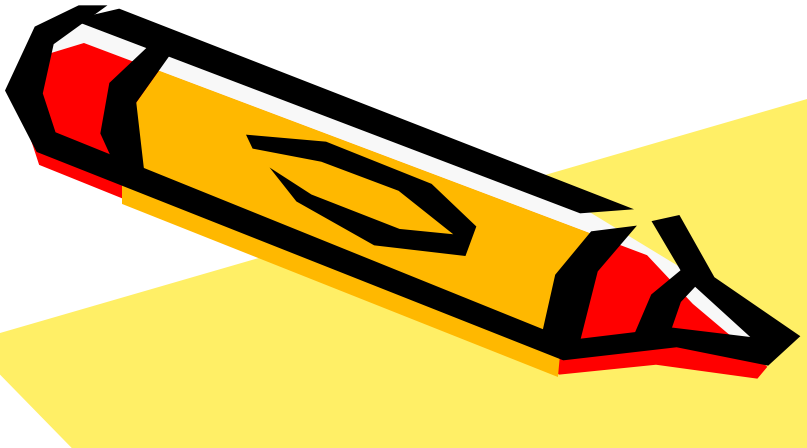


Chapter 7
Chemical Reactions

7.1 Describing Reactions

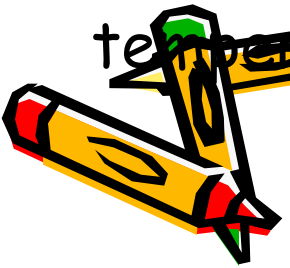
Pretest

1. Which of the following is an example of a physical change?

a. Wood burns and becomes ash.
b. A steel nail rusts over time.
c. Ice melts and becomes water.
d. Milk curdles when acid is added to it.

2. Which of the following characteristics can you determine about a substance based on its chemical formula?

a. the number and types of atoms that make up the substance
b. the mass of an unknown sample of the substance
c. the melting point of the substance
d. the density and state of the substance at room temperature



Pretest *(continued)*

3. How do you find the atomic mass of an element?

4. Which conversion factor would you multiply 0.020 m by in order to express the quantity in centimeters?

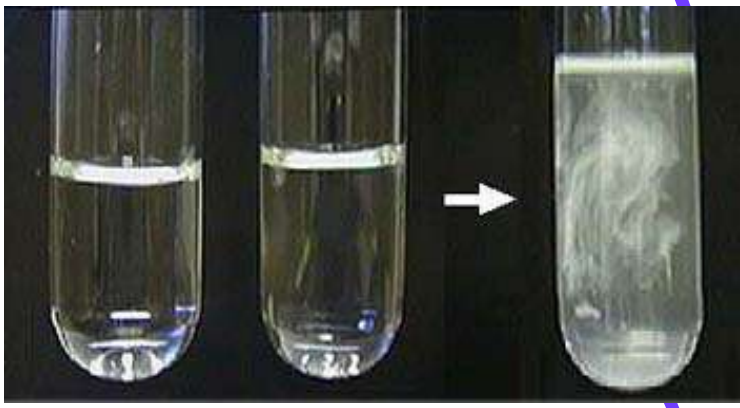
a. 1000 m/1 km
b. 1 km/1000 m
c. 1 m/100 cm
d. 100 cm/1 m

5. Which is the correct chemical formula for potassium hydroxide?

a. POH **b.** KOH
c. P_5OH **d.** K_2OH

Signs of Reactions

- Production of a gas
- Production of a solid (precipitate)
- Change in color
- Change in energy



Chemical Equations

The law of conservation of mass states that mass is neither created nor destroyed in a chemical reaction.

Chemical Equations

The substances that undergo change are called reactants.

- **The new substances formed as a result of that change are called products.**
- **Reactants → Products**

Chemical Equations

To describe the burning of charcoal, you can write reactants and products of the reaction in the following word equation.

Carbon + Oxygen → Carbon dioxide

Write the reactants and products as chemical formulas.

Chemical Equations

A chemical equation is a representation of a chemical reaction in which the reactants and products are expressed as formulas. You can read the equation $C + O_2 \rightarrow CO_2$ as

- **"Carbon and oxygen react and form carbon dioxide," or,**
- **"The reaction of carbon and oxygen yields carbon dioxide."**

Chemical Equations

Conservation of Mass

During chemical reactions, the mass of the products is always equal to the mass of the reactants. This principle is the law of conservation of mass.

Balancing Equations

- **Why must chemical equations be balanced?**
- **In order to show that mass is conserved during a reaction, a chemical equation must be balanced.**

Balancing Equations

You can balance a chemical equation by changing the coefficients, the numbers that appear before the formulas.

$2H_2O$ means there are two water molecules; a total of 4 Hydrogen atoms and 2 Oxygen atoms

Balancing Equations

Balancing Chemical Equations

Write a balanced equation for the reaction between copper and oxygen to produce copper(II) oxide, CuO.

$$Cu + O \rightarrow CuO$$

You must consider the oxidation numbers for each element (Cu^{+2} and O^{-2}) to determine how many atoms of each are needed.

Examples

1) $H_2 + O_2 \rightarrow H_2O_2$
2) $CH_4 + O_2 \rightarrow CO_2 + H_2O$

Examples

1) $H_2 + O_2 \rightarrow H_2O_2$ is balanced

2) $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

Practice

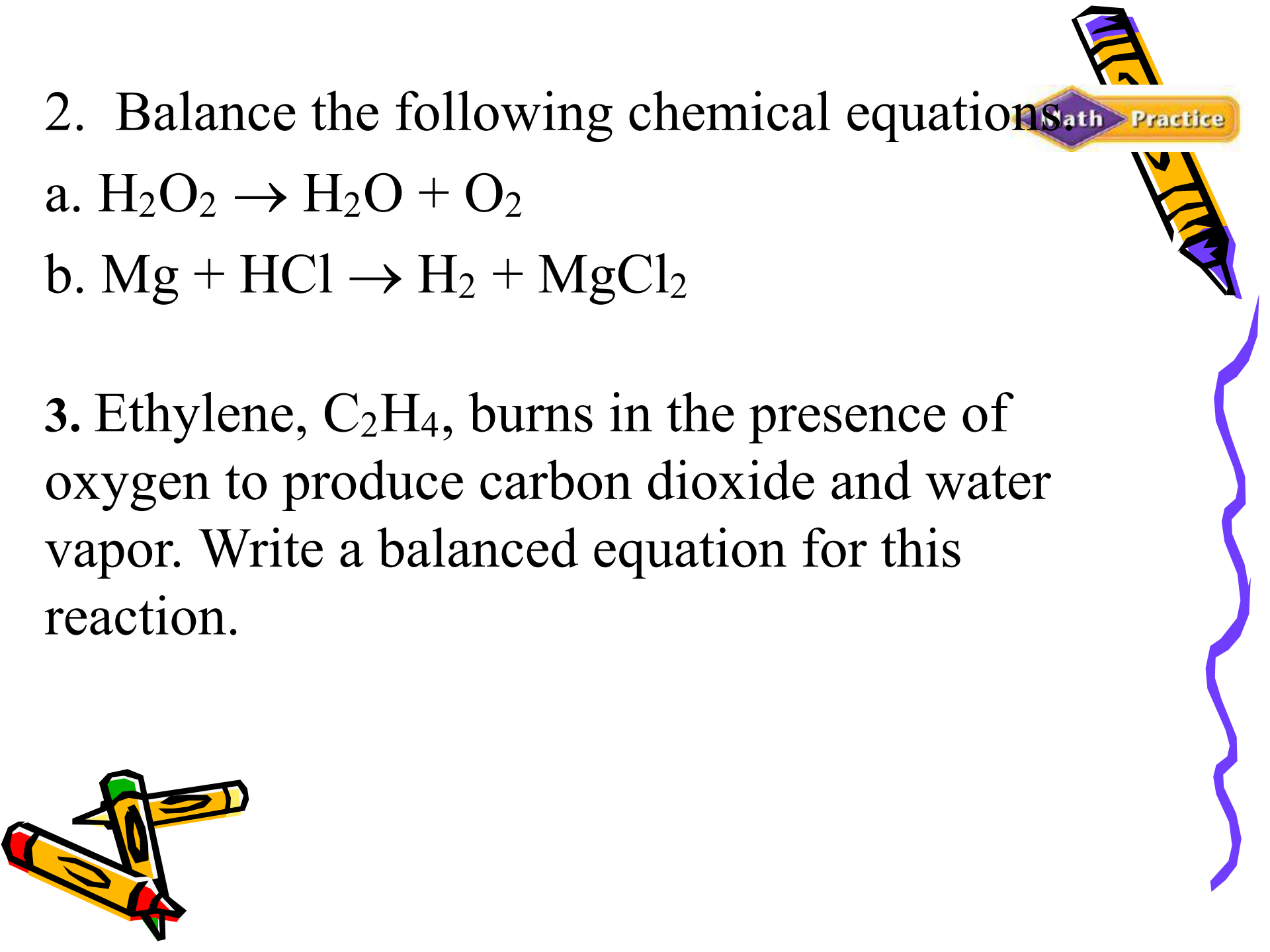
1) $BaCl_2 + H_2SO_4 \rightarrow BaSO_4 + HCl$
2) $P + O_2 \rightarrow P_4O_{10}$
3) $KClO_3 \rightarrow KCl + O_2$
4) $Cu + AgNO_3 \rightarrow Cu(NO_3)_2 + Ag$

Practice

1) $BaCl_2 + H_2SO_4 \rightarrow BaSO_4 + 2HCl$
2) $4P + 5O_2 \rightarrow P_4O_{10}$
3) $2KClO_3 \rightarrow 2KCl + 3O_2$
4) $Cu + 2AgNO_3 \rightarrow Cu(NO_3)_2 + 2Ag$

1. Hydrogen chloride, or HCl, is an important industrial chemical. Write a balanced equation for the production of hydrogen chloride from hydrogen and chlorine.

$H_2 + Cl_2 \rightarrow 2HCl$



2. Balance the following chemical equations.

a. $H_2O_2 \rightarrow H_2O + O_2$

b. $Mg + HCl \rightarrow H_2 + MgCl_2$

3. Ethylene, C_2H_4, burns in the presence of oxygen to produce carbon dioxide and water vapor. Write a balanced equation for this reaction.

2. Balance the following chemical equations.

a. $2H_2O_2 \rightarrow 2H_2O + O_2$

b. $Mg + 2HCl \rightarrow H_2 + MgCl_2$

3. Ethylene, C_2H_4, burns in the presence of oxygen to produce carbon dioxide and water vapor. Write a balanced equation for this reaction.

$$C_2H_4 + 3O_2 \rightarrow 2\ CO_2 + 2H_2O$$

Assessment Questions

1. Which of the following is a balanced chemical equation for the reaction of aluminium and ammonium perchlorate?

   a. $Al + NH_4ClO_4 \rightarrow Al_2O_3 + NH_4Cl$

   b. $4Al + 3NH_4ClO_4 \rightarrow 4Al_2O_3 + 3NH_4Cl$

   c. $8Al + NH_4ClO_4 \rightarrow 4Al_2O_3 + NH_4Cl$

   d. $8Al + 3NH_4ClO_4 \rightarrow 4Al_2O_3 + 3NH_4Cl$

Assessment Questions

4. In the chemical equation below, the reactants are carbon dioxide and water.

$CH_4 + 2O_2 \rightarrow CO2 + 2H_2O$

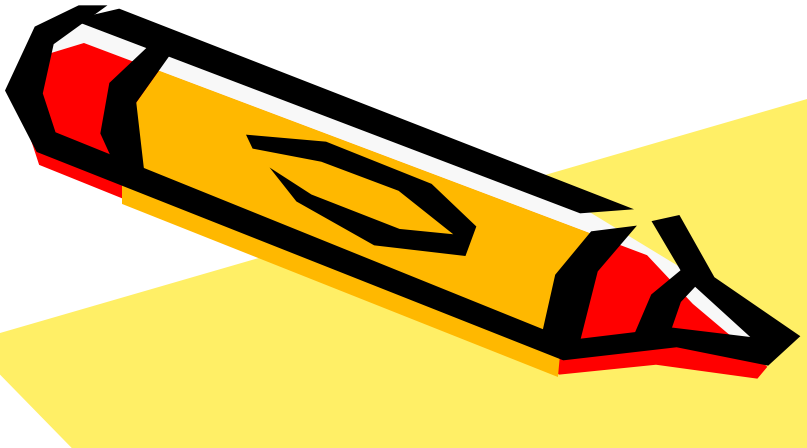
True
False

Question

5. Cooking an egg until it is hard-boiled involves a chemical reaction. Cutting a piece of paper into a hundred does not involve a chemical reaction. Explain the difference between the two processes.

Questions

6. Why can't you change symbols, formulas, or subscripts to balance equations?
7. How are chemical equations related to equations found in math?



Chapter 7
Chemical Reactions

7.2 Types of Reactions

Classifying Reactions

- **What are the general types of chemical reactions?**

- Some general types of chemical reactions are synthesis reactions, decomposition reactions, single-replacement reactions, double-replacement reactions, and combustion reactions.

Classifying Reactions

Synthesis

A **synthesis reaction** is a reaction in which two or more substances react to form a single substance.

- The reactants may be either elements or compounds.
- The product synthesized is always a compound.
- The general equation for a synthesis reaction is

$$A + B \rightarrow AB$$

Classifying Reactions

Decomposition

A **decomposition reaction** is a reaction in which a compound breaks down into two or more simpler substances.

- The reactant in a decomposition reaction must be a compound.
- The products may be elements or compounds.
- The general equation for a decomposition reaction is

$$AB \rightarrow A + B$$

Classifying Reactions

Single Replacement

A **single-replacement reaction** is a reaction in which one element takes the place of another element in a compound. Single-replacement reactions have the general form

$$A + BC \rightarrow B + AC$$

Classifying Reactions

Double Replacement

A **double-replacement reaction** is one in which two different compounds exchange positive ions and form two new compounds.

- The general form of a double replacement reaction is

$$AB + CD \rightarrow AD + CB$$

- Two replacements take place in this reaction. A replaces C, and C replaces A.

Classifying Reactions

Combustion

A **combustion reaction** is one in which a substance reacts rapidly with oxygen, often producing heat and light.

The main component of natural gas is methane. When methane burns in oxygen, a combustion reaction occurs.

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

Reactions as Electron Transfers

- **How did the discovery of subatomic particles affect the classification of reactions?**
- The discovery of subatomic particles enabled scientists to classify certain chemical reactions as transfers of electrons between atoms.

Reactions as Electron Transfers

A reaction in which electrons are transferred from one reactant to another is called an **oxidation-reduction reaction**, or redox reaction.

Reactions as Electron Transfers

Oxidation and reduction always occur together.

- When one element loses electrons, another element must gain electrons.
- A reactant is said to be reduced if it gains electrons. A reactant is oxidized if it loses electrons.

Assessment Questions

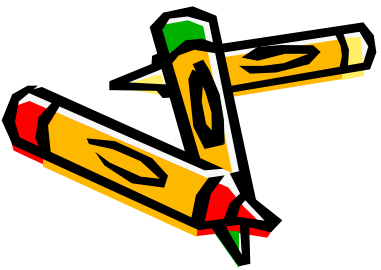
1. Which of these statements best describes a double-replacement reaction?
   a. Two different compounds exchange positive ions and form two new compounds.
   b. An element takes the place of another element in a compound.
   c. One compound breaks down into two or more simpler substances.
   d. Two or more substances react to form a single substance.

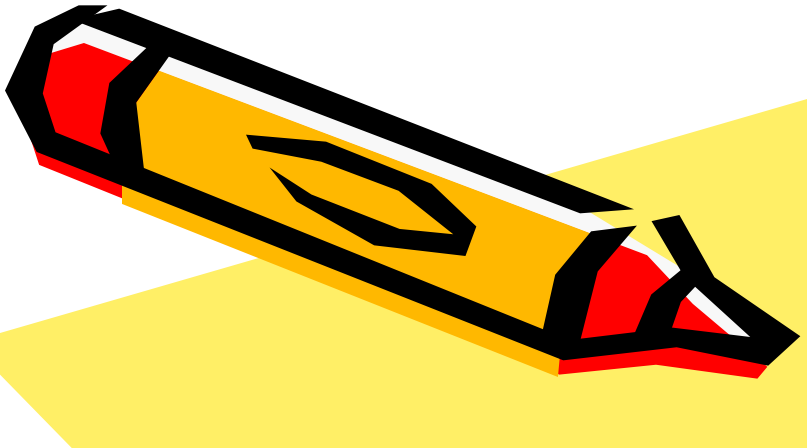
Assessment Questions

2. Which of the following statements about oxidation-reduction reactions is true?
   a. Oxidation-reduction reactions always involve a transfer of protons between atoms.
   b. Oxidation is the process in which electrons are gained.
   c. Oxidation and reduction always occur together.
   d. Oxidation-reduction reactions always involve oxygen as one of the reactants.

Classify the Reactions

1) $CaCO_3 \rightarrow CaO + CO_2$
2) $C + O_2 \rightarrow CO_2$
3) $BaBr_2 + K_2SO_4 \rightarrow 2KBr + BaSO_4$





Chapter 7
Chemical Reactions

7.3 Energy Changes in Reactions

Chemical Bonds and Energy

- **What happens to chemical bonds during a chemical reaction?**
- **Chemical reactions involve the breaking of chemical bonds in the reactants and the formation of chemical bonds in the products.**

Chemical Bonds and Energy

The heat produced by a propane grill is a form of energy.

When you write the chemical equation for the combustion of propane, you can include "heat" on the right side of the equation.

$$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O + \text{Heat}$$

Chemical Bonds and Energy

Chemical energy is the energy stored in the chemical bonds of a substance.

Exothermic and Endothermic Reactions

- **What happens to energy during a chemical reaction?**
- During a chemical reaction, energy is either released or absorbed.

Exothermic and Endothermic Reactions

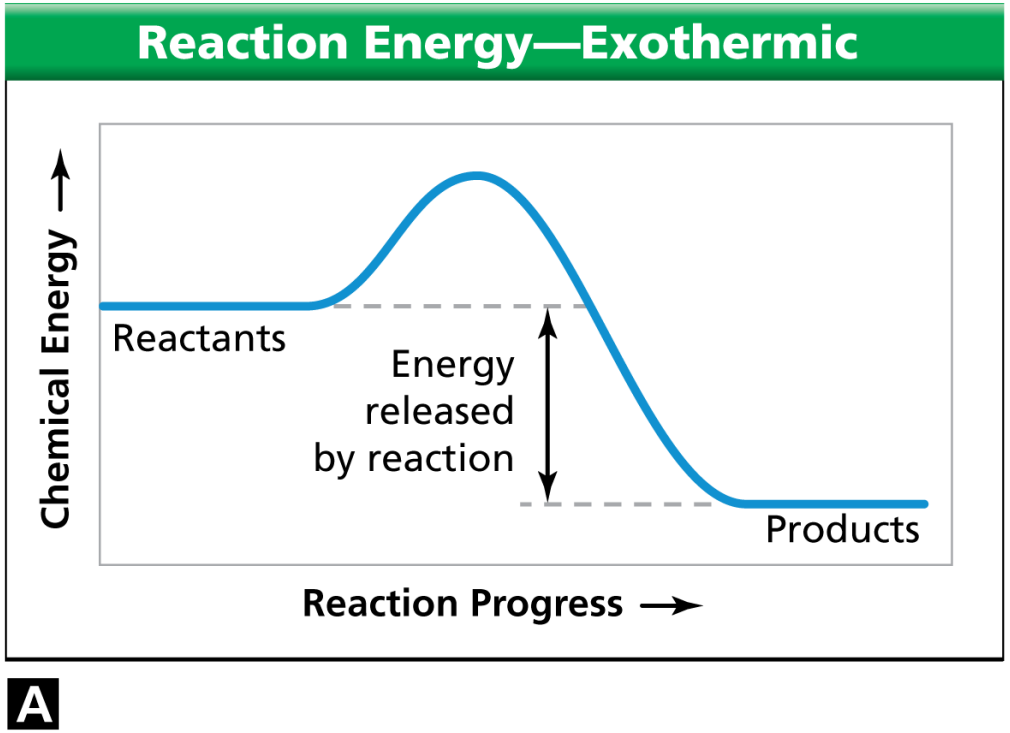
Exothermic Reactions

A chemical reaction that releases energy to its surroundings is called an **exothermic reaction.**

In exothermic reactions, the energy released as the products form is greater than the energy required to break the bonds in the reactants.

Exothermic and Endothermic Reactions

In an exothermic reaction, the chemical energy of the reactants is greater than the chemical energy of the products.



Exothermic and Endothermic Reactions

In a chemical reaction, the chemical energy reaches a peak before the reactants change into products.

- This peak represents the amount of energy required to break the chemical bonds of the reactants.
- Particles must collide with enough energy to break these bonds, or the reaction will not occur.

Exothermic and Endothermic Reactions

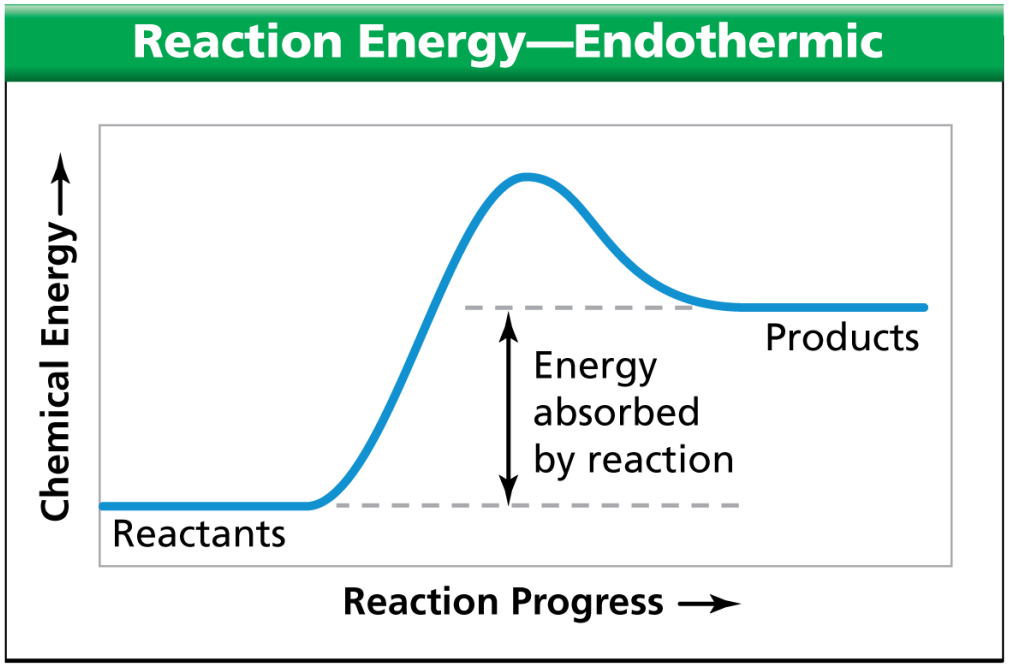
Endothermic Reactions

A chemical reaction that absorbs energy from its surroundings is called an **endothermic reaction.**

In an endothermic reaction, more energy is required to break the bonds in the reactants than is released by the formation of the products.

Exothermic and Endothermic Reactions

In an endothermic reaction, the energy of the products is greater than the energy of the reactants.



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Conservation of Energy

In an exothermic reaction, the chemical energy of the reactants is converted into heat plus the chemical energy of the products. In an endothermic reaction, heat plus the chemical energy of the reactants is converted into the chemical energy of the products.

In both cases, the total energy before and after the reaction is the same. This principle is known as the **law of conservation of energy**.

Assessment Questions

1. During a chemical reaction, an input of energy is always required to
   a. break chemical bonds in a molecule.
   b. build chemical bonds as a molecule forms.
   c. separate products from reactants.
   d. change reactants to the liquid phase so they can react.

Assessment Questions

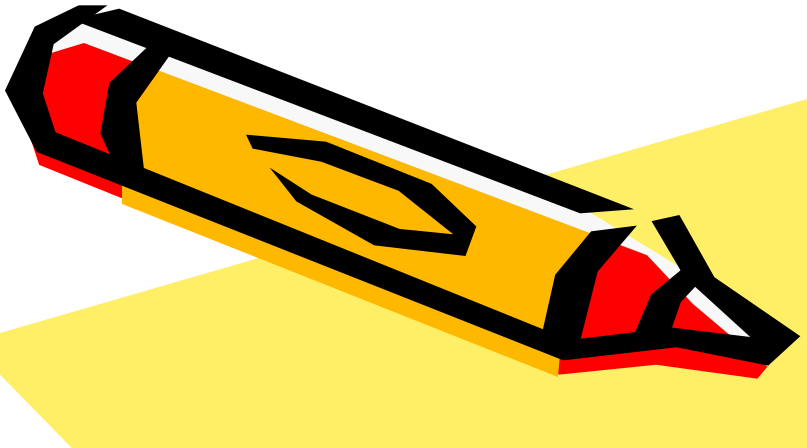
2. In an exothermic reaction, the total chemical energy of the products added to the energy released by the reactions is
   a. less than the energy of the reactants.
   b. equal to the chemical energy of the reactants.
   c. greater than the chemical energy of the reactants.
   d. not related to the chemical energy of the reactants.

Assessment Questions

1. Combustion is always an exothermic reaction.

   True
   False

2.



Chapter 7
Chemical Reactions

7.4 Reaction Rates

Reactions Over Time

What does a reaction rate tell you?

A **reaction rate** is the rate at which reactants change into products over time.

Reaction rates tell you how fast a reaction is going.

Factors Affecting Reaction Rates

- What factors cause reaction rates to change?
- Factors that affect reaction rates include temperature, surface area, concentration, stirring, and catalysts.

Factors Affecting Reaction Rates

The reaction rate of a chemical reaction depends on how often reactant particles collide.

- If the collisions occur more frequently, then the reaction rate increases.
- If the collisions occur less frequently, then the reaction rate decreases.
- Reaction rates can be changed by varying conditions.

Factors Affecting Reaction Rates

Increasing the temperature of a substance causes its particles to move faster, on average.

Particles that move faster are both more likely to collide and more likely to react. If the number of collisions that produce reactions increases, then the reaction rate increases.

Factors Affecting Reaction Rates

Surface Area

The smaller the particle size of a given mass, the larger is its surface area.

- Increased surface area increases collisions that involve reacting particles.
- With more collisions, more particles will react.

Factors Affecting Reaction Rates

Stirring

Stirring reactants increases their exposure to each other.

Factors Affecting Reaction Rates

Concentration

Concentration refers to the number of particles in a given volume.

The more reacting particles that are present in a given volume, the more opportunities there are for collisions involving those particles. The reaction rate is faster.

Factors Affecting Reaction Rates

For gases, concentration changes with pressure.

The greater the pressure of a gaseous reactant, the greater is its concentration, and the faster is the reaction rate.

Factors Affecting Reaction Rates

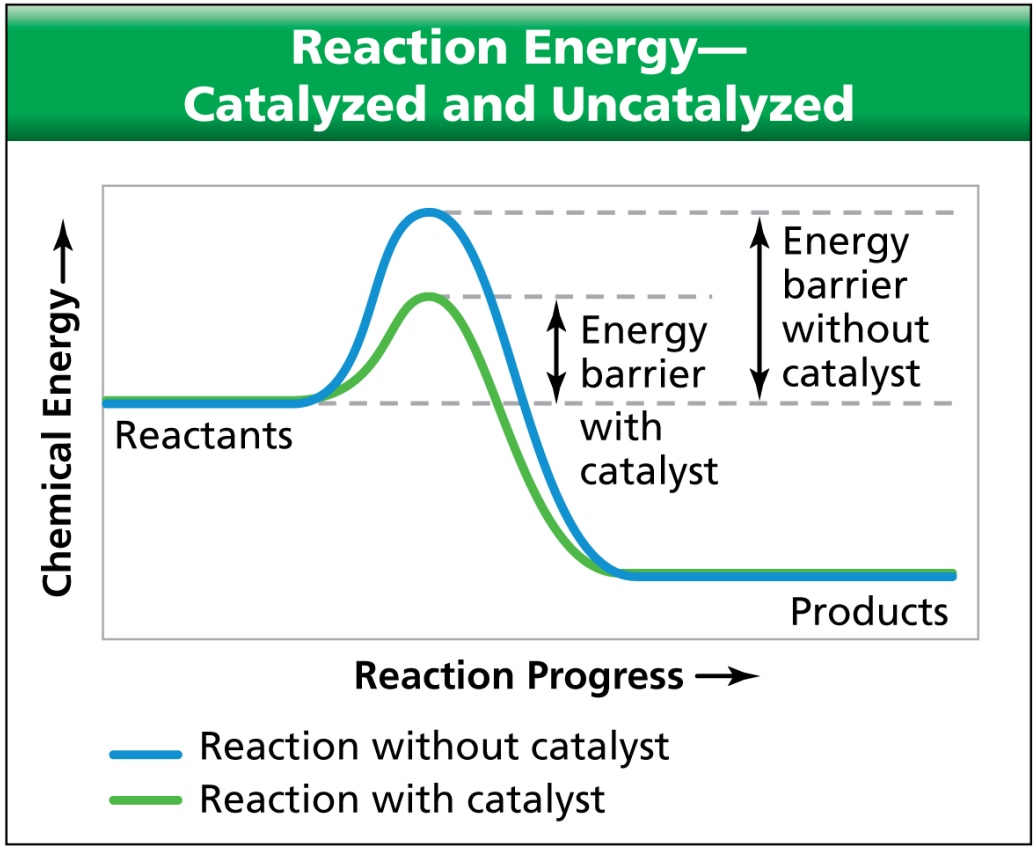
Catalysts

A **catalyst** is a substance that affects the reaction rate without being used up in the reaction.

Chemists often use catalysts to speed up a reaction or enable a reaction to occur at a lower temperature.

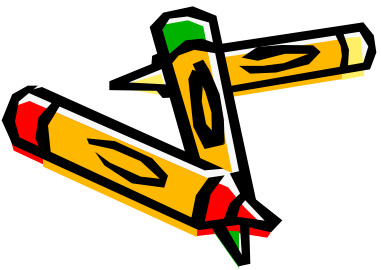
Factors Affecting Reaction Rates

The catalyst lowers the amount of energy required for effective collisions between reacting particles.



Assessment Questions

1. Which of the following changes will decrease the rate of a chemical reaction?
   a. increasing the temperature
   b. grinding a reactant into a fine powder
   c. stirring the reaction mixture
   d. decreasing the concentration of one of the reactants

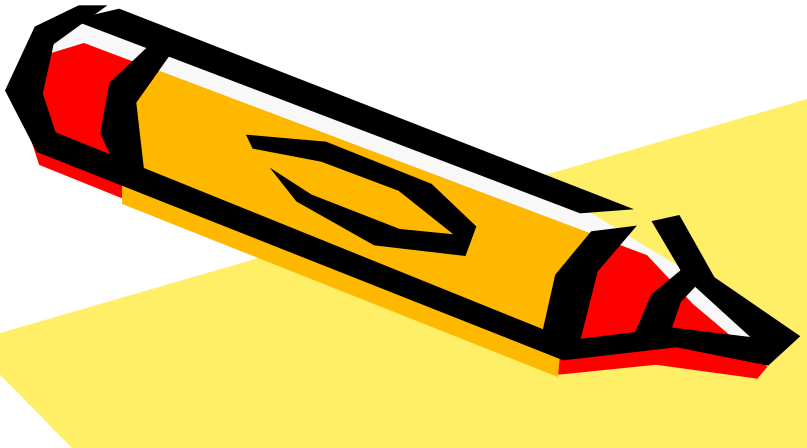


Assessment Questions

1. A reaction rate is the rate at which reactants change into products over time.

   True
   False

2. 



Chapter 7
Chemical Reactions

7.5 Equilibrium

Types of Equilibria

Equilibrium is a state in which the forward and reverse paths of a change take place at the same rate.

When opposing physical changes take place at the same rate, a **physical equilibrium** is reached.

When opposing chemical changes take place at the same rate, a **chemical equilibrium** is reached.

Types of Equilibria

Chemical Equilibrium

When a chemical reaction does not go to completion, a chemical equilibrium is established between the forward and reverse reactions.

Most reactions are reversible to some extent.

A **reversible reaction** is a reaction in which the conversion of reactants into products and the conversion of products into reactants can happen simultaneously.

Factors Affecting Chemical Equilibrium

How do equilibrium systems respond to change?

When a change is introduced to a system in equilibrium, the equilibrium shifts in the direction that relieves the change.

This rule was first observed by Henri Le Châtelier. Today, the rule is known as **Le Châtelier's principle**.

Factors Affecting Chemical Equilibrium

The making of ammonia is an example of a process in which chemists apply Le Châtelier's principle.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) + \text{Heat}$$

If a system containing nitrogen, hydrogen, and ammonia is in equilibrium, you can predict how the system will be affected by changes in **temperature, pressure, and concentration**.

Factors Affecting Chemical Equilibrium

According to Le Châtelier's principle, if you added heat to the system, the equilibrium would shift in the direction that removes heat from the system.

Factors Affecting Chemical Equilibrium

Pressure

According to Le Châtelier's principle, if you increased the pressure, the equilibrium would shift in the direction that decreases the pressure of the system.

In order to decrease pressure, the system would favor the reaction that produces fewer gas molecules.

Factors Affecting Chemical Equilibrium

Concentration

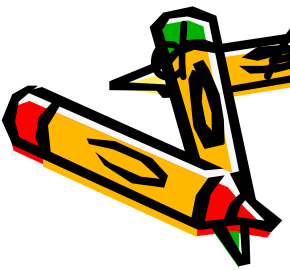
Le Châtelier's principle tells you that if you decreased the ammonia concentration by removing ammonia from the system, the equilibrium would shift in the direction that produces ammonia.

Le Chatelier's Principle

- Temp: increase favors side that absorbs energy
- Pressure: increase favors side with less moles of gas
- Concentration: increase of reactant favors products and vice versa

Assessment Questions

1. In a chemical reaction that is at equilibrium, which of the following is true?
   a. All of the reactants have been converted to products.
   b. The reaction stops even though some reactants remain.
   c. Forward and reverse reactions occur at the same rate.
   d. All of the products are gases.



Assessment Questions

2. In the chemical reaction below, how could you shift the equilibrium toward water?

$$2H_2(g) + O_2(g) \rightleftharpoons 2H_2O(g) + \text{heat}$$

a. increase the temperature
b. increase the pressure
c. decrease the amount of oxygen
d. add steam to the mixture