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11 CHEMICAL REACTIONS

SECTION 11.1 DESCRIBING CHEMICAL REACTIONS (pages 321–329)

This section explains how to write equations describing chemical reactions using appropriate symbols. It also describes how to write balanced chemical equations when given the names or formulas of the reactants and products in a chemical reaction.

▶ Writing Chemical Equations (pages 321–323)

1. A chemical reaction occurs when one or more reactants change into one or more new substances called products.

2. The arrow in a reaction means yields, gives, or reacts to produce.

3. Is the following sentence true or false? When there are two or more reactants or products, they are separated by an arrow. false

4. Write a word equation that describes the following reactions.

a. Acetylene reacts with oxygen to produce carbon dioxide and water.

acetylene + oxygen ⟶ carbon dioxide + water

b. When heated, mercury(II) oxide reacts to form mercury and oxygen.

mercury(II) oxide ⟶ mercury + oxygen

5. What is a chemical equation?

A chemical equation is a representation of a chemical reaction; the formulas of the reactants (on the left) are connected by an arrow with formulas of the products (on the right).

6. A chemical reaction that shows only the formulas, but not the relative amounts of the reactants and products is a(n) skeleton equation.

7. Identify the reactant(s) and product(s) in the chemical equation $Li + Br_2 \longrightarrow LiBr$.

a. reactant(s) Li and Br_2

b. product(s) LiBr

8. Circle the letter of each statement that is true about a catalyst.

a. A catalyst is the new material produced as a result of a chemical reaction.

(b.) A catalyst is not used up in a chemical reaction.

c. A catalyst adds heat to a chemical reaction.

(d.) A catalyst speeds up a chemical reaction.

9. Use the symbols in Table 11.1 on page 323 to write a skeleton equation for the following chemical reaction. Hydrochloric acid reacts with zinc to produce aqueous zinc(II) chloride and hydrogen gas.

$HCl(aq) + Zn(s) \longrightarrow ZnCl_2(aq) + H_2(g)$

▶ Balancing Chemical Equations (pages 324–328)

10. What is the law of conservation of mass?

In any physical or chemical change, mass is neither created nor destroyed.

11. Complete the flowchart for balancing equations.

Determine the correct formulas and physical states for the _____reactants_____ and _____products_____ .

↓

Write a _____skeleton equation_____ with the formulas for the reactants on the left and the formulas for the products on the right of a yields sign (⟶).

↓

Count the number of _____atoms_____ of each element in the reactants and in the products.

↓

Balance the number of atoms of the elements on the two sides of the equation by placing _____coefficients_____ in front of formulas. Never try to balance an equation by changing the _____subscripts_____ in formulas.

↓

Check each atom or polyatomic ion to be sure the equation is _____balanced_____, and make sure that all coefficients are in the _____lowest_____ possible ratio.

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12. Balance the following chemical equations.

a. 2 $Na(s)$ + 2 $H_2O(l) \longrightarrow$ 2 $NaOH(aq)$ + $H_2(g)$

b. 2 $AgNO_3(aq)$ + $Zn(s) \longrightarrow Zn(NO_3)_2(aq)$ + 2 $Ag(s)$

SECTION 11.2 TYPES OF CHEMICAL REACTIONS (pages 330–339)

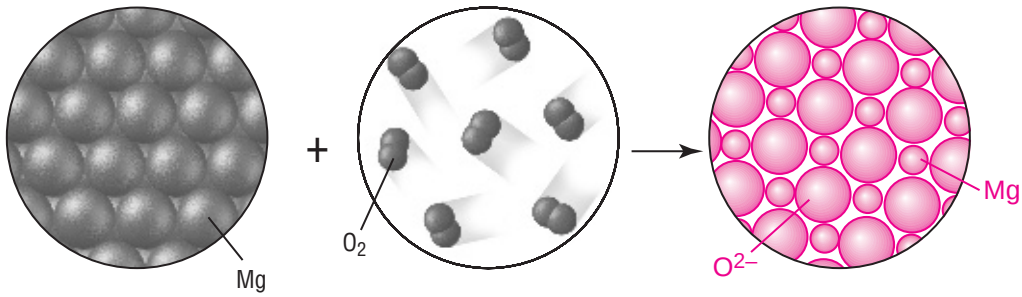
This section explains how to identify a reaction as a combination, decomposition, single-replacement, double-replacement, or combustion reaction. It also describes how to predict the products of each type of reaction.

▶ Classifying Reactions (page 330)

1. There are five general types of chemical reactions.

2. Complete the diagram of a combination reaction. Which characteristic of this type of reaction is shown in the diagram?

Two reactants combine to form a single compound.



3. Is the following sentence true or false? The product of a combination reaction is always a molecular compound. false

4. Circle the letter of each set of reactants that can produce more than one product.

(a.) two nonmetals

b. a Group A metal and a nonmetal

(c.) a transition metal and a nonmetal

d. two metals

5. Look at Figure 11.6 on page 332. Which characteristics of a decomposition reaction are shown in the diagram?

The reaction has a single reactant, which is a binary compound. The products are two elements.

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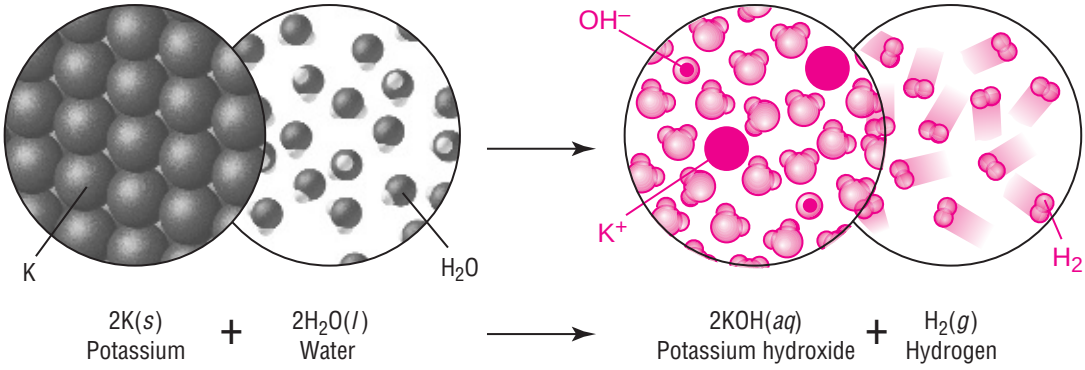
CHAPTER 11, Chemical Reactions *(continued)*

6. Rapid decomposition reactions can cause explosions as a result of the formation of gaseous products and heat.

7. Most decomposition reactions require the addition of energy in the form of heat, light, or electricity.

8. Complete the diagram of a single replacement reaction. Which characteristics of this type of reaction are shown in the diagram?

One element in a compound is replaced by another element.



9. Using Table 11.2 on page 333, state whether the following combinations will produce a reaction or no reaction.

a. $Ag(s) + HCl(aq)$ no reaction

b. $Cu(s) + AgNO_3(aq)$ reaction

10. Look at Figure 11.8 on page 335. Which characteristics of a double-replacement reaction are shown in the diagram?

The reaction involves the exchange of positive ions between two ionic compounds in an aqueous solution. One product precipitates from solution.

11. When solutions of ionic compounds are mixed, what three circumstances may indicate that a double-replacement reaction has occurred?

a. A precipitate forms.

b. A gas evolves.

c. One product is a molecular compound such as water.

12. Look at the diagram of a combustion reaction in Figure 11.9 on page 336. Which characteristics of this type of reaction are shown in the diagram?

One reactant is a compound and the other is oxygen.

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13. Is the following sentence true or false? Hydrocarbons, compounds of hydrogen and carbon, are often the reactants in combustion reactions. true

14. Circle the letter of each compound that can be produced by combustion reactions.

a. oxygen **c.** water

b. carbon dioxide **d.** glucose

▶ Predicting the Products of a Chemical Reaction (pages 337–339)

15. Classify the reaction in each of the following equations.

a. $BaCl_2(aq) + K_2CrO_4(aq) \longrightarrow BaCrO_4(s) + 2KCl\ (aq)$ double-replacement

b. $Si(s) + 2Cl_2(g) \longrightarrow SiCl_4(l)$ combination

c. $2C_6H_6(l) + 15O_2(g) \longrightarrow 6H_2O(l) + 12CO_2(g)$ combustion

16. Use Figure 11.10 on page 339. The equation for the combustion of pentane is $C_5H_{12} + 8O_2 \longrightarrow 5CO_2 + 6H_2O$. What numbers in this equation are represented by *x* and *y* in the general equation? 5, 12

SECTION 11.3 REACTIONS IN AQUEOUS SOLUTION (pages 342–344)

This section explains how to write and balance net ionic equations. It also describes the use of solubility rules to predict the formation of precipitates in double-replacement reactions.

▶ Net Ionic Equations (pages 342–343)

1. Many important chemical reactions take place in aqueous solution .

2. An equation that shows dissolved ionic compounds as their free ions is called a(n) complete ionic equation .

3. Is the following sentence true or false? A spectator ion is not directly involved in a reaction. true

4. What is a net ionic equation? A net ionic equation is an equation that shows only those particles that actually take part in the reaction.

5. Circle the letter of each sentence that is true about ionic equations.

a. A complete ionic equation shows only the ions involved in the reaction.

b. Spectator ions are left out of a net ionic equation.

c. Atoms do not need to be balanced in an ionic equation.

d. Ionic charges must be balanced in a net ionic equation.

6. Write the balanced net ionic equation for this reaction:
$Pb(NO_3)_2(aq) + KI(aq) \longrightarrow PbI_2(s) + KNO_3(aq)$. Show your work.

Write the complete ionic equation:

$Pb^{2+}(aq) + NO_3^-(aq) + K^+(aq) + I^-(aq) \longrightarrow PbI_2(s) + K^+(aq) + NO_3^-(aq)$

eliminate the spectator ions: $Pb^{2+}(aq) + I^-(aq) \longrightarrow PbI_2(s)$

balance the atoms and charges: $Pb^{2+}(aq) + 2I^-(aq) \longrightarrow PbI_2(s)$

▶ Predicting the Formation of a Precipitate (page 344)

7. What determines whether a precipitate forms when two solutions of ionic compounds are mixed?

The solubilities of the new ionic compounds determine whether a precipitate will form.

8. Use Table 11.3 on page 344 to predict whether the following compounds are soluble or insoluble.

a. $Fe(OH)_3$ insoluble

b. NaOH soluble

c. $Ca(ClO_3)_2$ soluble

d. $HgSO_4$ insoluble

Reading Skill Practice

A flowchart can help you to remember the order in which events occur. On a separate sheet of paper, create a flowchart that describes the steps for writing a balanced net ionic equation. This process is explained on pages 342–343 of your textbook.

Students' flowcharts will vary. A typical flowchart might include these steps: Write a complete ionic equation that shows dissolved ionic compounds as their free ions. Eliminate the spectator ions from both sides of the equation. Balance the ionic charges in the net ionic equation. Balance the atoms on both sides of the equation.

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GUIDED PRACTICE PROBLEMS

GUIDED PRACTICE PROBLEM 2 (page 324)

2. Sulfur burns in oxygen to form sulfur dioxide. Write a skeleton equation for this chemical reaction. Include appropriate symbols from table 11.1.

Analyze

Step 1. Identify the relevant concepts.
Write the formula for each reactant and each product. Include the common STP state of each substance.

Reactants

sulfur = $S(s)$

oxygen = $O_2(g)$

Products

sulfur dioxide = $SO_2(s)$

Solve

Step 2. Write the skeleton equation using + between reactants on the left hand side and → to separate reactants from products:

$S(s) + O_2(g) \rightarrow SO_2(s)$

GUIDED PRACTICE PROBLEM 3 (page 327)

3. Balance each equation.

a. $AgNO_3 + H_2S \rightarrow Ag_2S + HNO_3$

b. $Zn(OH)_2 + H_3PO_4 \rightarrow Zn_3(PO_4)_2 + H_2O$

a. $AgNO_3 + H_2S \rightarrow Ag_2S + HNO_3$

Analyze

Step 1. Identify the relevant concepts.
Count the number of atoms of each element on both sides of the skeleton equation.

Left hand side (lhs):	Right hand side (rhs):
1 Ag	2 Ag
1 N	1 N
1 S	1 S
2 H	1 H
3 O	3 O

Solve

Step 2. Apply concepts to this situation.
The reactant containing Ag on the lhs needs a multiple of 2, and the product containing H on the rhs needs a multiple of 2. Rewrite the equation with these coefficients and count again.

$2AgNO_3 + H2S \rightarrow Ag_2S + 2HNO_3$

Left hand side (lhs):	Right hand side (rhs):
2 Ag	2 Ag
2 N	2 N
1 S	1 S
2 H	2 H
6 O	6 O

Because the number of atoms of each element is the same on both sides, the equation is balanced: $2AgNO_3 + H_2S \rightarrow Ag_2S + 2HNO_3$

b. $Zn(OH)_2 + H_3PO_4 \rightarrow Zn_3(PO_4)_2 + H_2O$

Analyze

Step 1. Look at the zinc ions on both sides of the equation. Make the number of zinc ions in zinc hydroxide match the number in zinc phosphate.

3 $Zn(OH)_2$ + H_3PO_4 ⟶ $Zn_3(PO_4)_2$ + H_2O

Step 2. Look at the phosphate ions on both sides of the equation. Make the number of phosphate ions in phosphoric acid match the number of phosphate ions in zinc phosphate.

$3Zn(OH)_2$ + 2 H_3PO_4 ⟶ $Zn_3(PO_4)_2$ + H_2O

Step 3. Look at the remaining ions in the reactants—OH^- and H^+.

3 × 2 ions of OH^-
2 × 3 ions of H^+ ⟶ will form 6 molecules of H_2O

Step 4. Complete the balanced equation.

3 $Zn(OH)_2$ + 2 H_3PO_4 ⟶ $Zn_3(PO_4)_2$ + 6 H_2O

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GUIDED PRACTICE PROBLEM 5 (page 328)

5. Balance each equation.

a. $FeCl_3 + NaOH \rightarrow Fe(OH)_3 + NaCl$

b. $CS_2 + Cl_3 \rightarrow CCl_4 + S_2Cl_2$

a. $FeCl_3 + NaOH \rightarrow Fe(OH)_3 + NaCl$

Analyze

Step 1. Identify the relevant concepts.
Count the number of atoms of each element for both sides of the skeleton equation.

Solve

Step 2. Apply concepts to this situation.
The product containing Cl on the rhs needs a multiple of 3, which then means the reactant containing Na on the lhs needs a multiple of 3. Rewrite the equation with these coefficients and count again. This produces a balanced equation.

$FeCl_3 + 3NaOH \rightarrow Fe(OH)_3 + 3NaCl$

b. $CS_2 + Cl_3 \rightarrow CCl_4 + S_2Cl_2$

Analyze

Step 1. Identify the relevant concepts.
Count the number of atoms of each element for both sides of the skeleton equation.

Solve

Step 2. Apply concepts to this situation.
The product containing Cl on the lhs needs a multiple of 2 to give a total of six Cl atoms for the rhs. Rewrite the equation with these coefficients and count again. This produces a balanced equation.

$CS_2 + 2Cl_3 \rightarrow CCl_4 + S_2Cl_2$

GUIDED PRACTICE PROBLEM 13 (page 331)

13. Complete and balance the equation for a combination reaction.

$Be + O_2 \rightarrow$

Analyze

Step 1. Identify the relevant concepts.
Beryllium is a group 2A metal, which means it will have a 1:1 bond with a group 6A gas, such as oxygen.

Solve

Step 2. Apply concepts to this situation.
The skeleton equation for this combination reaction is: $Be + O_2 \rightarrow BeO$

A coefficient of 2 is needed before the product to balance the number of oxygen atoms. Then a coefficient of 2 is needed before the reactant Be.
The balanced equation is:

$2Be + O_2 \rightarrow 2BeO$

GUIDED PRACTICE PROBLEM 15 (page 332)

15. Complete and balance the equation for a decomposition reaction.
$HI \rightarrow$

Analyze

Step 1. Identify relevant concepts.
Remember that both hydrogen and iodine exist as diatomic molecules.

Solve

Step 2. Apply concepts to this situation.
The skeleton equation for this decomposition reaction is: $HI \rightarrow H_2 + I_2$

Balancing the equation gives the result.

$2HI \rightarrow H_2 + I_2$

GUIDED PRACTICE PROBLEM 17 (page 334)

17. Complete the equations for these single-replacement reactions in aqueous solution. Balance each equation. Write "no reaction" if a reaction does not occur. Use the activity series.

a. $Fe(s) + Pb(NO_3)_2(aq) \rightarrow$

b. $Cl_2(aq) + NaI(aq) \rightarrow$

c. $Ca(s) + H_2O(l) \rightarrow$

a. $Fe(s) + Pb(NO_3)_2(aq) \rightarrow$

Analyze

Step 1. Identify relevant concepts.
Table 11.2 shows that iron is more reactive than lead.

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Solve

Step 2. Apply concepts to this situation.
Fe replaces Pb. A reaction occurs resulting in the balanced equation:

$Fe(s) + Pb(NO_3)_2(aq) \rightarrow Pb(s) + Fe(NO_3)_2(aq)$

b. $Cl_2(aq) + NaI(aq) \rightarrow$

Analyze

Step 1. Identify relevant concepts.
On the periodic table, notice that Cl and I are group 7A halogens and Cl is more reactive than I.

Solve

Step 2. Apply concepts to this situation.
Cl replaces I. Recall that iodine exists as a diatomic molecule. A reaction occurs resulting in the skeleton equation:
$Cl_2(aq) + NaI(aq) \rightarrow I_2(aq) + NaCl(aq)$.

Balancing this equation gives this result.

$Cl_2(aq) + 2NaI(aq) \rightarrow I_2(aq) + 2NaCl(aq)$

c. $Ca(s) + H_2O(l) \rightarrow$

Analyze

Step 1. Identify relevant concepts.
In Table 11.2, notice that Ca is more reactive than H and can replace H in water as well as in an acid.

Solve

Step 2. Apply concepts to this situation.
One Ca replaces one H, but notice Ca has a 2+ charge and OH has a 1− charge. Also, hydrogen gas exists as a diatomic molecule. A reaction occurs resulting in the skeleton equation:
$Ca(s) + H_2O(l) \rightarrow H_2(g) + Ca(OH)_2(aq)$

Balancing the equation gives this result.

$Ca(s) + 2H_2O(l) \rightarrow 2H_2(g) + Ca(OH)_2(aq)$

GUIDED PRACTICE PROBLEM 18 (page 335)

18. Write the products of these double-replacement reactions. Balance each equation.

a. $NaOH + Fe(NO_3)_3 \rightarrow$ (Iron (III) hydroxide is a precipitate.)

b. $Ba(NO_3)_2 + H_3PO_4 \rightarrow$ (Barium phosphate is a precipitate.)

a. $NaOH + Fe(NO_3)_3 \rightarrow$

Analyze

Step 1. Identify relevant concepts.
The driving force is the formation of the precipitate iron (III) hydroxide—$Fe(OH)_3$

Solve

Step 2. Apply concepts to this situation.
Fe and Na replace each other. A reaction occurs resulting in the skeleton equation:

$NaOH(aq) + Fe(NO_3)_3(aq) \rightarrow Fe(OH)_3(s) + NaNO_3(aq)$

Balancing this equation gives this result:

$3NaOH(aq) + Fe(NO_3)_3(aq) \rightarrow Fe(OH)_3(s) + 3NaNO_3(aq)$

b. $Ba(NO_3)_2 + H_3PO_4 \rightarrow$

Analyze

Step 1. Identify relevant concepts.
The driving force is the formation of the precipitate barium phosphate—$Ba_3(PO_4)_2$

Solve

Step 2. Apply concepts to this situation.
Ba and H replace each other. A reaction occurs resulting in the skeleton equation:

$Ba(NO_3)_2(aq) + H_3PO_4(aq) \rightarrow Ba_3(PO_4)_2(s) + HNO_3(aq)$

Balancing this equation gives the result:

$3Ba(NO_3)_2(aq) + 2H_3PO_4(aq) \rightarrow Ba_3(PO_4)_2(s) + 6HNO_3(aq)$

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GUIDED PRACTICE PROBLEM 21 (page 337)

21. Write a balanced equation for the complete combustion of glucose ($C_6H_{12}O_6$).

Analyze

Step 1. Identify the relevant concepts.
Oxygen gas is the other reactant in a combustion reaction. The products are CO_2 and H_2O. Write a skeleton equation for this reaction.

$C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O$

Solve

Step 2. Apply concepts to this situation.
Balance the equation.

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$