oxidized metals turn out to be a good source of electrons. You'll learn more about this in Lesson 19: Current Events.

Key Term

activity series

Lesson Summary

Which metal atoms are most easily oxidized?

Metals that are easily oxidized give up their electrons easily. They are considered more active than other metals. Comparing metals experimentally allows you to rank the metals in terms of their ease of oxidation. The activity of a metal is demonstrated when it is combined with another metal cation. The more active metal will lose electrons, displacing the other metal in the compound. The displaced metal is reduced. The ranking of metals in order of their activity is referred to as an activity series.

EXERCISES

Reading Questions

1. Explain how you would figure out where tin should be listed in the activity series.
2. Why are metals that are more active also considered less stable?

Reason and Apply

3. If zinc nitrate, $Zn(NO_3)_2$, is paired with solid iron, what would you expect to observe? Explain your reasoning.
4. If iron (III) nitrate, $Fe(NO_3)_3$, were combined with solid zinc, what would you expect to observe? Explain your reasoning
5. Consider any reactions that occur in Exercises 3 and 4.
   a. Write chemical equations.
   b. Write the net ionic equation.
   c. Identify the more active metal.
   d. Which metal is oxidized? Which metal is reduced?
6. Platinum is more active than gold but less active than silver. Where does it belong in the activity series?
7. If cobalt ions are replaced by iron to form iron ions and solid cobalt, is cobalt above or below iron in the activity series? Explain.
8. Write net ionic equations for two reactions between magnesium and less active metals.
9. Name three combinations of ionic compounds and metals that will not react.