

BIG Idea

A chemical reaction involves changing one or more substances into a different substance or substances.

21.1 Chemical Changes**MAIN Idea**

The rearrangement of atoms in a chemical change is described by a chemical equation.

21.2 Chemical Equations**MAIN Idea**

A balanced chemical equation contains the same numbers and types of atoms in the reactants as in the products.

21.3 Classifying Chemical Reactions**MAIN Idea**

Reactions can be classified based on how atoms are rearranged.

21.4 Chemical Reactions and Energy**MAIN Idea**

Exergonic reactions release energy and endergonic reactions absorb energy.

All-American Chemistry

Few things are as American as fireworks on the Fourth of July. Crowds everywhere enjoy the explosions of color and deafening booms. These sights and sounds are the results of chemical reactions.

Science Journal

Describe several events that might happen in your refrigerator. Later, decide which of the events are chemical reactions.

Chemical Reactions



Start-Up Activities



Rusting—A Chemical Reaction

Like exploding fireworks, rusting is a chemical reaction in which iron metal combines with oxygen. Other metals combine with oxygen, too—some more readily than others. In this lab, you will compare how iron and aluminum react with oxygen.



1. Place a clean iron or steel nail in a dish prepared by your teacher.
2. Place a clean aluminum nail in a second dish. These dishes contain agar gel and an indicator that detects a reaction with oxygen.
3. Observe both nails after one hour. Record any changes around the nails in your Science Journal.
4. Carefully examine both of the dishes the next day.
5. **Think Critically** Record any differences you noticed between the two dishes. Predict if a reaction occurred. How can you tell? What might have caused the differences you observed between the two nails. Explain.

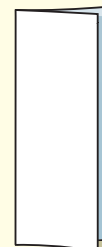


Preview this chapter's content and activities at gpscience.com

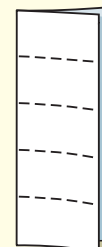
FOLDABLES™ Study Organizer

Chemical Reactions Make the following Foldable to help you classify chemical reactions.

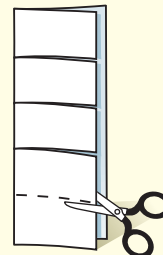
- STEP 1** **Fold** a sheet of paper in half lengthwise.



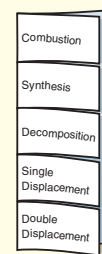
- STEP 2** **Mark** four lines evenly spaced at even intervals down the page.



- STEP 3** **Cut** only the top layer along the four marks to make five tabs.



- STEP 4** **Label** the tabs as shown.



Classify As you read, record examples of each type of reaction from the book, then review the chapter and list other examples mentioned in the text or from classroom discussions.

Chemical Changes

Reading Guide

What You'll Learn

- **Identify** the reactants and products in a chemical reaction.
- **Determine** how a chemical reaction satisfies the law of conservation of mass.
- **Determine** how chemists express chemical changes using equations.

Why It's Important

Chemical reactions cook our food, warm our homes, and provide energy for our bodies.



Review Vocabulary

equation: a statement of the equality or equivalence of mathematical or logical quantities

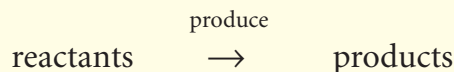
New Vocabulary

- chemical reaction
- reactant
- product
- chemical equation
- coefficient

Describing Chemical Reactions

Dark mysterious mixtures react, gas bubbles up and expands, and powerful aromas waft through the air. Where are you? Are you in a chemical laboratory carrying out a crucial experiment? No. You are in the kitchen baking a chocolate cake. Nowhere in the house do so many chemical reactions take place as in the kitchen.

Actually, chemical reactions are taking place all around you and even within you. A **chemical reaction** is a change in which one or more substances are converted into new substances. The substances that react are called **reactants**. The new substances produced are called **products**. This relationship can be written as follows:



Conservation of Mass

By the 1770s, chemistry was changing from the art of alchemy to a true science. Instead of being satisfied with a superficial explanation of unknown events, scientists began to study chemical reactions more thoroughly. Through such study, the French chemist Antoine Lavoisier established that the total mass of the products always equals the total mass of the reactants. This principle is demonstrated in **Figure 1**.



Figure 1 The mass of the candles and oxygen before burning is exactly equal to the mass of the remaining candle and gaseous products.



Figure 2 Antoine Lavoisier's wife, Marie-Anne, drew this view of Lavoisier in his laboratory performing studies on oxygen. She depicted herself at the right taking notes.

Lavoisier's Contribution One of the questions that motivated Lavoisier was the mystery of exactly what happened when substances changed form. He began to answer this question by experimenting with mercury. In one experiment, Lavoisier placed a carefully measured mass of solid mercury(II) oxide, which he knew as mercury calx, into a sealed container. When he heated this container, he noted a dramatic change. The red powder had been transformed into a silvery liquid that he recognized as mercury metal, and a gas was produced. When he determined the mass of the liquid mercury and gas, their combined masses were exactly the same as the mass of the red powder he had started with.

mercury(II) oxide		oxygen	plus	mercury
10.0 g	=	0.7 g	+	9.3 g

Lavoisier also established that the gas produced by heating mercury(II) oxide, which we call oxygen, was a component of air. He did this by heating mercury metal with air and saw that a portion of the air combined to give red mercury(II) oxide. He studied the effect of this gas on living animals, including himself. Hundreds of experiments carried out in his laboratory, as shown in **Figure 2**, confirmed that in a chemical reaction, matter is not created or destroyed, but is conserved. This principle became known as the law of conservation of mass. This means that the total starting mass of all reactants equals the total final mass of all products.



Reading Check

What does the law of conservation of mass state?



Topic: Antoine Lavoisier

Visit gpscience.com for Web links to information about Antoine Lavoisier and his contributions to chemistry.

Activity In your Science Journal, write a brief biography of Antoine Lavoisier that includes some of his non-scientific activities and political interests, as well as his scientific contributions.

The Father of Modern Chemistry When Lavoisier demonstrated the law of conservation of mass, he set the field of chemistry on its modern path. In fact, Lavoisier is known today as the father of modern chemistry for his more accurate explanation of the conservation of mass and for describing a common type of chemical reaction called combustion, which you will learn about later in this chapter. Lavoisier also pioneered early experimentation on the biological phenomena of respiration and metabolism that contributed early milestones in the study of biochemistry, medicine, and even sports science.

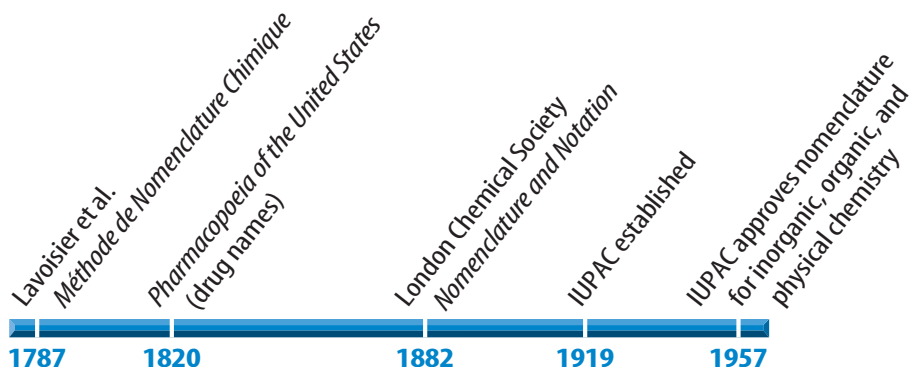
Nomenclature Lavoisier's work led him to the conclusion that language and terminology would be critical to communicate novel scientific ideas. In his book *Elements of Chemistry* (1790), Lavoisier wrote, "...we cannot improve a science without improving the language or nomenclature which belongs to it..." With that recognition, Lavoisier began to develop the system of naming substances based on their composition that we still use today. In 1787, Lavoisier and several colleagues published *Méthode de Nomenclature Chimique* as one of the first sets of nomenclature guidelines. Since then, the guidelines have continued to evolve with scientific discovery, and in 1919 the International Union of Pure and Applied Chemistry (IUPAC) was formed. The primary mission of the IUPAC is to coordinate guidelines for naming chemical compounds systematically. Before a new element gets a permanent name, it has a IUPAC name. Element 110, which is now called darmstadtium, was previously named ununnilium. **Figure 3** illustrates some of the early key events in nomenclature development.



Reading Check

How did Lavoisier's contributions earn him the name *Father of Modern Chemistry*?

Figure 3 This time line of nomenclature development and publications does not end in 1957. In fact, today there are nomenclature organizations for almost every branch of scientific study, and the rules and guidelines for naming substances continue to evolve.



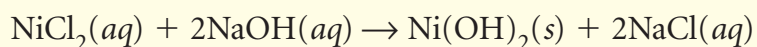
Writing Equations

If you wanted to describe the chemical reaction shown in **Figure 4**, you might write something like this:

Nickel(II) chloride, dissolved in water, plus sodium hydroxide, dissolved in water, produces solid nickel(II) hydroxide plus sodium chloride, dissolved in water.

This series of words is rather cumbersome, but all of the information is important. The same is true of descriptions of most chemical reactions. Many words are needed to state all the important information. As a result, scientists have developed a shorthand method to describe chemical reactions. A **chemical equation** is a way to describe a chemical reaction using chemical formulas and other symbols. Some of the symbols used in chemical equations are listed in **Table 1**.

The chemical equation for the reaction described above in words and shown in **Figure 4** looks like this:



It is much easier to tell what is happening by writing the information in this form. Later, you will learn how chemical equations make it easier to calculate the quantities of reactants that are needed and the quantities of products that are formed.

Table 1 Symbols Used in Chemical Equations

Symbol	Meaning
→	produces or forms
+	plus
(s)	solid
(l)	liquid
(g)	gas
(aq)	aqueous, a substance is dissolved in water
heat →	the reactants are heated
light →	the reactants are exposed to light
elec. →	an electric current is applied to the reactants



Figure 4 A white precipitate of nickel(II) hydroxide forms when sodium hydroxide is added to a green solution of nickel(II) chloride. Sodium chloride, the other product formed, is in solution.

Mini LAB

Designing a Team Equation

Procedure

1. Obtain **15 index cards** and mark each as follows: five with *Guard*, five with *Forward*, and five with *Center*.
2. Group the cards to form as many complete basketball teams as possible. Each team needs two guards, two forwards, and one center.

Analysis

1. Write the formula for a team. Write the formation of a team as an equation. Use coefficients in front of each type of player needed for a team.
2. How is this equation like a chemical equation? Why can't you use the remaining cards?
3. How do the remaining cards illustrate the law of conservation of matter in this example?



Unit Managers

What do the numbers to the left of the formulas for reactants and products mean? Remember that according to the law of conservation of mass, matter is neither made nor lost during chemical reactions. Atoms are rearranged but never lost or destroyed. These numbers, called **coefficients**, represent the number of units of each substance taking part in a reaction. Coefficients can be thought of as unit managers.



Reading Check

What is the function of coefficients in a chemical equation?

Imagine that you are responsible for making sandwiches for a picnic. You have been told to make a certain number of three kinds of sandwiches, and that no substitutions can be made. You would have to figure out exactly how much food to buy so that you had enough without any food left over. You might need two loaves of bread, four packages of turkey, four packages of cheese, two heads of lettuce, and ten tomatoes. With these supplies you could make exactly the right number of each kind of sandwich.

In a way, your sandwich-making effort is like a chemical reaction. The reactants are your bread, turkey, cheese, lettuce, and tomatoes. The number of units of each ingredient are like the coefficients of the reactants in an equation. The sandwiches are like the products, and the numbers of each kind of sandwich are like coefficients, also.

Knowing the number of units of reactants enables chemists to add the correct amounts of reactants to a reaction. Also, these units, or coefficients, tell them exactly how much product will form. An example of this is the reaction of one unit of NiCl_2 with two units of NaOH to produce one unit of Ni(OH)_2 and two units of NaCl . You can see these units in **Figure 5**.

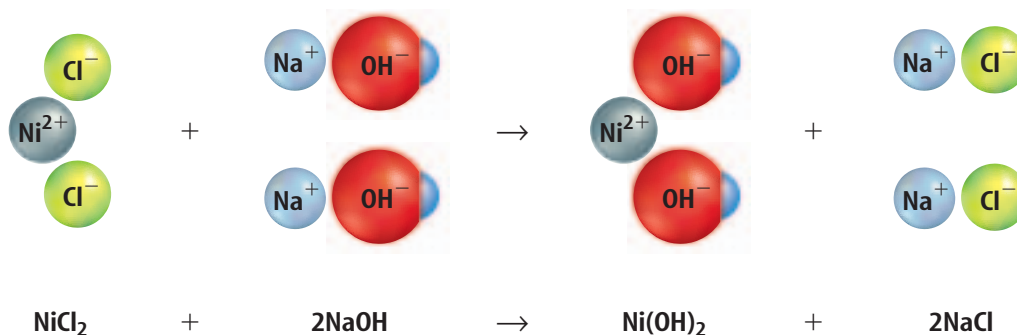


Figure 5 Each coefficient in the equation represents the number of units of each type in this reaction.



Metals and the Atmosphere

When iron is exposed to air and moisture, it corrodes or rusts, forming hydrated iron(III) oxide. Rust can seriously damage iron structures because it crumbles and exposes more iron to the air. This leads to more breakdown of the iron and eventually can destroy the structure. However, not all reactions of metals with the atmosphere are damaging like rust. Some are helpful.

Aluminum also reacts with oxygen in the air to form aluminum oxide. Unlike rust, aluminum oxide adheres to the aluminum surface, forming an extremely thin layer that protects the aluminum from further attack. You can see this thin layer of aluminum oxide on aluminum outdoor furniture. It makes the once shiny aluminum look dull.

Copper is another metal that corrodes when it is exposed to air, forming a blue-green coating called a patina. You can see this type of corrosion on many public monuments and also on the Statue of Liberty, shown in **Figure 6**.

Figure 6 The blue-green patina that coats the Statue of Liberty contains copper(II) sulfate, among other copper corrosion products.



section 1 review

Summary

Describing Chemical Reactions

- A chemical reaction is a process that involves one or more reactants changing into one or more products.

Conservation of Mass

- A basic principle of chemistry is that matter, during a chemical change, can neither be created nor destroyed.
- Antoine Lavoisier is often considered to be “the father of modern chemistry” for his work in defining the law of conservation of mass.

Writing Equations

- Chemical equations describe the change of reactants to products and obey the law of conservation of mass.

Unit Managers

- Coefficients represent how many units of each substance are involved in a chemical reaction.

Self Check

1. **Identify** the reactants and the products in the following chemical equation.
$$\text{Cd}(\text{NO}_3)_2(aq) + \text{H}_2\text{S}(g) \longrightarrow \text{CdS}(s) + 2\text{HNO}_3(aq)$$
2. **Identify** the state of matter of each substance in the following reaction.
$$\text{Zn}(s) + 2\text{HCl}(aq) \longrightarrow \text{H}_2(g) + \text{ZnCl}_2(aq)$$
3. **Explain** why the reaction of oxygen with iron is a problem, but the reaction of oxygen with aluminum is not.
4. **Explain** the importance of the law of conservation of mass.
5. **Think Critically** Why do you think the copper patina was kept when the Statue of Liberty was restored?

Applying Math

6. **Solve One-Step Equations** When making soap, if 890 g of a specific fat react completely with 120 g of sodium hydroxide, the products formed are soap and 92 g of glycerin. Calculate the mass of soap formed to satisfy the law of conservation of mass.

Chemical Equations

Reading Guide

What You'll Learn

- **Identify** what is meant by a balanced chemical equation.
- **Determine** how to write balanced chemical equations.

Why It's Important

Chemical equations are the language used to describe chemical change, which allow scientists to develop products for our world.

Review Vocabulary

subscript: in a chemical formula, a number below and to the right of a symbol indicating number of atoms

New Vocabulary

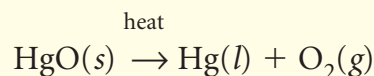
- balanced chemical equation

Figure 7 Mercury metal forms when mercury oxide is heated. Because mercury is poisonous, this reaction is never performed in a classroom laboratory.



Balanced Equations

Lavoisier's mercury(II) oxide reaction, shown in **Figure 7**, can be written as:



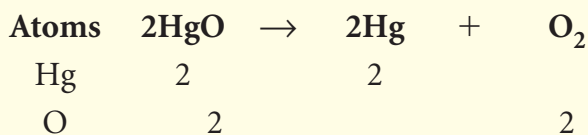
Notice that the number of mercury atoms is the same on both sides of the equation but that the number of oxygen atoms is not the same. One oxygen atom appears on the reactant side of the equation and two appear on the product side.

Atoms	HgO	→	Hg	+	O ₂
Hg	1		1		
O	1				2

But according to the law of conservation of mass, one oxygen atom cannot just become two. Nor can you simply add the subscript 2 and write HgO₂ instead of HgO. The formulas HgO₂ and HgO do not represent the same compound. In fact, HgO₂ does not exist. The formulas in a chemical equation must accurately represent the compounds that react.

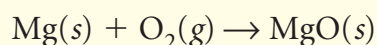
Fixing this equation requires a process called balancing. Balancing an equation doesn't change what happens in a reaction—it simply changes the way the reaction is represented. The balancing process involves changing coefficients in a reaction to achieve a **balanced chemical equation**, which has the same number of atoms of each element on both sides of the equation.

Choosing Coefficients Finding out which coefficients to use to balance an equation is often a trial-and-error process. In the equation for Lavoisier's experiment, the number of mercury atoms is balanced, but one oxygen atom is on the left and two are on the right. If you put a coefficient of 2 before the HgO on the left, the oxygen atoms will be balanced, but the mercury atoms become unbalanced. To balance the equation, also put a 2 in front of mercury on the right. The equation is now balanced.

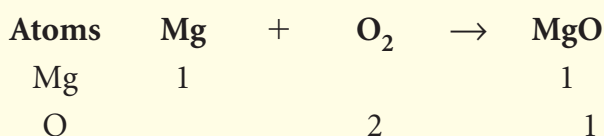


Try Your Balancing Act Magnesium burns with such a brilliant white light that it is often used in emergency flares as shown in **Figure 8**. Burning leaves a white powder called magnesium oxide. To write a balanced chemical equation for this and most other reactions, follow these four steps.

Step 1 Write a chemical equation for the reaction using formulas and symbols. Recall that oxygen is a diatomic molecule.

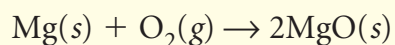


Step 2 Count the atoms in reactants and products.

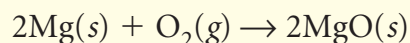


The magnesium atoms are balanced, but the oxygen atoms are not. Therefore, this equation isn't balanced.

Step 3 Choose coefficients that balance the equation. Remember, never change subscripts of a correct formula to balance an equation. Try putting a coefficient of 2 before MgO.



Step 4 Recheck the numbers of each atom on each side of the equation and adjust coefficients again if necessary. Now two Mg atoms are on the right side and only one is on the left side. So a coefficient of 2 is needed for Mg to balance the equation.



Reading Check

How can you balance a chemical equation using coefficients?



Topic: Balancing Chemical Equations

Visit gpscience.com for Web links to information about balancing chemical equations.

Activity Using the Web links, locate a website that offers practice problems for balancing chemical equations. Copy several of the unbalanced equations in your Science Journal and try to balance them. Check your work against the answers on the web site when you are done.



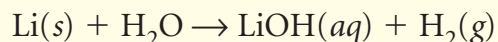
Figure 8 Magnesium combines with oxygen, giving an intense white light.



Figure 9 When lithium metal is added to water, it reacts, producing a solution of lithium hydroxide and bubbles of hydrogen gas.

Polish Your Skill When lithium metal is treated with water, hydrogen gas and lithium hydroxide are produced, as shown in **Figure 9**.

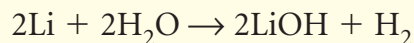
Step 1 Write the chemical equation.



Step 2 Check for balance by counting the atoms.

Atoms	Li	+	H ₂ O	→	LiOH	+	H ₂
Li	1				1		
H			2		1		2
O			1		1		

This equation is not balanced. There are three hydrogen atoms on the right and only two on the left. Complete steps 3 and 4 to balance the equation. After each step, count the atoms of each element. When equal numbers of atoms of each element are on both sides, the equation is balanced. The balanced chemical equation looks like this:



This accurate statement tells chemists how much lithium metal to use to produce a certain amount of hydrogen gas.

section 2 review

Summary

Balanced Equations

- A chemical equation is a way to indicate reactants and products and relative amounts of each.
- A balanced chemical equation tells the exact number of atoms involved in the reaction.
- Balanced chemical equations must satisfy the law of conservation of matter; no atoms of reactant or product can be lost from one side to the other.
- Coefficients are used to achieve balance in a chemical equation.
- Chemical equations cannot be balanced by adjusting the subscript numerals in compound names because doing so would change the compounds.

Self Check

1. **Describe** two reasons for balancing chemical equations.
2. **Balance** this chemical equation: $\text{Fe}(s) + \text{O}_2(g) \rightarrow \text{FeO}(s)$.
3. **Explain** why oxygen gas must always be written as O_2 in a chemical equation.
4. **Infer** What coefficient is assumed if no coefficient is written before a formula in a chemical equation?
5. **Think Critically** Explain why the sum of the coefficients on the reactant side of a balanced equation does not have to equal the sum of the coefficients on the product side of the equation.

Applying Math

6. **Use Numbers** Balance the equation for the reaction $\text{Fe}(s) + \text{Cl}_2(g) \rightarrow \text{FeCl}_3(s)$.

Classifying Chemical Reactions

Emory Kristof/National Geographic Image Collection

Reading Guide

What You'll Learn

- **Identify** the five general types of chemical reactions.
- **Define** the terms *oxidation* and *reduction*.
- **Identify** redox reactions.
- **Predict** which metals will replace other metals in compounds.

Why It's Important

Classifying chemical reactions helps to understand what is happening and predict the outcome of reactions.



Review Vocabulary

states of matter: the physical forms in which all matter naturally exists, most commonly solid, liquid, and gas

New Vocabulary

- combustion reaction
- synthesis reaction
- decomposition reaction
- single-displacement reaction
- double-displacement reaction
- precipitate
- oxidation
- reduction

Types of Reactions

You might have noticed that there are all sorts of chemical reactions. In fact, there are literally millions of chemical reactions that occur every day, and scientists have described many of them and continue to describe more. With all these reactions, it would be impossible to use the information without first having some type of organization. With this in mind, chemists have defined five main categories of chemical reactions: combustion, synthesis, decomposition, single displacement, and double displacement.

Combustion Reactions If you have ever observed something burning, you have observed a combustion reaction. As mentioned previously, Lavoisier was one of the first scientists to accurately describe combustion. He deduced that the process of burning (combustion) involves the combination of a substance with oxygen. Our definition states that a **combustion reaction** occurs when a substance reacts with oxygen to produce energy in the form of heat and light. Combustion reactions also produce one or more products that contain the elements in the reactants. For example, the reaction between carbon and oxygen produces carbon dioxide. Many combustion reactions also will fit into other categories of reactions. For example, the reaction between carbon and oxygen also is a synthesis reaction.

Figure 10 Rust has accumulated on the *Titanic* since it sank in 1912.





Figure 11 Water decomposes into hydrogen and oxygen when an electric current is passed through it. A small amount of sulfuric acid is added to increase conductivity. Notice the proportions of the gases collected.

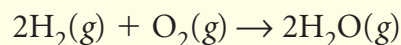
Describe how this is related to the coefficients of the products in the equation.



Figure 12 Copper in a wire replaces silver in silver nitrate, forming a blue-tinted solution of copper(II) nitrate.

Synthesis Reactions One of the easiest reaction types to recognize is a synthesis reaction. In a **synthesis reaction**, two or more substances combine to form another substance. The generalized formula for this reaction type is as follows: $A + B \rightarrow AB$.

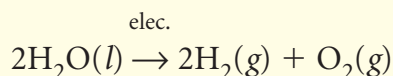
The reaction in which hydrogen burns in oxygen to form water is an example of a synthesis reaction.



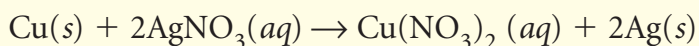
This reaction is used to power some types of rockets. Another synthesis reaction is the combination of oxygen with iron in the presence of water to form hydrated iron(II) oxide or rust. This reaction is shown in **Figure 10**.

Decomposition Reactions A decomposition reaction is just the reverse of a synthesis. Instead of two substances coming together to form a third, a **decomposition reaction** occurs when one substance breaks down, or decomposes, into two or more substances. The general formula for this type of reaction can be expressed as follows: $AB \rightarrow A + B$.

Most decomposition reactions require the use of heat, light, or electricity. For example, an electric current passed through water produces hydrogen and oxygen as shown in **Figure 11**.



Single Displacement When one element replaces another element in a compound, it is called a **single-displacement reaction**. Single-displacement reactions are described by the general equation $A + BC \rightarrow AC + B$. Here you can see that atom A displaces atom B to produce a new molecule AC. A single displacement reaction is illustrated in **Figure 12**, where a copper wire is put into a solution of silver nitrate. Because copper is a more active metal than silver, it replaces the silver, forming a blue copper(II) nitrate solution. The silver, which is not soluble, forms on the wire.



Reading Check

Describe a single-displacement reaction.

Sometimes single-displacement reactions can cause problems. For example, if iron-containing vegetables such as spinach are cooked in aluminum pans, aluminum can displace iron from the vegetable. This causes a black deposit of iron to form on the sides of the pan. For this reason, it is better to use stainless steel or enamel cookware when cooking spinach.

We can predict which metal will replace another using the diagram shown in **Figure 13**, which lists metals according to how reactive they are. A metal will replace any less active metal. Notice that copper, silver, and gold are the least active metals on the list. That is why these elements often occur as deposits of the relatively pure element. For example, gold is sometimes found as veins in quartz rock, and copper is found in pure lumps known as native copper. Other metals occur as compounds.

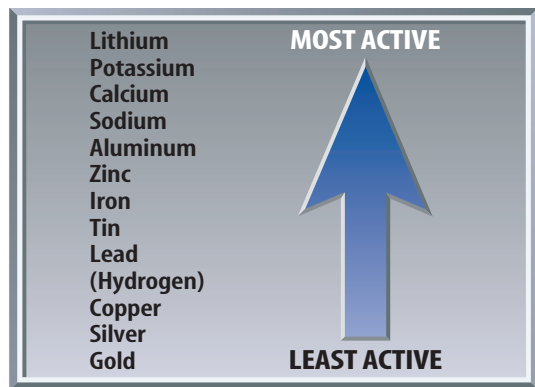
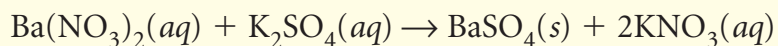


Figure 13 This figure shows the activity series of metals. A metal will replace any other metal that is less active.

Double Displacement In a **double-displacement reaction**, the positive ion of one compound replaces the positive ion of the other to form two new compounds. A double-displacement reaction takes place if a precipitate, water, or a gas forms when two ionic compounds in solution are combined. A **precipitate** is an insoluble compound that comes out of solution during this type of reaction. The generalized formula for this type of reaction is as follows: $AB + CD \rightarrow AD + CB$.

 **Reading Check** What type of reaction produces a precipitate?

The reaction of barium nitrate with potassium sulfate is an example of this type of reaction. A precipitate—barium sulfate—forms, as shown in **Figure 14**. The chemical equation is as follows:



These are a few examples of chemical reactions classified into types. Many more reactions of each type occur around you.

Figure 14 Solid barium sulfate is formed from the reaction of two solutions.

Observe Has a chemical change occurred in this photo? How can you tell?

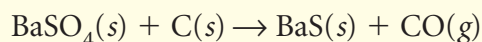


Applying Science

BALANCING EQUATIONS A sample of barium sulfate is placed on a piece of paper, which is then ignited. Barium sulfate reacts with the carbon from the burned paper producing barium sulfide and carbon monoxide. Write a balanced chemical equation for this reaction.

IDENTIFY known values

We know the substances that are involved in the reaction. From this, we can write a chemical equation showing reactants and products.

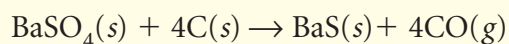


SOLVE the problem

The chemical equation above is not balanced. There are more oxygen atoms on the left side of the equation than there are on the right side. This must be corrected while keeping all other atom counts in balance. Begin to balance the equation by first counting and listing the atoms on the before and after the reaction.

Kind of Atom	Number of Atoms Before Reaction	Number of Atoms After Reaction
Ba	1	1
S	1	1
O	4	1
C	1	1

Next, adjust the coefficients until all atoms are balanced on the left and right sides of the arrow. Try putting a 4 in front of CO. Now you have 4 oxygen atoms on the right, which balances on both sides, but the carbon atoms become unbalanced. To fix this, add a 4 in front of the C in the reactants. The balanced equation looks like this:



CHECK the answer

Review the number of atoms on each side of the equation and verify that they are equal.

Practice Problems

1. HCl is slowly added to aqueous Na_2CO_3 forming NaCl, H_2O , and CO_2 . Follow the steps above to write a balanced equation for this reaction.
2. Balance this equation: $\text{NaOH}(aq) + \text{CaBr}_2(aq) \rightarrow \text{Ca}(\text{OH})_2(s) + \text{NaBr}(aq)$.

For more practice problems, go to page 834 and visit gpscience.com/extra_problems.

Oxidation-Reduction Reactions One characteristic that is common to many chemical reactions is the tendency of the substances to lose or gain electrons. Chemists use the term **oxidation** to describe the loss of electrons and the term **reduction** to describe the gain of electrons. Chemical reactions involving electron transfer of this sort often involve oxygen, which is very reactive, pulling electrons from metallic elements. Corrosion of metal is a visible result, as shown in **Figure 15**.

The cause and effect of oxidation and reduction can be taken one step further by describing the substances after the electron transfer. The substance that gains an electron or electrons obviously becomes more negative, so we say it is reduced. On the other hand, the substance that loses an electron or electrons then becomes more positive, and we say it is oxidized. The electrons that were pulled from one atom were gained by another atom in a chemical reaction called reduction. Reduction is the partner to oxidation; the two always work as a pair, which is commonly referred to as redox.



Figure 15 One of the results of all of these electrons moving from one place to another might show up on the metal body of a tanker.

section 3 review

Summary

Types of Reactions

- Chemical reactions are organized into five basic classes: combustion, synthesis, decomposition, single displacement, and double displacement.
- Lavoisier was one of the first scientists to accurately describe a combustion reaction.
- For single-displacement reactions, we can predict which metal will replace another by comparing the activity characteristic of each.
- Some reactions produce a solid called a precipitate when two ionic substances are combined.

Oxidation-Reduction Reactions

- Oxidation is the loss of electrons and reduction is the corresponding gain of electrons.
- Redox reactions often result in corrosion and rust.
- A substance that gains electrons is reduced, and a substance that loses electrons is oxidized.

Self Check

1. **Classify** each of the following reactions:
 - a. $\text{CaO}(s) + \text{H}_2\text{O} \rightarrow \text{Ca}(\text{OH})_2(aq)$
 - b. $\text{Fe}(s) + \text{CuSO}_4(aq) \rightarrow \text{FeSO}_4(aq) + \text{Cu}(s)$
 - c. $\text{NH}_4\text{NO}_3(s) \rightarrow \text{N}_2\text{O}(g) + 2\text{H}_2\text{O}(g)$
2. **Describe** what happens in a combustion reaction.
3. **Explain** the difference between synthesis and decomposition reactions.
4. **Determine**, using **Figure 13**, if zinc will displace gold in a chemical reaction and explain why or why not.
5. **Think Critically** Describe one possible economic impact of redox reactions. How might that impact be lessened?

Applying Math

6. **Use Proportions** The following chemical equation is balanced, but the coefficients used are larger than necessary. Rewrite this balanced equation using the smallest coefficients.

$$9\text{Fe}(s) + 12\text{H}_2\text{O}(g) \rightarrow 3\text{Fe}_3\text{O}_4(s) + 12\text{H}_2(g)$$
7. **Use Coefficients** Sulfur trioxide, (SO_3), a pollutant released by coal-burning plants, can react with water in the atmosphere to produce sulfuric acid, H_2SO_4 . Write a balanced equation for this reaction.

Chemical Reactions and Energy

Reading Guide

What You'll Learn

- **Identify** the source of energy changes in chemical reactions.
- **Compare and contrast** exergonic and endergonic reactions.
- **Examine** the effects of catalysts and inhibitors on the speed of chemical reactions.

Why It's Important

Chemical reactions provide energy to cook your food, keep you warm, and transform the food you eat into substances you need to live and grow.

Review Vocabulary

chemical bond: the force that holds two atoms together

New Vocabulary

- exergonic reaction
- exothermic reaction
- endergonic reaction
- endothermic reaction
- catalyst
- inhibitor

Figure 16 When its usefulness is over, a building is sometimes demolished using dynamite. Dynamite charges must be placed carefully so that the building collapses inward, where it cannot harm people or property.



Chemical Reactions—Energy Exchanges

Often a crowd gathers to watch a building being demolished using dynamite. In a few breathtaking seconds, tremendous structures of steel and cement that took a year or more to build are reduced to rubble and a large cloud of dust. A dynamite explosion, as shown in **Figure 16**, is an example of a rapid chemical reaction.

Most chemical reactions proceed more slowly, but all chemical reactions release or absorb energy. This energy can take many forms, such as thermal energy, light, sound, or electricity. The thermal energy produced by a wood fire and the light emitted by a glow stick are examples of energy release.

Chemical bonds are the source of this energy. When most chemical reactions take place, some chemical bonds in the reactants are broken, which requires energy. In order for products to be produced, new bonds must form. Bond formation releases energy. Reactions such as dynamite combustion require much less energy to break chemical bonds than the energy released when new bonds are formed. The result is a release of energy and sometimes a loud explosion. Another release of energy is used to power rockets, as shown in **Figure 17**.

Figure 17

Rockets burn fuel to provide the thrust necessary to propel them upward. In 1926, engineer Robert Goddard used gasoline and liquid oxygen to propel the first ever liquid-fueled rocket. Although many people at the time ridiculed Goddard's space travel theories, his rockets eventually served as models for those that have gone to the Moon and beyond. A selection of rockets—including Goddard's—is shown here. The number below each craft indicates the amount of thrust—expressed in newtons (N)—produced during launch.

▶ **JUPITER C** This rocket launched the first United States satellite in 1958. It used a fuel called hydyne plus liquid oxygen.

▼ **GODDARD'S MODEL ROCKET** Although his first rocket rose only 12.6 m, Goddard successfully launched 35 rockets in his lifetime. The highest reached an altitude of 2.7 km.



◀ **SPACE SHUTTLE** The main engines produce enormous amounts of energy by combining liquid hydrogen and oxygen. Coupled with solid rocket boosters, they produce over 32.5 million newtons (N) of thrust to lift the system's 2 million kg off the ground.



▼ **LUNAR MODULE** Smaller rocket engines, like those used by the Lunar Module to leave the Moon, use hydrazine-peroxide fuels. The number shown below indicates the fixed thrust from one of the module's two engines; the other engine's thrust was adjustable.



400 N

369,350 N

32,500,000 N

15,920 N

Mini LAB

Creating a Colorful Chemical Reaction

Procedure



1. Pour 5 mL of **water** into a **test tube**.
2. Sprinkle a few crystals of **copper(II) bromide** into the test tube and observe the color change of the crystals.
3. Slowly add more water and observe what happens.

Analysis

1. What color were the copper(II) bromide crystals after you added them to the test tube of water?
2. What color were they when you added more water?
3. What caused this color change?

More Energy Out

You have probably seen many reactions that release energy. Chemical reactions that release energy are called **exergonic** (ek sur GAH nihk) **reactions**. In these reactions less energy is required to break the original bonds than is released when new bonds form. As a result, some form of energy, such as light or thermal energy, is given off by the reaction. The familiar glow from the reaction inside a glow stick, shown in **Figure 18**, is an example of an exergonic reaction, which produces visible light. In other reactions however, the energy given off is thermal energy. This is the case with some heat packs that are used to treat muscle aches and other problems.

Thermal Energy Released When the energy given off is primarily in the form of thermal energy, the reaction is called an **exothermic reaction**. Wood burning and the explosion of dynamite are exothermic reactions. Iron rusting is also exothermic, but, under typical conditions, the reaction proceeds so slowly that it's difficult to detect any temperature change.

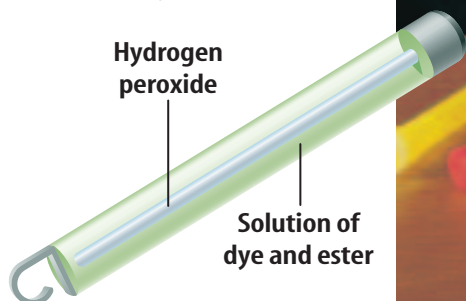


Reading Check

Why is a log fire considered to be an exothermic reaction?

Exothermic reactions provide most of the power used in homes and industries. Fossil fuels that contain carbon, such as coal, petroleum, and natural gas, combine with oxygen to yield carbon dioxide gas and energy. Unfortunately impurities in these fuels, such as sulfur, burn as well, producing pollutants such as sulfur dioxide. Sulfur dioxide combines with water in the atmosphere, producing acid rain.

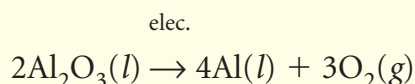
Figure 18 Glow sticks contain three different chemicals—an ester and a dye in the outer section and hydrogen peroxide in a center glass tube. Bending the stick breaks the tube and mixes the three components. The energy released is in the form of visible light.



More Energy In

Sometimes a chemical reaction requires more energy to break bonds than is released when new ones are formed. These reactions are called **endergonic reactions**. The energy absorbed can be in the form of light, thermal energy, or electricity.

Electricity is often used to supply energy to endergonic reactions. For example, electroplating deposits a coating of metal onto a surface, as shown in **Figure 19**. Also, aluminum metal is obtained from its ore using the following endergonic reaction.



In this case, electrical energy provides the energy needed to keep the reaction going.

Thermal Energy Absorbed When the energy needed is in the form of thermal energy, the reaction is called an **endothermic reaction**. The term *endothermic* is not just related to chemical reactions. It also can describe physical changes. The process of dissolving a salt in water is a physical change. If you ever had to soak a swollen ankle in an Epsom salt solution, you probably noticed that when you mixed the Epsom salt in water, the solution became cold. The dissolving of Epsom salt absorbs thermal energy. Thus, it is a physical change that is endothermic.

Some reactions are so endothermic that they can cause water to freeze. One such endothermic reaction is that of barium hydroxide (BaOH_2) and ammonium chloride (NH_4Cl) in water, shown in **Figure 20**. Several drops of water were placed on the board, and when the reaction had taken place for several minutes, the temperature of the water in the beaker was cold enough to freeze the water drops and adhere the wood to the beaker. A cold pack, which contains ammonium nitrate crystals and water, is another example of an endothermic reaction.



Figure 19 Electroplating of a metal is an endergonic reaction that requires electricity. A coating of copper was plated onto this coin.



Figure 20 As an endothermic reaction happens, such as the reaction of barium hydroxide and ammonium chloride, energy from the surrounding environment is absorbed, causing a cooling effect. Here, the reaction absorbs so much thermal energy that a drop of water freezes and the beaker holding the reaction sticks to the wood.



INTEGRATE History

Catalysts Metals, such as platinum and palladium, are used as catalysts in the exhaust systems of automobiles. What reactions do you think they catalyze?

Catalysts and Inhibitors Some reactions proceed too slowly to be useful. To speed them up, a catalyst can be added. A **catalyst** is a substance that speeds up a chemical reaction without being permanently changed itself. When you add a catalyst to a reaction, the mass of the product that is formed remains the same, but it will form more rapidly. The catalyst remains unchanged and often is recovered and reused. Catalysts are used to speed many reactions in industry, such as polymerization to make plastics and fibers.



Reading Check

Why would a catalyst be needed for a chemical reaction?

At times, it is worthwhile to prevent certain reactions from occurring. Substances called **inhibitors** are used to slow down a chemical reaction. The food preservatives BHT and BHA are inhibitors that prevent spoilage of certain foods, such as cereals and crackers.

One thing to remember when thinking about catalysts and inhibitors is that they do not change the amount of product produced. They only change the rate of production. Catalysts increase the rate and inhibitors decrease the rate. Other factors, including concentration, pressure, and temperature, also affect the rate of reaction and must be considered when catalyzing or inhibiting a reaction.

section 4 review

Summary

Chemical Reactions—Energy Exchanges

- Chemical reactions release or absorb energy as chemical bonds are broken and formed.
- The energy of chemical reactions can be in the form of thermal energy, light, sound, and/or electricity.
- Catalysts are used to increase the chemical reaction rate.

Chemical Energy

- Chemical reactions that release energy are called exergonic. Chemical reactions that absorb energy are called endergonic.
- Exothermic reactions give off thermal energy.
- Endothermic reactions absorb energy in the form of thermal energy.
- Exothermic reactions provide most of the power used in homes and industries.

Self Check

1. **Classify** the chemical reaction photosynthesis, which requires energy to proceed, as endergonic or exergonic.
2. **Explain** why a catalyst is not considered a reactant or product in a chemical reaction.
3. **Explain** why crackers containing BHT stay fresh longer than those without it.
4. **Classify** the reaction that makes a firefly glow in terms of energy input or output.
5. **Think Critically** To develop a product that warms people's hands, would you choose an exothermic or endothermic reaction to use? Why?

Applying Math

6. **Calculate** If an endothermic reaction begins at 26°C and loses 2°C per minute, how long will it take to reach 0°C ?
7. **Use Graphs** Create a graph of the data in question 6. After 5 min, what is the temperature of the reaction?

CATALYZED Reaction

A balanced chemical equation tells nothing about the rate of a reaction. One way to affect the rate is to use a catalyst.

Real-World Question

How does the presence of a catalyst affect the rate of a chemical reaction?

Goals

- **Observe** the effect of a catalyst on the rate of reaction.
- **Conclude**, based on your observations, whether the catalyst remained unchanged.

Possible Materials

test tubes (3)	hot plate
test-tube rack	wooden splint
3% hydrogen peroxide, H_2O_2 (15 mL)	beaker of hot water
10-mL graduated cylinder	manganese dioxide, MnO_2
small plastic teaspoon	($\frac{1}{4}$ tsp)
sand ($\frac{1}{4}$ tsp)	

Safety Precautions



WARNING: Hydrogen peroxide can irritate skin and eyes. Wipe up spills promptly. Point test tubes away from other students.

Procedure

1. Label three test tubes and set them in a test-tube stand. Pour 5 mL of hydrogen peroxide into each tube.
2. Place about $\frac{1}{4}$ teaspoon of sand in tube 2 and the same amount of MnO_2 in tube 3.
3. In the presence of a catalyst, H_2O_2 decomposes rapidly producing oxygen gas, O_2 .



Test each tube by: Lighting a wooden splint, blowing out the flame, and inserting the glowing splint into the tube. The splint will relight if oxygen is present.

4. Place all three tubes in a beaker of hot water. Heat on a hot plate until all of the remaining H_2O_2 is driven away and no liquid remains.

Conclude and Apply

1. **Observe** the changes that happened when the solids were added to the tubes.
2. **Infer** which substance, sand or MnO_2 , was the catalyst.
3. **Identify** what remained in each tube after the H_2O_2 was driven away.

Communicating Your Data

Compare your results with those of your classmates and discuss any differences observed. **For more help refer to the Science Skill Handbook.**

Fossil Fuels and Greenhouse Gases

Goals

- **Observe** how you use fossil fuels in your daily life.
- **Gather data** on the process of burning fossil fuels and how greenhouse gases are released.
- **Research** the chemical reactions that produce greenhouse gases.
- **Identify** the importance of fossil fuels and their effect on the environment.
- **Communicate** your findings to other students.

Data Source



Visit gpscience.com/internet_lab for more information about fossil fuels, the chemical reactions that produce greenhouse gases, uses of fossil fuels, their effects on the environment, and data from other students.

Real-World Question

You've probably heard a lot about global warming and the greenhouse effect. According to one theory, certain gases in the atmosphere might be causing Earth's average global temperature to rise. The gases carbon dioxide, nitrous oxide, and methane, known as greenhouse gases, result from chemical reactions with oxygen when fossil fuels, such as coal, oil, and gas, are burned. What are some everyday activities that you do that might involve energy from fossil fuels? Form a hypothesis about how certain activities add greenhouse gases to our atmosphere.

Make a Plan

1. **Observe** the activities of your daily life. How are fossil fuels used each day?
2. **Develop** a way to categorize the different chemical reactions and the greenhouse gases they produce.
3. **Search** reference sources to learn which chemical reactions produce greenhouse gases.
4. **Identify** some activities and functions that do not use fossil fuels.
5. **Infer** if it is possible to never use fossil fuels.



Using Scientific Methods

Follow Your Plan

1. Make sure your teacher approves your plan before you start.
2. **Research** the chemical reactions that are commonly understood to produce greenhouse gases.
3. **Compare** the different reactions and their products.
4. **Record** your data in your Science Journal.

Analyze Your Data

1. **Record** in your Science Journal the activities that scientists believe contribute the greatest amount of greenhouse gases to our atmosphere.
2. **Analyze** the types of chemical reactions that produce greenhouse gases. What types of reactions are they?
3. **Compare** your results with other students. Do your results agree with those of environmental scientists? Why might you have identified different contributors to the greenhouse effect?
4. **Make a table** of your data.

Conclude and Apply

1. **Predict** How do you think your data would be affected if you had performed this experiment 100 years ago?
2. **Infer** What processes in nature might also contribute to the release of greenhouse gases? Compare their impact to that made by fossil fuels.



Communicating Your Data

Find this lab at the link below. Post your data in the table provided. Compare your data to that of other students. Combine your data with that of other students and write an entry in your Science Journal that explains how the production of greenhouse gases could be reduced.

 ScienceOnline

gpscience.com/internet_lab



Accidents in SCIENCE

**SOMETIMES
GREAT
DISCOVERIES
HAPPEN BY
ACCIDENT!**

A Clumsy Move Pays Off

Great scientific discoveries can happen in some very unlikely ways. Most people might not think that an accidental spill left uncleaned would become significant, but that's exactly what led a chemist named Hilaire de Chardonnet (hee LAYR • duh • shar doh NAY) to his discovery. In 1878, Chardonnet accidentally knocked over some nitrate chemicals. He put off cleaning up the mess and ended up inventing artificial silk.

Silk is produced naturally by silkworms. In the mid-1800s, though, silkworms were dying from disease and the silk industry was suffering. Businesses were going under and people were put out of work. Many scientists were working to develop a solution to this problem. Chardonnet had been searching for a silk substitute for years—he just didn't plan to find it by knocking it over!



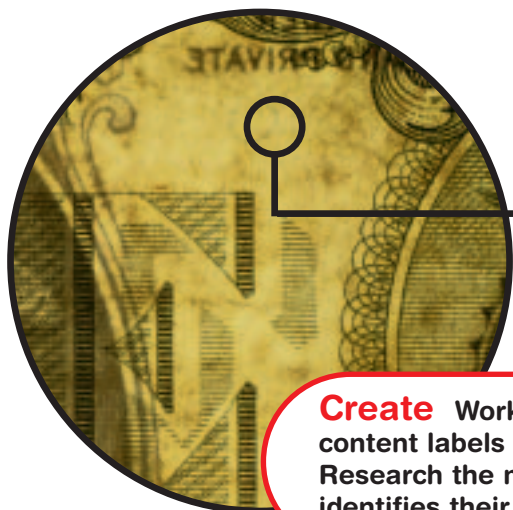
Hilaire de Chardonnet

A Messy Discovery

Chardonnet was in his darkroom developing photographs when the accidental spill took place. He decided to clean up the spill later and finish what he was working on. By the time he returned to wipe up the spill, the chemical solution had turned into a thick, gooey mess. When he pulled the cleaning cloth away, the goop formed long, thin strands of fiber that stuck to the cloth. The chemicals had reacted with the cellulose in the wooden table and liquefied it. The strands of fiber looked just like the raw silk made by silkworms.

Within six years, Chardonnet had developed a way to make the fibers into an artificial silk. Other scientists extended his work, developing a fiber called rayon. Today's rayon is made from sodium hydroxide mixed with wood fibers, which is then stranded and woven into cloth.

Rayon has another real-world application. To help prevent counterfeiting, dollars are printed on paper that contains red and blue rayon fibers. If you can scratch off the red or blue, that means it's ink and your bill is counterfeit. If you can pick out the red or blue fiber with a needle, it's a real bill.



**Rayon
fiber**

Create Work with a partner to examine the fabric content labels on the inside collars of your clothes. Research the materials, then make a data table that identifies their characteristics.

Science online

For more information, visit
gpscience.com/oops

Reviewing Main Ideas

Section 1 Chemical Changes

1. In a chemical reaction, one or more substances are changed to new substances.
2. The substances that react are called reactants, and the new substances formed are called products. Charcoal, the reactant shown below, is almost pure carbon.



3. The law of conservation of mass states that in chemical reactions, matter is neither created nor destroyed, just rearranged.
4. Chemical equations efficiently describe what happens in chemical reactions.

Section 2 Chemical Equations

1. Balanced chemical equations give the exact number of atoms involved in the reaction.
2. A balanced chemical equation has the same number of atoms of each element on both sides of the equation. This satisfies the law of conservation of mass.
3. When balancing chemical equations, change only the coefficients of the formulas, never the subscripts. To change a subscript would change the compound.

Section 3 Classifying Chemical Reactions

1. In synthesis reactions, two or more substances combine to form another substance.
2. In single-displacement reactions, one element replaces another in a compound.
3. In double-displacement reactions, ions in two compounds switch places, often forming a gas or insoluble compound.
4. Using the activity series chart, scientists can determine which metal can replace another metal.

Section 4 Chemical Reactions and Energy

1. Energy in the form of light, thermal energy, sound or electricity is released from some chemical reactions known as exergonic reactions. This flame releases light and thermal energy.
2. Reactions that absorb more energy than they release are called endergonic reactions.
3. Reactions may be sped up by adding catalysts and slowed down by adding inhibitors.
4. When energy is released in the form of thermal energy, the reaction is exothermic.

**FOLDABLES™**

Use the Foldable that you made at the beginning of this chapter to help you review chemical reactions.

Using Vocabulary

balanced chemical equation p. 638	endothermic reaction p. 649
catalyst p. 650	exergonic reaction p. 648
chemical equation p. 635	exothermic reaction p. 648
chemical reaction p. 632	inhibitor p. 650
coefficient p. 636	oxidation p. 645
combustion reaction p. 641	precipitate p. 643
decomposition reaction p. 642	product p. 632
double-displacement reaction p. 643	reactant p. 632
endergonic reaction p. 649	reduction p. 645
	single-displacement reaction p. 642
	synthesis reaction p. 642

For each set of vocabulary words below, explain the relationship that exists.

- coefficient—balanced chemical equation
- synthesis reaction—decomposition reaction
- reactant—product
- catalyst—inhibitor
- exothermic reaction—endothermic reaction
- chemical reaction—product
- endergonic reaction—exergonic reaction
- single-displacement reaction—double-displacement reaction
- chemical reaction—synthesis reaction
- oxidation—reduction

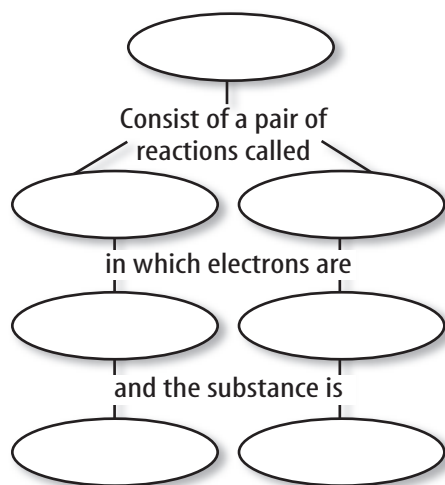
Checking Concepts

Choose the word or phrase that best answers the question.

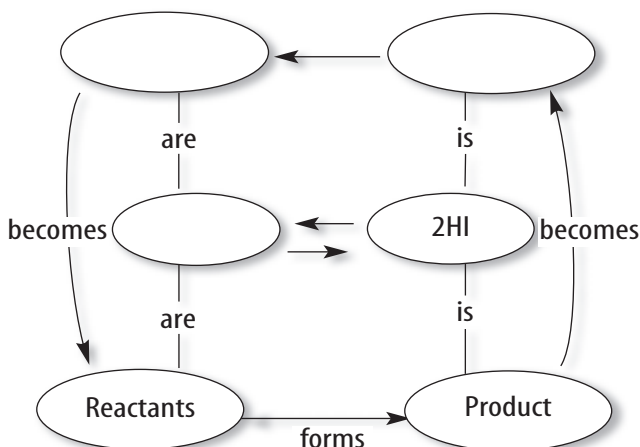
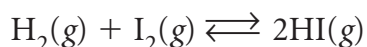
- Oxygen gas is always written as O_2 in chemical equations. What term is used to describe the “2” in this formula?
A) product C) catalyst
B) coefficient D) subscript
- What law is based on the experiments of Lavoisier?
A) coefficients C) chemical reaction
B) gravity D) conservation of mass
- What must an element be in order to replace another element in a compound?
A) more reactive C) more inhibiting
B) less reactive D) less inhibiting
- How do you indicate that a substance in an equation is a solid?
A) (l) C) (s)
B) (g) D) (aq)
- What term is used to describe the “4” in the expression $4\text{Ca}(\text{NO}_3)_2$?
A) coefficient C) subscript
B) formula D) symbol
- What type of compound is the food additive BHA?
A) catalyst C) inhibitor
B) oxidized D) reduced
- How do you show that a substance is dissolved in water when writing an equation?
A) (aq) C) (g)
B) (s) D) (l)
- What word would you use to describe HgO in the reaction that Lavoisier used to show conservation of mass?
A) catalyst C) product
B) inhibitor D) reactant
- When hydrogen burns, what is oxygen’s role?
A) catalyst C) product
B) inhibitor D) reactant
- What kind of chemical reaction involves one substance losing an electron and another substance gaining an electron?
A) combustion C) redox
B) decomposition D) synthesis

Interpreting Graphics

21. Copy and complete the concept map using the following terms: *oxidized*, *redox reactions*, *lost*, *reduced*, *oxidation*, *gained*, and *reduction*.



22. Sometimes a bond formed in a chemical reaction is weak and the product breaks apart as it forms. This is shown by a double arrow in chemical equations. Copy and complete the concept map, using the words *product(s)* and *reactant(s)*. In the blank in the center, fill in the formulas for the substances appearing in the reversible reaction.



Thinking Critically

23. Write a balanced chemical equation for the reaction of propane $\text{C}_3\text{H}_8(\text{g})$ burning in oxygen to form carbon dioxide and water vapor.
24. Interpret the balanced chemical equation from question 23 to explain the law of conservation of mass.
25. Hypothesize Zn is placed in a solution of $\text{Cu}(\text{NO}_3)_2$ and Cu is placed in a $\text{Zn}(\text{NO}_3)_2$ solution. In which of these will a reaction occur?
26. Predict what kind of energy process happens when lye, $\text{NaOH}(\text{s})$, is put in water and the water gets hot.
27. Recognize Cause and Effect Sucrose, or table sugar, is a disaccharide. This means that sucrose is composed of two simple sugars chemically bonded together. Sucrose can be separated into its components by heating it in an aqueous sulfuric acid solution. Research what products are formed by breaking up sucrose. What role does the acid play?
28. Classify Make an outline with the general heading *Chemical Reactions*. Include the five types of reactions, with a description and example of each.

Applying Math

29. Interpret Data When 46 g of sodium were exposed to dry air, 62 g of sodium oxide formed. How many grams of oxygen from the air were used?
30. Calculate Mass Chromium is produced by reacting its oxide with aluminum. If 76 g of Cr_2O_3 and 27 g of Al completely react to form 51 g of Al_2O_3 , how many grams of Cr are formed?

Part 1 Multiple Choice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

Use the photograph below to answer questions 1 and 2.



1. The photograph above shows a chemical reaction in which water decomposes into hydrogen gas and oxygen gas when an electric current is passed through it. Which of the following is the correct chemical equation for this reaction?

A. $\text{H}_2\text{O}(l) \rightarrow \text{H}_2(g) + \text{O}(g)$
 B. $\text{H}_2\text{O}(l) \rightarrow 2\text{H}(g) + \text{O}(g)$
 C. $2\text{H}_2\text{O}(l) \rightarrow 2\text{H}_2(g) + 2\text{O}(g)$
 D. $2\text{H}_2\text{O}(l) \rightarrow 2\text{H}_2(g) + \text{O}_2(g)$

2. Which of the following is the correct classification for the chemical reaction shown in the photograph?

A. synthesis
 B. decomposition
 C. single displacement
 D. double displacement

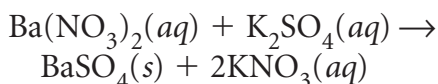
Test-Taking Tip

Missing Information Questions often will ask about missing information. Notice what is missing as well as what is given.

3. Which of the following types of reaction is the opposite of a synthesis reaction?

A. displacement C. combustion
 B. reversible D. decomposition

4. Which substance is the precipitate in the following reaction?

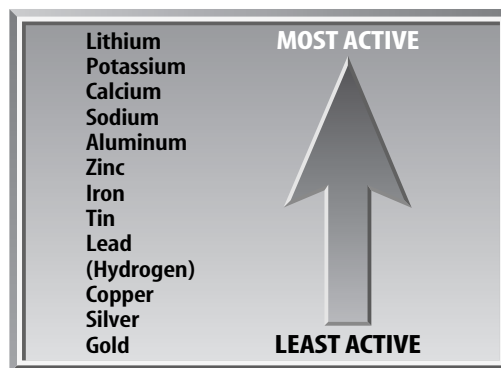


A. $\text{Ba}(\text{NO}_3)_2$ C. BaSO_4
 B. K_2SO_4 D. KNO_3

5. Which of the following reactions is endothermic?

A. iron rusting
 B. burning wood
 C. exploding dynamite
 D. mixing Epsom salt in water

Use the figure below to answer questions 6 and 7.



6. Which of the metals in the activity series shown above would you expect to be mostly found in nature as a deposit of a relatively pure element?

A. copper C. silver
 B. lithium D. iron

7. Which of the following metals would most likely replace lead in a solution?

A. potassium C. silver
 B. copper D. gold

Part 2 Short Response/Grid In

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

8. What is a synthesis reaction?
9. What is the source of the heat, light, sound, and electricity that can be produced during a chemical reaction?

Use the photograph below to answer questions 10 and 11.



10. The photograph above shows the reaction of aqueous nickel(II) chloride, NiCl_2 , and aqueous sodium hydroxide, NaOH , to form solid nickel(II) hydroxide, $\text{Ni}(\text{OH})_2$, and aqueous sodium chloride, NaCl . Write a balanced chemical equation for this reaction.
11. State the conservation of mass as it applies to the chemical reaction in the photograph above.
12. What do the symbols *s*, *aq*, *g*, and *l* mean when they are placed in parentheses next to the formulas for substances in chemical equations?
13. Food preservatives are a type of inhibitor. Explain why this is useful in foods.
14. What are the substances that react and the substances that are produced in a chemical reaction called?

Part 3 Open Ended

Record your answers on a sheet of paper.

Use the photograph below to answer questions 15 and 16.



15. The photograph above shows a chemical reaction between, Mg , and oxygen gas, O_2 . This reaction is exergonic and exothermic. Explain what these terms mean and how you can tell that a chemical reaction is exergonic or exothermic.
16. The reaction of magnesium and oxygen gas forms magnesium oxide, MgO . Write chemical equation for this reaction and explain the process you use to balance the equation.
17. Name and describe three notations that may be used above the arrow in a chemical equation.
18. Explain what is wrong with the following balanced equation:

$$4\text{Al}(s) + 6\text{O}(g) \rightarrow 2\text{Al}_2\text{O}_3(s)$$

What is the correct form of the equation?
19. What is a double-displacement reaction? Describe the double-displacement reaction shown in the following chemical equation in which lead nitrate, $\text{Pb}(\text{NO}_3)_2$, and potassium iodide, KI , react to form lead iodide, PbI_2 , and potassium nitrate, KNO_3 .

$$\text{Pb}(\text{NO}_3)_2 + 2\text{KI} \rightarrow \text{PbI}_2 + 2\text{KNO}_3$$