After you read this section, you should be able to answer these questions:

- How is energy involved in a chemical reaction?
- What are exothermic and endothermic reactions?
- How fast do chemical reactions occur?

What Happens to Energy During a Reaction?

Chemical energy is part of all chemical reactions. Energy is needed to break chemical bonds in reactants. Energy is released as new bonds form. You can find out if more energy is absorbed or released in the reaction. You do this by comparing the chemical energy of the products to the chemical energy of the reactants.

EXOTHERMIC REACTIONS

A reaction that gives off energy is an exothermic reaction. Exo means “go out” or “exit.” Thermic means “heat” or “energy.” During an exothermic reaction, energy is released into the surroundings. Exothermic reactions can give off energy in several forms, such as light, heat, and electricity. The energy released by a reaction is sometimes included in the chemical equation. For example,

\[ 2Na + Cl_2 \rightarrow 2NaCl + \text{energy} \]

Types of Energy Released in Exothermic Reactions

- **Light energy** is released in the exothermic reaction that is taking place in these light sticks.
- **Electrical energy** is released in the exothermic reaction that will take place in this battery.
- **Light and thermal energy** are released in the exothermic reaction taking place in this campfire.
ENDOTHERMIC REACTIONS

A reaction that takes in energy is an endothermic reaction. Endo means “go in.” During an endothermic reaction, energy is taken in from the surroundings.

The energy in endothermic reactions can be in several forms. Some reactions take in light energy. For example, plants use light energy to make food during the process of photosynthesis. Photosynthesis is an endothermic reaction.

\[6\text{CO}_2 + 6\text{H}_2\text{O} + \text{energy} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2\]

Electric energy is used to decompose water. An electric current is passed through water producing hydrogen and oxygen gases.

Some endothermic reactions take in heat energy. In the figure, the reaction in the flask is endothermic. The reaction in the flask absorbs energy from the water between the wood and the flask, causing it to freeze.

Where Does the Energy Go?

The law of conservation of energy states that energy cannot be created or destroyed. However, energy can change forms. Energy can move from one object to another. For example, the chemical reaction between gasoline and oxygen in a car engine makes parts of the engine move. The energy changes from chemical energy to kinetic energy, the energy of motion.

The energy given off in an exothermic reaction was once contained in the chemical bonds in the original substances. The energy taken in during an endothermic reaction is stored in the bonds in the new substances.
How Fast Do Reactions Occur?

A chemical reaction happens only if reactant particles collide. Even when they do collide, a reaction can occur only if there is enough energy to break chemical bonds. How fast reactants break apart and products form is called the rate of a reaction.

A boost of energy is necessary to start a reaction. This boost is called activation energy. Activation energy is the smallest amount of energy that molecules need to react.

An example of activation energy is striking a match. The match contains all of the reactants needed to cause the match to start burning. A match can be kept for many years, but it does not start burning by itself. As soon as you strike it against a surface, a chemical reaction starts. Striking the match on the box causes friction. Heat from this friction provides activation energy to start the reaction.

The figure below shows energy diagrams for an exothermic and an endothermic reaction. See that the reactants gain the activation energy and form the products of the reaction. Also see that the energy change, energy given off or absorbed, is the difference in energy between reactants and products.

Energy Diagrams

**Exothermic Reaction** After the activation energy is supplied, an exothermic reaction continues. The energy given off by the reaction continues to supply more activation energy.

**Endothermic Reaction** The reaction keeps absorbing energy. Energy must be constantly supplied to keep the reaction going.

**READ CHECK**

5. Describe What must happen to reactant particles for a reaction to occur?

**Say It**

Discuss With a partner, discuss chemical reactions you both are familiar with and identify the source of the activation energy for each.

**TAKE A LOOK**

6. Describe The activation energy is always the energy gain between what two points on an energy diagram?

7. Identify For an endothermic reaction, do reactants or products have more energy?
What Factors Affect Reaction Rates?

The rate of a reaction measures how fast the reaction takes place. It depends on how fast particles break apart and how fast new particles form. There are four factors that affect the rate of a reaction:

- temperature
- surface area
- concentration
- inhibitors or catalysts

TEMPERATURE

Higher temperature causes a faster rate of reaction. At higher temperatures, particles of the reactant move faster. That means that they collide more often and they have more energy. Because the particles have more energy, more collisions provide the activation energy to react. As temperature goes up, more reactants change to products in a shorter time. ✓

The figure shows the effect of temperature on a reaction. The chemical reaction inside the light stick produces energy as light. A faster reaction makes a brighter light.

SURFACE AREA

Surface area is the amount of exposed surface of a substance. Increasing the surface area of solid reactants increases the rate of a reaction. For example, cutting wood into small pieces or grinding it into a powder increases surface area. Small pieces of wood or sawdust burn fast. ✓

A larger surface area means that more particles of the reactant are exposed to particles of other reactants. As a result, there are more collisions between particles. More collisions increase the rate of reaction.
CONCENTRATION

Concentration is the amount of one substance dissolved in another. The figure below shows the difference in the number of particles at different concentrations.

**Concentration of Solutions**

![Image showing difference in concentration](image)

When the concentration is high, the average distance between ions from copper sulfate is small. When the concentration is low, the average distance between ions from copper sulfate is large.

Usually, a high concentration of reactants causes a faster rate of reaction. The distance between particles is smaller, so collisions happen more often. The particles collide more often and react faster. ✓

INHIBITORS

Sometimes, it is useful to slow a chemical reaction. For example, it can be helpful to slow a reaction that causes iron to rust. An inhibitor is a substance that slows down or stops a chemical reaction.

Preservatives are inhibitors that are added to foods to slow down the growth of bacteria and fungi. The preservatives slow down reactions in cells and keep them from making substances that spoil food. Some antibiotics are inhibitors.

CATALYSTS.

Some reactions are more useful if they can be made to occur faster. A catalyst is a substance that speeds up a reaction without being permanently changed. That means that a catalyst is not a reactant. ✓

A catalyst works by lowering the activation energy of a reaction. Lower activation energy means that the reaction will occur more quickly. Catalysts called enzymes speed up reactions inside your body. The catalytic converter in a car speeds up reactions that destroy harmful products from the car engine.

**READING CHECK**

10. Describe What is the effect of higher concentration of reactants on reaction rate?

11. Compare How do catalysts differ from inhibitors?
1. Compare  How are exothermic reactions different from endothermic reactions?

2. Explain  What happens to energy when a chemical bond forms? What happens to energy when a chemical bond is broken?

3. List  Give one example of an exothermic reaction and one example of an endothermic reaction.

4. Interpret Graphics  Does this energy diagram show an exothermic reaction or an endothermic reaction? How can you tell?

5. Apply Concepts  How does chewing your food well speed up the reactions in your digestive system?
3. chemical bond
4. When water boils, a new substance is not formed. The water vapor that forms during boiling can condense into liquid water.
5. The chemical properties of the material in the beaker are different from those of the original substances. This shows that a chemical reaction must have occurred.

SECTION 2 CHEMICAL FORMULAS AND EQUATIONS
1. the elements found in a substance and how many atoms of each element are in a molecule
2. three
3. PCl₃
4. 3+
5. a short way to show what happens in a chemical reaction using symbols and formulas
6. Reactants: C, O₂
   Products: CO₂
7. If you use the wrong chemical formula, a chemical equation will not describe the reaction you are trying to describe.
8. A chemical equation shows that no atoms are lost or gained during a chemical reaction.
9. a number that is placed in front of a chemical formula
10. subscripts
11. 2Na + Cl₂ → 2NaCl

Review
1. A chemical formula represents a substance. A chemical equation represents a chemical reaction.

<table>
<thead>
<tr>
<th>Chemical equation</th>
<th>Number of atoms in the reactants</th>
<th>Number of atoms in the products</th>
<th>Is the equation balanced?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na + Cl₂ → NaCl</td>
<td>Na = 1 Cl = 2</td>
<td>Na = 1 Cl = 1</td>
<td>no</td>
</tr>
<tr>
<td>HCl + NaOH → NaCl + H₂O</td>
<td>H = 2 Cl = 1</td>
<td>H = 2 Cl = 1</td>
<td>yes</td>
</tr>
<tr>
<td>2Sb + 3I₂ → 2SbI₅</td>
<td>Sb = 2 I = 6</td>
<td>Sb = 2 I = 6</td>
<td>yes</td>
</tr>
</tbody>
</table>

3. SiO₂: silicon dioxide
   SbF₅: antimony trifluoride
4. Changing the subscripts changes the substance in the chemical reaction. Therefore, if you change subscripts, you change the chemical reaction that you are describing.
5. 3Mg + N₂ → Mg₃N₂

SECTION 3 TYPES OF CHEMICAL REACTIONS
1. a reaction in which two or more substances combine to form a new compound
2. C → A + B
3. a new compound and the replaced element
4. more reactive
5. synthesis, decomposition, single-displacement, and double-displacement reactions

Review
1. synthesis and decomposition.
2. Synthesis is the combination of two or more substances to make a new substance. The new substance cannot be an element, because it is a combination of at least two elements.
3. double-displacement, decomposition, synthesis
4. Aluminum must be less reactive than calcium. In a single displacement reaction, a more reactive element replaces a less reactive element.
5. It appears to be a double-displacement reaction. A precipitate is often an indication that a new substance formed by the exchange of ions between two compounds in the solutions.

SECTION 4 ENERGY AND RATES OF CHEMICAL REACTIONS
1. It is released into the surroundings.
2. It is absorbed from the surroundings.
3. heat, light, and electricity
4. Energy cannot be created or destroyed.
5. They must collide.
6. the reactants to the highest point on the curve
7. products
8. Reactions occur faster at higher temperatures.
9. It increases the rate of reaction.
10. The reaction rate is faster.
11. Catalysts speed up reactions, and inhibitors slow or stop them.
Review

1. Exothermic reactions give off energy. Endothermic reactions take in energy.
2. Energy is released when a chemical bond forms. Energy is consumed when a chemical bond breaks.
3. Possible answer: exothermic—fire, endothermic—photosynthesis
4. It is an exothermic reaction because the products have less energy than the reactants.
5. Chewing increases surface area of the food.

Chapter 15 Chemical Compounds

SECTION 1 IONIC AND COVALENT COMPOUNDS

1. what happens to the valence electrons
2. Metals form positively charged ions, and nonmetals form negatively charged ions.
3. A crystal lattice is a pattern. Each ion in the pattern bonds to the oppositely charged ions around it.
4. They have strong bonds that hold the ions together.
5. They conduct an electric current because their ions are now free to move past each other.
6. Covalent compounds often are not soluble in water, have low melting points, and form water solutions that don’t conduct electricity.

Review

1. Ionic compounds have a much higher melting point than covalent compounds.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Property</th>
<th>Ionic or covalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>low melting point</td>
<td>covalent</td>
</tr>
<tr>
<td>B</td>
<td>molecule as smallest particle</td>
<td>covalent</td>
</tr>
<tr>
<td>C</td>
<td>water solution that conducts an electric current</td>
<td>ionic</td>
</tr>
<tr>
<td>D</td>
<td>high melting point</td>
<td>ionic</td>
</tr>
</tbody>
</table>

3. Ionic compounds break apart easily because they bond together in a pattern called a crystal lattice. If you hit an ionic compound, the ions move and the pattern changes. Ions that have the same charge line up and repel each other.
4. When the crystals dissolve in water, ions become free to move.

5. Each atom of the metal loses one or more electrons to atoms of the nonmetal. The metal atoms form positive ions, and the nonmetal atoms form negative ions. The oppositely charged ions attract, forming ionic bonds.

SECTION 2 ACIDS AND BASES

1. A hydrogen ion bonds with a water molecule to form the hydronium ion.
2. sour taste
3. The left beaker should be colored blue, and the right beaker yellow.
4. hydrogen gas and zinc chloride
5. ions
6. making fertilizers
7. Acids produce hydronium ions, and bases produce hydroxide ions.
8. hydroxide ions
9. It could hurt you because chemicals such as acids and bases can be corrosive or poisonous.
10. The left beaker should be colored pale blue, and the right beaker dark blue.
11. blue
12. household cleaners and fertilizers

Review

1. Acids produce hydronium (H\(_3\)O\(^+\)) ions, and bases produce hydroxide (OH\(^-\)) ions.

2. Property | Acids | Bases
---|---|---
Taste | sour | bitter
Color change of litmus paper | to red | to blue
Reaction with metals to produce hydrogen gas | yes | no
Electrical conductivity | yes | yes

3. hydronium
4. No, because acids and bases both conduct electricity.
5. It turns blue because ammonia is a base.
6. The acid or base is corrosive.
7. A base; rinse them with lots of water and tell the teacher.

SECTION 3 SOLUTIONS OF ACIDS AND BASES

1. the amount of acid or base dissolved in water