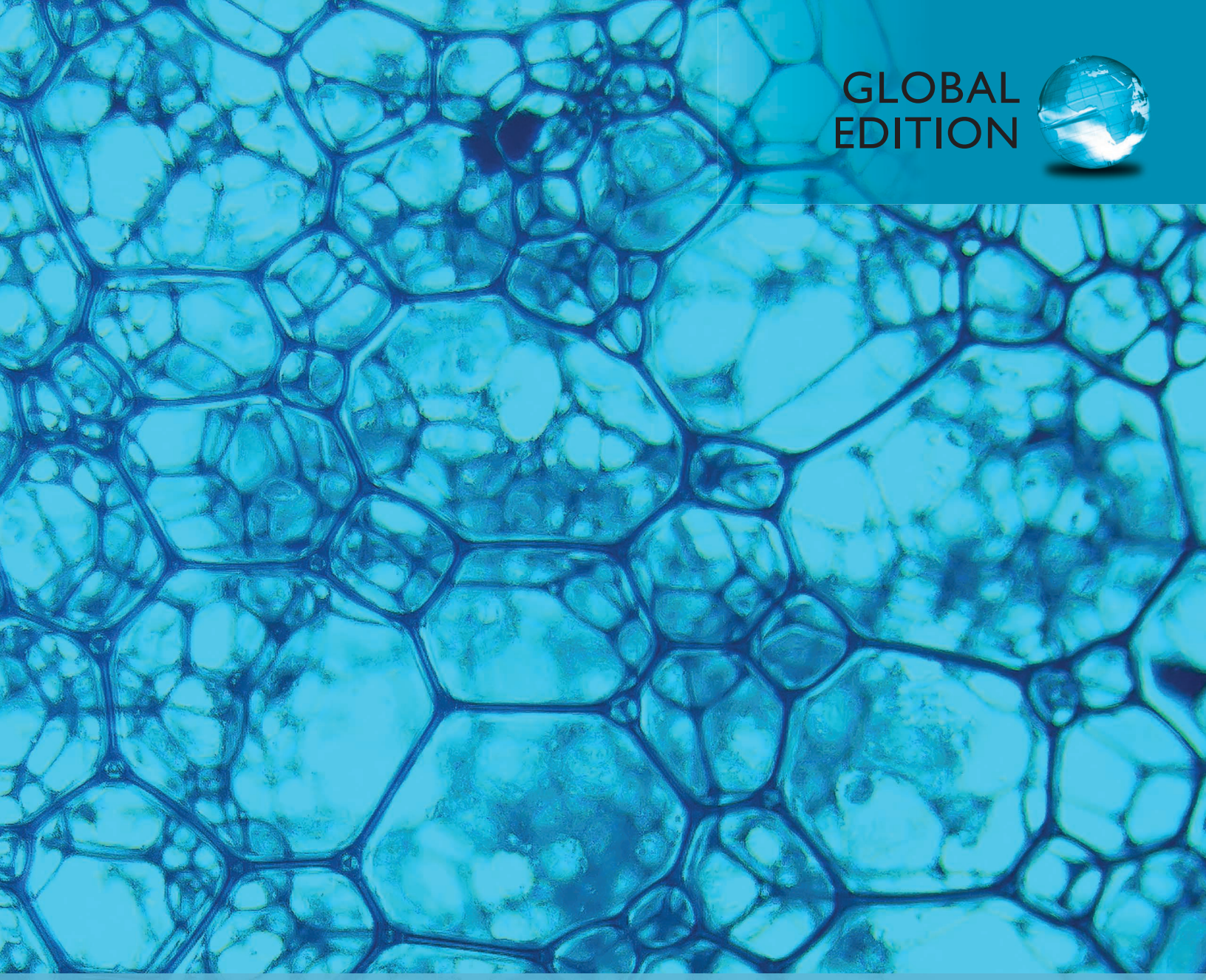


GLOBAL EDITION

General, Organic, and Biological Chemistry

Structures of Life

SIXTH EDITION

Timberlake

General, Organic, and Biological Chemistry

STRUCTURES OF LIFE

FIGURE 7.8 gives a summary of the calculations to show the connections between the moles of a compound, its mass in grams, the number of molecules (or formula units if ionic), and the moles and atoms of each element in that compound.

ENGAGE

Why are there more grams of chlorine than grams of fluorine in 1 mole of Freon-12, CCl_2F_2?

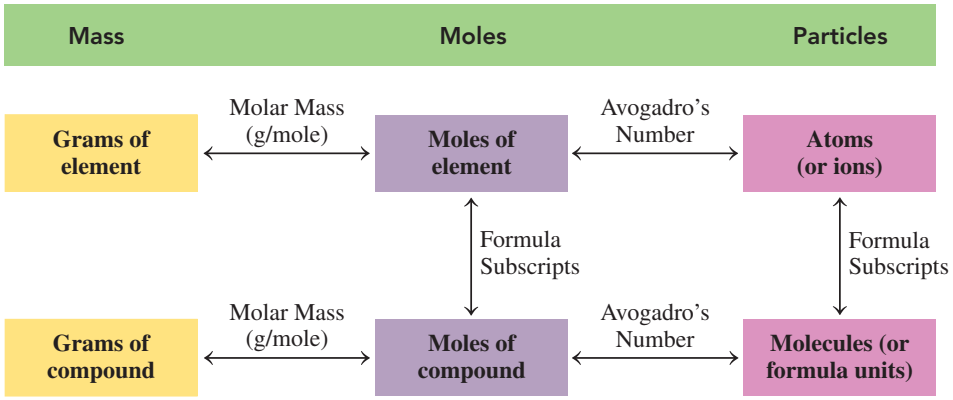


FIGURE 7.8 ▶ The moles of a compound are related to its mass in grams by molar mass, to the number of molecules (or formula units) by Avogadro's number, and to the moles of each element by the subscripts in the formula.

What steps are needed to calculate the number of atoms of H in 5.00 g of CH_4?

PRACTICE PROBLEMS

7.6 Calculations Using Molar Mass

7.41 Calculate the mass, in grams, for each of the following:
a. 1.50 moles of Na **b.** 2.80 moles of Ca
c. 0.125 mole of CO_2 **d.** 0.0485 mole of Na_2CO_3
e. 7.14×10^2 moles of PCl_3

7.42 Calculate the mass, in grams, for each of the following:
a. 5.12 moles of Al **b.** 0.75 mole of Cu
c. 3.52 moles of $MgBr_2$ **d.** 0.145 mole of C_2H_6O
e. 2.08 moles of $(NH_4)_2SO_4$

7.43 Calculate the mass, in grams, in 0.150 mole of each of the following:
a. Ne **b.** I_2 **c.** Na_2O
d. $Ca(NO_3)_2$ **e.** C_6H_{14}

7.44 Calculate the mass, in grams, in 2.28 moles of each of the following:
a. Pd **b.** SO_3 **c.** $C_3H_6O_3$
d. $Mg(HCO_3)_2$ **e.** SF_6

7.45 Calculate the number of moles in each of the following:
a. 82.0 g of Ag **b.** 0.288 g of C
c. 15.0 g of ammonia, NH_3 **d.** 7.25 g of CH_4
e. 245 g of Fe_2O_3

7.46 Calculate the number of moles in each of the following:
a. 85.2 g of Ni **b.** 144 g of K
c. 6.4 g of H_2O **d.** 308 g of $BaSO_4$
e. 252.8 g of fructose, $C_6H_{12}O_6$

7.47 Calculate the number of moles in 25.0 g of each of the following:
a. He **b.** O_2 **c.** $Al(OH)_3$
d. Ga_2S_3 **e.** C_4H_{10}, butane

7.48 Calculate the number of moles in 4.00 g of each of the following:
a. Au **b.** SnO_2 **c.** CS_2
d. Ca_3N_2 **e.** $C_6H_8O_6$, vitamin C

Clinical Applications

7.49 Chloroethane, C_2H_5Cl, is used to diagnose dead tooth nerves.
a. How many moles are in 34.0 g of chloroethane?
b. How many grams are in 1.50 moles of chloroethane?

7.50 Allyl sulfide, $(C_3H_5)_2S$, gives garlic, onions, and leeks their characteristic odor.

The characteristic odor of garlic is due to a sulfur-containing compound.

a. How many moles are in 23.2 g of allyl sulfide?
b. How many grams are in 0.75 mole of allyl sulfide?

7.51 **a.** The compound $MgSO_4$, Epsom salts, is used to soothe sore feet and muscles. How many grams will you need to prepare a bath containing 5.00 moles of Epsom salts?
b. Potassium iodide, KI, is used as an expectorant. How many grams are in 0.450 mole of potassium iodide?

7.52 **a.** Cyclopropane, C_3H_6, is an anesthetic given by inhalation. How many grams are in 0.25 mole of cyclopropane?
b. The sedative Demerol hydrochloride has the formula $C_{15}H_{22}ClNO_2$. How many grams are in 0.025 mole of Demerol hydrochloride?

7.53 Dinitrogen oxide (or nitrous oxide), N_2O, also known as laughing gas, is widely used as an anesthetic in dentistry.
a. How many grams are in 1.50 moles of dinitrogen oxide?
b. How many moles are in 34.0 g of dinitrogen oxide?

7.54 Chloroform, $CHCl_3$, was formerly used as an anesthetic but its use was discontinued due to respiratory and cardiac failure.
a. How many grams are in 0.122 mole of chloroform?
b. How many moles are in 26.7 g of chloroform?

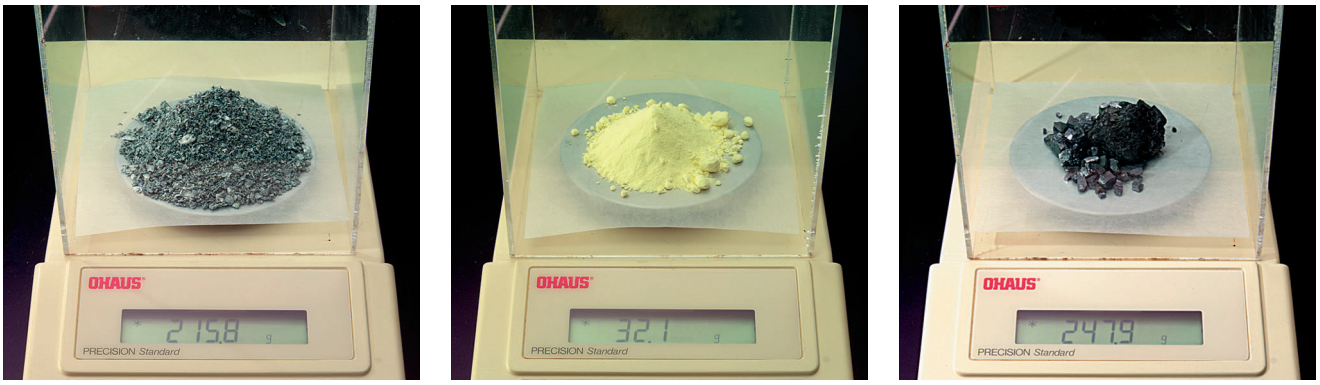
7.7 Mole Relationships in Chemical Equations

LEARNING GOAL Use a mole–mole factor from a balanced chemical equation to calculate the number of moles of another substance in the reaction.

In any chemical reaction, the total amount of matter in the reactants is equal to the total amount of matter in the products. Thus, the total mass of all the reactants must be equal to the total mass of all the products. This is known as the *Law of Conservation of Mass*, which states that there is no change in the total mass of the substances reacting in a chemical reaction.

For example, tarnish (Ag_2S) forms when silver reacts with sulfur to form silver sulfide.

$$2Ag(s) + S(s) \longrightarrow Ag_2S(s)$$



$2Ag(s)$ + $S(s)$ ⟶ $Ag_2S(s)$

Mass of reactants = Mass of product

In the chemical reaction of Ag and S, the mass of the reactants is the same as the mass of the product, Ag_2S.

In this reaction, the number of silver atoms that reacts is twice the number of sulfur atoms. When 200 silver atoms react, 100 sulfur atoms are required. However, in the actual chemical reaction, many more atoms of both silver and sulfur would react. If we are dealing with moles of silver and sulfur, then the coefficients in the equation can be interpreted in terms of moles. Thus, 2 moles of silver react with 1 mole of sulfur to form 1 mole of Ag_2S. Because the molar mass of each can be determined, the moles of Ag, S, and Ag_2S can also be stated in terms of mass in grams of each. Thus, 215.8 g of Ag and 32.1 g of S react to form 247.9 g of Ag_2S. The total mass of the reactants (247.9 g) is equal to the mass of product (247.9 g). The various ways in which a chemical equation can be interpreted are seen in **TABLE 7.6**.

TABLE 7.6 Information Available from a Balanced Equation

	Reactants		Products
Equation	$2Ag(s)$	+ $S(s)$	⟶ $Ag_2S(s)$
Atoms	2 Ag atoms	+ 1 S atom	⟶ 1 Ag_2S formula unit
	200 Ag atoms	+ 100 S atoms	⟶ 100 Ag_2S formula units
Avogadro's Number of Atoms	$2(6.02 \times 10^{23})$ Ag atoms	+ $1(6.02 \times 10^{23})$ S atoms	⟶ $1(6.02 \times 10^{23})$ Ag_2S formula units
Moles	2 moles of Ag	+ 1 mole of S	⟶ 1 mole of Ag_2S
Mass (g)	2(107.9 g) of Ag	+ 1(32.07 g) of S	⟶ 1(247.9 g) of Ag_2S
Total Mass (g)	247.9 g		⟶ 247.9 g

Mole–Mole Factors from a Balanced Equation

When iron reacts with sulfur, the product is iron(III) sulfide.

$$2Fe(s) + 3S(s) \longrightarrow Fe_2S_3(s)$$

Iron (Fe) $2Fe(s)$ + Sulfur (S) $3S(s)$ $\longrightarrow$ Iron(III) sulfide (Fe_2S_3) $Fe_2S_3(s)$

In the chemical reaction of Fe and S, the mass of the reactants is the same as the mass of the product, Fe_2S_3.

From the balanced chemical equation, we see that 2 moles of iron reacts with 3 moles of sulfur to form 1 mole of iron(III) sulfide. Actually, any amount of iron or sulfur may be used, but the *ratio* of iron reacting with sulfur will always be the same. From the coefficients, we can write **mole–mole factors** between reactants and between reactants and products. The coefficients used in the mole–mole factors are exact numbers; they do not limit the number of significant figures.

Fe and S: $\dfrac{2 \text{ moles Fe}}{3 \text{ moles S}}$ and $\dfrac{3 \text{ moles S}}{2 \text{ moles Fe}}$

Fe and Fe_2S_3: $\dfrac{2 \text{ moles Fe}}{1 \text{ mole } Fe_2S_3}$ and $\dfrac{1 \text{ mole } Fe_2S_3}{2 \text{ moles Fe}}$

S and Fe_2S_3: $\dfrac{3 \text{ moles S}}{1 \text{ mole } Fe_2S_3}$ and $\dfrac{1 \text{ mole } Fe_2S_3}{3 \text{ moles S}}$

TEST

Try Practice Problems 7.55 and 7.56

Using Mole–Mole Factors in Calculations

CORE CHEMISTRY SKILL

Using Mole–Mole Factors

Whenever you prepare a recipe, adjust an engine for the proper mixture of fuel and air, or prepare medicines in a pharmaceutical laboratory, you need to know the proper amounts of reactants to use and how much of the product will form. Now that we have written all the possible conversion factors for the balanced equation $2Fe(s) + 3S(s) \longrightarrow Fe_2S_3(s)$, we will use those mole–mole factors in a chemical calculation in Sample Problem 7.11.

▶SAMPLE PROBLEM 7.11 Calculating Moles of a Reactant

TRY IT FIRST

In the chemical reaction of iron and sulfur, how many moles of sulfur are needed to react with 1.42 moles of iron?

$$2Fe(s) + 3S(s) \longrightarrow Fe_2S_3(s)$$

SOLUTION

STEP 1 **State the given and needed quantities (moles).**

	Given	Need	Connect
ANALYZE THE PROBLEM	1.42 moles of Fe	moles of S	mole–mole factor
	Equation		
	$2Fe(s) + 3S(s) \longrightarrow Fe_2S_3(s)$		

STEP 2 **Write a plan to convert the given to the needed quantity (moles).**

moles of Fe → Mole–mole factor → moles of S

STEP 3 **Use coefficients to write mole–mole factors.**

$$\frac{2 \text{ moles of Fe}}{3 \text{ moles S}} \quad \text{and} \quad \frac{3 \text{ moles S}}{2 \text{ moles Fe}} \qquad (2 \text{ moles of Fe} = 3 \text{ moles of S})$$

STEP 4 **Set up the problem to give the needed quantity (moles).**

Exact

$$1.42 \text{ moles Fe} \times \frac{3 \text{ moles S}}{2 \text{ moles Fe}} = 2.13 \text{ moles of S}$$

Three SFs — Exact — Three SFs

STUDY CHECK 7.11

Using the equation in Sample Problem 7.11, calculate each of the following:

a. moles of iron needed to react with 2.75 moles of sulfur
b. moles of iron(III) sulfide produced by the reaction of 0.758 mole of sulfur

TEST

Try Practice Problems 7.57 to 7.60

ANSWER

a. 1.83 moles of iron
b. 0.253 mole of iron(III) sulfide

PRACTICE PROBLEMS

7.7 Mole Relationships in Chemical Equations

7.55 Write all of the mole–mole factors for each of the following chemical equations:

a. $2SO_2(g) + O_2(g) \longrightarrow 2SO_3(g)$
b. $4P(s) + 5O_2(g) \longrightarrow 2P_2O_5(s)$

7.56 Write all of the mole–mole factors for each of the following chemical equations:

a. $2Al(s) + 3Cl_2(g) \longrightarrow 2AlCl_3(s)$
b. $4HCl(g) + O_2(g) \longrightarrow 2Cl_2(g) + 2H_2O(g)$

7.57 The chemical reaction of hydrogen with oxygen produces water.

$$2H_2(g) + O_2(g) \longrightarrow 2H_2O(g)$$

a. How many moles of O_2 are required to react with 2.6 moles of H_2?
b. How many moles of H_2 are needed to react with 5.0 moles of O_2?
c. How many moles of H_2O form when 2.5 moles of O_2 reacts?

7.58 Ammonia is produced by the chemical reaction of nitrogen and hydrogen.

$$N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$$

Ammonia

a. How many moles of H_2 are needed to react with 1.8 moles of N_2?
b. How many moles of N_2 reacted if 0.60 mole of NH_3 is produced?
c. How many moles of NH_3 are produced when 1.4 moles of H_2 reacts?

7.59 Carbon disulfide and carbon monoxide are produced when carbon is heated with sulfur dioxide.

$$5C(s) + 2SO_2(g) \xrightarrow{\Delta} CS_2(l) + 4CO(g)$$

a. How many moles of C are needed to react with 0.500 mole of SO_2?
b. How many moles of CO are produced when 1.2 moles of C reacts?
c. How many moles of SO_2 are needed to produce 0.50 mole of CS_2?
d. How many moles of CS_2 are produced when 2.5 moles of C reacts?

7.60 In the acetylene torch, acetylene gas (C_2H_2) burns in oxygen to produce carbon dioxide, water, and energy.

$$2C_2H_2(g) + 5O_2(g) \xrightarrow{\Delta} 4CO_2(g) + 2H_2O(g)$$

a. How many moles of O_2 are needed to react with 2.40 moles of C_2H_2?
b. How many moles of CO_2 are produced when 3.5 moles of C_2H_2 reacts?
c. How many moles of C_2H_2 are needed to produce 0.50 mole of H_2O?
d. How many moles of CO_2 are produced from 0.100 mole of O_2?

7.8 Mass Calculations for Chemical Reactions

REVIEW
Using Significant Figures in Calculations (2.3)

LEARNING GOAL Given the mass in grams of a substance in a reaction, calculate the mass in grams of another substance in the reaction.

When we have the balanced chemical equation for a reaction, we can use the mass of one of the substances (A) in the reaction to calculate the mass of another substance (B) in the reaction. However, the calculations require us to convert the mass of A to moles of A using the molar mass of A. Then we use the mole–mole factor that links substance A to substance B, which we obtain from the coefficients in the balanced equation. This mole–mole factor (B/A) will convert the moles of A to moles of B. Then the molar mass of B is used to calculate the grams of substance B.

CORE CHEMISTRY SKILL
Converting Grams to Grams

	Substance A			Substance B	
grams of A	Molar mass A	moles of A	Mole–mole factor B/A	moles of B	Molar mass B	grams of B

▶SAMPLE PROBLEM 7.12 Calculating Mass of a Product

TRY IT FIRST

When acetylene, C_2H_2, burns in oxygen, high temperatures are produced that are used for welding metals.

$$2C_2H_2(g) + 5O_2(g) \xrightarrow{\Delta} 4CO_2(g) + 2H_2O(g)$$

How many grams of CO_2 are produced when 54.6 g of C_2H_2 is burned?

A mixture of acetylene and oxygen undergoes combustion during the welding of metals.

SOLUTION

STEP 1 State the given and needed quantities (grams).

	Given	Need	Connect
ANALYZE THE PROBLEM	54.6 g of C_2H_2	grams of CO_2	molar masses, mole–mole factor
	Equation		
	$2C_2H_2(g) + 5O_2(g) \xrightarrow{\Delta} 4CO_2(g) + 2H_2O(g)$		

STEP 2 Write a plan to convert the given to the needed quantity (grams).

grams of C_2H_2	Molar mass	moles of C_2H_2	Mole–mole factor	moles of CO_2	Molar mass	grams of CO_2

STEP 3 Use coefficients to write mole–mole factors; write molar masses.

$$1 \text{ mole of } C_2H_2 = 26.04 \text{ g of } C_2H_2$$

$$\frac{26.04 \text{ g } C_2H_2}{1 \text{ mole } C_2H_2} \quad \text{and} \quad \frac{1 \text{ mole } C_2H_2}{26.04 \text{ g } C_2H_2}$$

$$1 \text{ mole of } CO_2 = 44.01 \text{ g of } CO_2$$

$$\frac{44.01 \text{ g } CO_2}{1 \text{ mole } CO_2} \quad \text{and} \quad \frac{1 \text{ mole } CO_2}{44.01 \text{ g } CO_2}$$

$$2 \text{ moles of } C_2H_2 = 4 \text{ moles of } CO_2$$

$$\frac{2 \text{ moles } C_2H_2}{4 \text{ moles } CO_2} \quad \text{and} \quad \frac{4 \text{ moles } CO_2}{2 \text{ moles } C_2H_2}$$

STEP 4 Set up the problem to give the needed quantity (grams).

	Exact	Exact	Four SFs	
$54.6 \text{ g } \cancel{C_2H_2} \times$	$\frac{1 \text{ } \cancel{\text{mole } C_2H_2}}{26.04 \text{ g } \cancel{C_2H_2}} \times$	$\frac{4 \text{ } \cancel{\text{moles } CO_2}}{2 \text{ } \cancel{\text{moles } C_2H_2}} \times$	$\frac{44.01 \text{ g } CO_2}{1 \text{ } \cancel{\text{mole } CO_2}} =$	$185 \text{ g of } CO_2$
Three SFs	Four SFs	Exact	Exact	Three SFs

INTERACTIVE VIDEO
Problem 7.67

TEST
Try Practice Problems 7.61 to 7.70

STUDY CHECK 7.12

Using the equation in Sample Problem 7.12, calculate each of the following:

a. the grams of CO_2 produced when 25.0 g of O_2 reacts
b. the grams of C_2H_2 needed when 65.0 g of H_2O are produced

ANSWER

a. 27.5 g of CO_2
b. 93.9 g of C_2H_2

PRACTICE PROBLEMS

7.8 Mass Calculations for Chemical Reactions

7.61 Sodium reacts with oxygen to produce sodium oxide.

$$4Na(s) + O_2(g) \longrightarrow 2Na_2O(s)$$

a. How many grams of Na_2O are produced when 57.5 g of Na reacts?
b. If you have 18.0 g of Na, how many grams of O_2 are needed for the reaction?
c. How many grams of O_2 are needed in a reaction that produces 75.0 g of Na_2O?

7.62 Nitrogen reacts with hydrogen to produce ammonia.

$$N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$$

a. If you have 3.64 g of H_2, how many grams of NH_3 can be produced?
b. How many grams of H_2 are needed to react with 2.80 g of N_2?
c. How many grams of NH_3 can be produced from 12.0 g of H_2?

7.63 Ammonia and oxygen react to form nitrogen and water.

$$4NH_3(g) + 3O_2(g) \longrightarrow 2N_2(g) + 6H_2O(g)$$

a. How many grams of O_2 are needed to react with 13.6 g of NH_3?
b. How many grams of N_2 can be produced when 6.50 g of O_2 reacts?
c. How many grams of H_2O are formed from the reaction of 34.0 g of NH_3?

7.64 Iron(III) oxide reacts with carbon to give iron and carbon monoxide.

$$Fe_2O_3(s) + 3C(s) \longrightarrow 2Fe(s) + 3CO(g)$$

a. How many grams of C are required to react with 16.5 g of Fe_2O_3?
b. How many grams of CO are produced when 36.0 g of C reacts?
c. How many grams of Fe can be produced when 6.00 g of Fe_2O_3 reacts?

7.65 Nitrogen dioxide and water react to produce nitric acid, HNO_3, and nitrogen oxide.

$$3NO_2(g) + H_2O(l) \longrightarrow 2HNO_3(aq) + NO(g)$$

a. How many grams of H_2O are needed to react with 28.0 g of NO_2?
b. How many grams of NO are produced from 15.8 g of H_2O?
c. How many grams of HNO_3 are produced from 8.25 g of NO_2?

7.66 Calcium cyanamide, $CaCN_2$, reacts with water to form calcium carbonate and ammonia.

$$CaCN_2(s) + 3H_2O(l) \longrightarrow CaCO_3(s) + 2NH_3(g)$$

a. How many grams of H_2O are needed to react with 75.0 g of $CaCN_2$?
b. How many grams of NH_3 are produced from 5.24 g of $CaCN_2$?
c. How many grams of $CaCO_3$ form if 155 g of H_2O reacts?

7.67 When solid lead(II) sulfide reacts with oxygen gas, the products are solid lead(II) oxide and sulfur dioxide gas.
a. Write the balanced chemical equation for the reaction.
b. How many grams of oxygen are required to react with 29.9 g of lead(II) sulfide?
c. How many grams of sulfur dioxide can be produced when 65.0 g of lead(II) sulfide reacts?
d. How many grams of lead(II) sulfide are used to produce 128 g of lead(II) oxide?

7.68 When the gases dihydrogen sulfide and oxygen react, they form the gases sulfur dioxide and water vapor.
a. Write the balanced chemical equation for the reaction.
b. How many grams of oxygen are needed to react with 2.50 g of dihydrogen sulfide?
c. How many grams of sulfur dioxide can be produced when 38.5 g of oxygen reacts?
d. How many grams of oxygen are needed to produce 55.8 g of water vapor?

Clinical Applications

7.69 In the body, the amino acid glycine, $C_2H_5NO_2$, reacts according to the following equation:

$$\underset{\text{Glycine}}{2C_2H_5NO_2(aq)} + 3O_2(g) \longrightarrow 3CO_2(g) + 3H_2O(l) + \underset{\text{Urea}}{CH_4N_2O(aq)}$$

a. How many grams of O_2 are needed to react with 15.0 g of glycine?
b. How many grams of urea are produced from 15.0 g of glycine?
c. How many grams of CO_2 are produced from 15.0 g of glycine?

7.70 In the body, ethanol, C_2H_6O, reacts according to the following equation:

$$\underset{\text{Ethanol}}{C_2H_6O(aq)} + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(l)$$

a. How many grams of O_2 are needed to react with 8.40 g of ethanol?
b. How many grams of H_2O are produced from 8.40 g of ethanol?
c. How many grams of CO_2 are produced from 8.40 g of ethanol?