Section 7.1

1 FOCUS

Objectives

7.1.1 **Interpret** chemical equations in terms of reactants, products, and conservation of mass.
7.1.2 **Balance** chemical equations by manipulating coefficients.
7.1.3 **Convert** between moles and mass of a substance using molar mass.
7.1.4 **Calculate** amounts of reactants or products by using molar mass, mole ratios, and balanced chemical equations.

Reading Focus

Build Vocabulary L2

Concept Map Have students construct a concept map of the terms *reactants, products, chemical equations, coefficients,* and *moles*. Instruct students to place the terms in ovals and connect the ovals with lines on which linking words are placed. Students should place the main concept (Describing Reactions) at the top or center and use descriptive linking phrases to connect the terms.

Reading Strategy L2

Answers may vary. Possible answer:
a. How to balance chemical equations
b. An unbalanced equation can be balanced by changing the coefficients.
c. How to convert from mass to moles
d. The mass of a substance can be converted to moles by using the molar mass as a conversion factor.

2 INSTRUCT

Chemical Equations

Use Visuals L1

Figure 1 Have students examine the reaction taking place in the photo. **What clues show that a chemical reaction is taking place?** *(Energy is released in the form of heat and light.)* Mention that one of the reactants, O_2, and the product, CO_2, are colorless gases. **How might a scientist determine that oxygen gas is involved in this reaction?** *(He or she could attempt to burn charcoal in an oxygen-free environment.)*
Visual

7.1 Describing Reactions

Reading Focus

Key Concepts

- What is the law of conservation of mass?
- Why must chemical equations be balanced?
- Why do chemists use the mole?
- How can you calculate the mass of a reactant or product in a chemical reaction?

Vocabulary

- reactants
- products
- chemical equation
- coefficients
- mole
- molar mass

Reading Strategy

Monitoring Your Understanding Preview the Key Concepts, topic headings, vocabulary, and figures in this section. List two things you expect to learn. After reading, state what you learned about each item you listed.

What I Expect to Learn	What I Learned
a. ____?____	b. ____?____
c. ____?____	d. ____?____

Figure 1 Burning is an example of a chemical reaction. When charcoal burns, the carbon in the charcoal reacts with oxygen in the air to produce carbon dioxide and heat.

What type of change is happening in Figure 1? When charcoal burns, it changes into other substances while producing heat and light. Burning is a chemical change. When a substance undergoes a chemical change, a chemical reaction is said to take place. In order to understand chemical reactions, you first must be able to describe them.

Chemical Equations

A useful way of describing a change is to state what is present before and after the change. For example, suppose you wanted to show how your appearance changed as you grew older. You could compare a photo of yourself when you were younger with a photo that was taken recently.

A useful description of a chemical reaction tells you the substances present before and after the reaction. In a chemical reaction, the substances that undergo change are called **reactants.** The new substances formed as a result of that change are called **products.** In Figure 1, the reactants are the carbon in the charcoal and the oxygen in the air. The product of the reaction is carbon dioxide gas.

Using Equations to Represent Reactions During a chemical reaction, the reactants change into products. You can summarize this process with a word equation.

$$\text{Reactants} \longrightarrow \text{Products}$$

Section Resources

Print
- ***Reading and Study Workbook With Math Support,*** Section 7.1 and **Math Skill:** Balancing Chemical Equations
- ***Math Skills and Problem Solving Workbook,*** Section 7.1
- ***Transparencies,*** Chapter Pretest and Section 7.1

Technology
- ***Interactive Textbook,*** Section 7.1
- ***Presentation Pro CD-ROM,*** Chapter Pretest and Section 7.1
- ***Go Online,*** NSTA SciLinks, Conservation of mass; *Science News*, Chemical reactions

To describe the burning of charcoal, you can substitute the reactants and products of the reaction into the word equation as follows.

$$\text{Carbon} + \text{Oxygen} \longrightarrow \text{Carbon dioxide}$$

You can then simplify the word equation by writing the reactants and products as chemical formulas.

$$C + O_2 \longrightarrow CO_2$$

Now you have a chemical equation. 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 above as, "Carbon and oxygen react and form carbon dioxide," or, "The reaction of carbon and oxygen yields carbon dioxide."

Reading Checkpoint ***What is a chemical equation?***

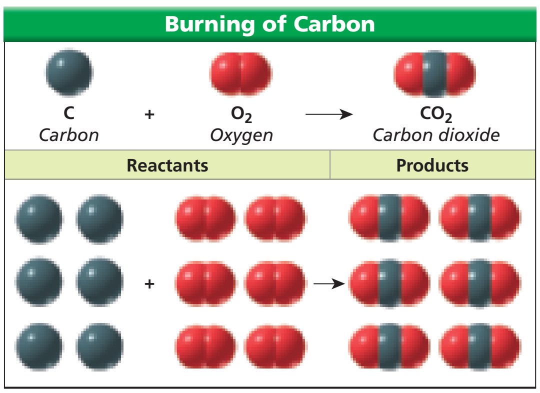
Conservation of Mass As a piece of charcoal burns, it gets smaller and smaller until it is finally reduced to a tiny pile of ash. Although the charcoal seems to disappear as it burns, it is actually being converted into carbon dioxide gas. If you measured the mass of the carbon dioxide produced, it would equal the mass of the charcoal and oxygen that reacted.

During chemical reactions, the mass of the products is always equal to the mass of the reactants. This principle, established by French chemist Antoine Lavoisier (1743–1794), is known as the law of conservation of mass. **The law of conservation of mass states that mass is neither created nor destroyed in a chemical reaction.** Recall that mass is a measure of the amount of matter. So, this law is also known as the law of conservation of matter. By demonstrating that mass is conserved in various reactions, Lavoisier laid the foundation for modern chemistry.

Figure 2 illustrates how a chemical equation can be restated in terms of atoms and molecules. The equation reads, "One atom of carbon reacts with one molecule of oxygen and forms one molecule of carbon dioxide." Suppose you have six carbon atoms. If each carbon atom reacts with one oxygen molecule to form one carbon dioxide molecule, then six carbon atoms react with six oxygen molecules to form six carbon dioxide molecules. Notice that the number of atoms on the left side of the equation equals the number of atoms on the right. The equation shows that mass is conserved.

For: Links on conservation of mass
Visit: www.SciLinks.org
Web Code: ccn-1071

Figure 2 Whether you burn one carbon atom or six carbon atoms, the equation used to describe the reaction is the same. **Using Models** ***How do both models of the reaction below show that mass is conserved?***



Address Misconceptions L2

Many students fail to recognize the conservation of particles that takes place during a chemical change. Challenge this misconception by having students count the numbers of carbon and oxygen atoms on both sides of the arrows in Figure 2. They should notice that both sides of the equation have the same number of each type of atom. Note that this chapter discusses only chemical reactions, not nuclear reactions (discussed in Chapter 10), in which mass is not conserved.
Visual

Build Math Skills L1

Formulas and Equations Have students write an equation for burning six carbon atoms in air to produce carbon dioxide. *($6C + 6O_2 \longrightarrow 6CO_2$)* Point out that while this equation is balanced, and represents the reaction of exactly six atoms of carbon and six molecules of oxygen, it is not the simplest equation for the reaction. Explain that a balanced chemical equation uses the simplest coefficients possible. Have students divide each coefficient by the greatest common factor, in this case 6, to get the simplest coefficients and the correctly balanced equation. *($C + O_2 \longrightarrow CO_2$)* **Logical**

Direct students to the **Math Skills** in the **Skills and Reference Handbook** at the end of the student text for additional help.

Download a worksheet on conservation of mass for students to complete, and find additional teacher support from NSTA SciLinks.

Customize for Inclusion Students

Visually Impaired
Provide students with molecular models that use different sizes or textures to identify the different types of atoms. Have them build molecular models that show the reaction for the burning of carbon. Then, have students use the models to demonstrate conservation of mass.

Answer to . . .

Figure 2 *In both models of the reaction $C + O_2 \longrightarrow CO_2$, the number of atoms of each element on the left equals the number of atoms of each element on the right.*

Reading Checkpoint *A chemical equation is a representation of a chemical reaction in which the reactants and products are expressed as formulas.*

Section 7.1 (continued)

Balancing Equations

Use Visuals L1

Figure 4 Have students use colored paperclips to model the different atoms of the reactants and products shown in Figure 4. As a class, go over the process of balancing the equation using the paperclips as a visual aid. Have students practice balancing the following equations by making lists of the numbers of each type of atom in the reactants and products as shown in Figure 4.

1. $\mathbf{Na + H_2O \longrightarrow NaOH + H_2}$
($2Na + 2H_2O \longrightarrow 2NaOH + H_2$)

2. $\mathbf{HCl + CaCO_3 \longrightarrow CaCl_2 + CO_2 + H_2O}$
($2HCl + CaCO_3 \longrightarrow CaCl_2 + CO_2 + H_2O$)

3. $\mathbf{Al + Cl_2 \longrightarrow AlCl_3}$
($2Al + 3Cl_2 \longrightarrow 2AlCl_3$)

Students may find it helpful to make two or three models of each reactant and product and then try various combinations, listing and checking the balance of the atoms for each combination.
Visual

Go Online active art

For: Activity on balancing equations
Visit: PHSchool.com
Web Code: ccp-1071

Students can view a simulation on how to balance chemical equations.

Figure 3 Water is a compound made up of the elements hydrogen and oxygen.

Go Online active art

For: Activity on balancing equations
Visit: PHSchool.com
Web Code: ccp-1071

Balancing Equations

Water is formed by the reaction of hydrogen and oxygen. You can describe the reaction by writing a chemical equation.

$$H_2 + O_2 \longrightarrow H_2O$$

If you examine this equation carefully, you will notice that the number of atoms on the left side does not equal the number of atoms on the right. The equation is not balanced. **In order to show that mass is conserved during a reaction, a chemical equation must be balanced.**

You can balance a chemical equation by changing the **coefficients,** the numbers that appear before the formulas. In the unbalanced equation above, the coefficients are understood to be 1. When you change a coefficient, you change the amount of that reactant or product represented in the chemical equation. As you balance equations, you should never change the subscripts in a formula. Changing the formula changes the identity of that reactant or product.

The first step in balancing an equation is to count the number of atoms of each element on each side of the equation, as shown in Figure 4. The left side of the unbalanced equation has two hydrogen atoms and two oxygen atoms. The right side has two hydrogen atoms and one oxygen atom. The oxygen atoms need to be balanced.

The next step is to change one or more coefficients until the equation is balanced. You can balance the oxygen atoms by changing the coefficient of H_2O to 2.

$$H_2 + O_2 \longrightarrow 2H_2O$$

The oxygen atoms are now balanced. However, the hydrogen atoms have become "unbalanced," with two on the left, and four on the right. To balance the hydrogen atoms, change the coefficient of H_2 to 2.

$$2H_2 + O_2 \longrightarrow 2H_2O$$

The equation is now balanced. Each side of the balanced equation has four hydrogen atoms and two oxygen atoms, as shown in Figure 4. According to the balanced equation, two molecules of hydrogen react with one molecule of oxygen to yield two molecules of water.

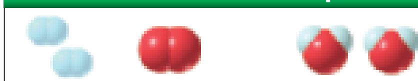
Figure 4 In the unbalanced equation, the hydrogen atoms are balanced but the oxygen atoms are not. After changing the coefficients, both the hydrogen and oxygen atoms are balanced. **Applying Concepts** ***Why must chemical equations be balanced?***

Unbalanced Chemical Equation

$H_2 + O_2 \longrightarrow H_2O$

Reactants	Product
2 hydrogen atoms	2 hydrogen atoms
2 oxygen atoms	1 oxygen atom

Balanced Chemical Equation



$2H_2 + O_2 \longrightarrow 2H_2O$

Reactants	Product
4 hydrogen atoms	4 hydrogen atoms
2 oxygen atoms	2 oxygen atoms

Answer to . . .

Figure 4 *To show that mass is conserved during a chemical reaction*

Reading Checkpoint *The first step in balancing a chemical equation is to count the number of atoms of each element on each side of the equation.*

Facts and Figures

Rocket Fuel One of the fuels used to propel the space shuttle is liquid hydrogen, also called LH2. Liquid oxygen, or LOX, serves as the oxidizer. LH2 and LOX for the space shuttle's main engines are stored in separate tanks within a large external fuel tank. The reaction of the hydrogen and oxygen generates thrust and produces water vapor as exhaust gas. It takes about 8.5 minutes for the shuttle to use up its LH2 and LOX supplies, after which the external tank is jettisoned.

Math Skills

Balancing Chemical Equations

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

1 Read and Understand

What information are you given?

Reactants: Cu, O_2 Product: CuO

2 Plan and Solve

Write a chemical equation with the reactants on the left side and the product on the right.

$$Cu + O_2 \longrightarrow CuO$$

This equation is not balanced. Change the coefficient of CuO in order to balance the number of oxygen atoms.

$$Cu + O_2 \longrightarrow 2CuO$$

Change the coefficient of Cu in order to balance the number of copper atoms.

$$2Cu + O_2 \longrightarrow 2CuO$$

3 Look Back and Check

Is your answer reasonable?

The number of atoms on the left equals the number of atoms on the right.

Math Practice

1. Hydrogen chloride, or HCl, is an important industrial chemical. Write a balanced equation for the production of hydrogen chloride from hydrogen and chlorine.
2. Balance the following chemical equations.
   a. $H_2O_2 \longrightarrow H_2O + O_2$
   b. $Mg + HCl \longrightarrow H_2 + MgCl_2$
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.

Counting With Moles

How many shoes do you own? Because shoes come in twos, you would most likely count them by the pair rather than individually. The counting units you use depend on what you are counting. For example, you might count eggs by the dozen or paper by the ream.

Chemists also need practical units for counting things. Although you can describe a reaction in terms of atoms and molecules, these units are too small to be practical. **Because chemical reactions often involve large numbers of small particles, chemists use a counting unit called the mole to measure amounts of a substance.**

A **mole** (mol) is an amount of a substance that contains approximately 6.02×10^{23} particles of that substance. This number is known as Avogadro's number. In chemistry, a mole of a substance generally contains 6.02×10^{23} atoms, molecules, or ions of that substance. For instance, a mole of iron is 6.02×10^{23} atoms of iron.

Figure 5 Shoes are often counted by the pair, eggs by the dozen, and paper by the ream (500 sheets). To count particles of a substance, chemists use the mole (6.02×10^{23} particles).

Math Practice

Solutions L2

1. $H_2 + Cl_2 \longrightarrow 2HCl$
2. a. $2H_2O_2 \longrightarrow 2H_2O + O_2$
   b. $Mg + 2HCl \longrightarrow H_2 + MgCl_2$
3. $C_2H_4 + 3O_2 \longrightarrow 2CO_2 + 2H_2O$

Logical

For Extra Help L1

Only the coefficients, not the subscripts, should change. **Logical**

Direct students to the **Math Skills** in the **Skills and Reference Handbook** at the end of the student text for additional help.

Additional Problems

1. Balance the reaction of silicon with oxygen to form silicon dioxide. *($Si + O_2 \longrightarrow SiO_2$)*
2. Balance $Fe + Cl_2 \longrightarrow FeCl_3$. *($2Fe + 3Cl_2 \longrightarrow 2FeCl_3$)*

Logical, Portfolio

Counting With Moles

Teacher Demo

Counting Particles L2

Purpose Students see the efficiency of using molar mass to count particles.

Materials 14 g graphite powder, small beaker, spatula, balance, a bag of rice, stack of paper plates

Procedure Count out 1 mole of carbon atoms while a volunteer attempts to count out 1 mole of rice grains (100 grains of rice onto each paper plate). Write the molar mass of carbon on the board and weigh out 12.01 g of graphite. Have students note how few rice grains there are compared to 1 mole. Ask, **How large could 1 mole of rice grains be?** *(1 mole of rice grains could fill more than 10^{13} classrooms that are 10m × 10m × 4m!)*

Expected Outcome Using molar mass to count is more efficient than counting particles one by one. **Visual, Logical**

Quick Lab

Modeling a Mole

L2

Objective
After completing this activity, students will be able to
- use the concept of moles to solve stoichiometric problems.

Skills Focus Observing, Measuring, Predicting, Calculating

Prep Time 5 minutes

Advance Prep Be sure the bolts, nuts, and washers are compatible.

Class Time 20 minutes

Expected Outcome Students will correctly assemble and predict the mass of the molecular model.

Analyze and Conclude
1. The mass of the molecule will equal the sum of the masses of all of its parts.
2. Students can make 10 models.
3. This answer will depend upon the mass of the nuts that are used. For example, if a nut has a mass of 10 g, then students would be able to make 10 models of the molecule.
Kinesthetic, Logical

For Enrichment

L3

Add bolts, washers, and nuts of different masses to the atom collection. Have students assemble a variety of new molecules with the same number of atoms but with different-sized pieces. They can determine whether the mass of the molecule changes and whether it is possible to assemble molecules that are different in structure but have the same mass.
Kinesthetic, Logical

Figure 6 The molar mass of carbon is 12.0 grams. The molar mass of sulfur is 32.1 grams. Inferring ***If each of the carbon and sulfur samples contains one mole of atoms, why do the samples have different masses?***

Molar Mass A dozen eggs has a different mass than a dozen oranges. Similarly, a mole of carbon has a different mass than a mole of sulfur, as shown in Figure 6. The mass of one mole of a substance is called a **molar mass.** For an element, the molar mass is the same as its atomic mass expressed in grams. For example, the atomic mass of carbon is 12.0 amu, so the molar mass of carbon is 12.0 grams.

For a compound, you can calculate the molar mass by adding up the atomic masses of its component atoms, and then expressing this sum in grams. A carbon dioxide molecule is composed of one carbon atom (12.0 amu) and two oxygen atoms (2 × 16.0 amu = 32.0 amu). So carbon dioxide has a molar mass of 44.0 grams.

Mole-Mass Conversions Once you know the molar mass of a substance, you can convert moles of that substance into mass, or a mass of that substance into moles. For either calculation, you need to express the molar mass as a conversion factor. For example, the molar mass of CO_2 is 44.0 grams, which means that one mole of CO_2 has a mass of 44.0 grams. This relationship yields the following conversion factors.

$$\frac{44.0\text{ g }CO_2}{1\text{ mol }CO_2} \qquad \frac{1\text{ mol }CO_2}{44.0\text{ g }CO_2}$$

Suppose you have 55.0 grams of CO_2. To calculate how many moles of CO_2 you have, multiply the mass by the conversion factor on the right.

$$55.0\text{ g }CO_2 \times \frac{1\text{ mol }CO_2}{44.0\text{ g }CO_2} = 1.25\text{ mol }CO_2$$

You can check your answer by using the conversion factor on the left.

$$1.25\text{ mol }CO_2 \times \frac{44.0\text{ g }CO_2}{1\text{ mol }CO_2} = 55.0\text{ g }CO_2$$

Quick Lab

Modeling a Mole

Materials
bolt, 2 nuts, 2 washers, balance

Procedure
1. Measure and record the mass of one bolt, one nut, and one washer. Each piece of hardware will represent an atom of a different element.
2. Assemble the bolt, nuts, and washers together so that they form a model of a molecule known as BN_2W_2.
3. Predict the mass of BN_2W_2.
4. Test your prediction by finding the mass of your model.

Analyze and Conclude
1. **Analyzing Data** Did your prediction match the actual mass of your model? Explain.
2. **Calculating** How many models of your molecule can you make with 20 washers and as many nuts and bolts as you need?
3. **Calculating** How many models of your molecule can you make with 100 grams of nuts and as many bolts and washers as you need?

Chemical Calculations

Think about baking a cake like the one in Figure 7. The directions on a box of cake mix might tell you to add two eggs and one cup of water to the cake mix. Suppose you wanted to make three cakes. Although the directions don't tell you specifically how many eggs and how much water are required for three cakes, you could figure out the amounts. To make three cakes, you would need three times as much of each ingredient—six eggs, three cups of water, and three packages of cake mix.

Chemical equations can be read as recipes for making new substances. Figure 8 shows the balanced equation for the formation of water. You can read this equation as, "Two molecules of hydrogen react with one molecule of oxygen and form two molecules of water." In terms of moles, the equation reads, "Two moles of hydrogen react with one mole of oxygen and form two moles of water." To convert from moles to mass, you need to use the molar masses as conversion factors. Figure 8 shows how the same equation can also be read as, "4.0 grams of H_2 reacts with 32.0 grams of O_2 and forms 36.0 grams of H_2O."

How many grams of oxygen would you need to make 144 grams of water? **In chemical reactions, the mass of a reactant or product can be calculated by using a balanced chemical equation and molar masses of the reactants and products.** The chemical equation tells you how to relate amounts of reactants to amounts of products. Molar masses let you convert those amounts into masses.

Reading Checkpoint *How do you convert from moles to mass?*

Figure 7 A cake recipe tells you how much of each ingredient to use for each cake you bake. **Using Analogies** ***How is a cake recipe like a chemical equation?***

Converting Mass to Moles

To calculate how much oxygen is required to make 144 grams of water, you need to begin with a balanced chemical equation for the reaction.

$$2H_2 + O_2 \longrightarrow 2H_2O$$

The first step in your calculations is to determine how many moles of water you are trying to make. By using the molar mass of water, you can convert the given mass of water into moles.

$$144\text{ g } H_2O \times \frac{1\text{ mol } H2O}{18.0\text{ g } H_2O} = 8.00\text{ mol } H_2O$$

Formation of Water

Equation	$2H_2$	+	O_2	→	$2H_2O$
Amount	2 mol		1 mol		2 mol
Molar Mass	2.0 g/mol		32.0 g/mol		18.0 g/mol
Mass (Moles × Molar Mass)	4.0 g	+	32.0 g	→	36.0 g

Figure 8 In a balanced chemical equation, the number of atoms of each element on the left equals the number of atoms of each element on the right. By using molar masses, you can show that the mass of the reactants equals the mass of the products.

Build Science Skills L2

Measuring and Calculating ACTIVITY

Purpose Students calculate and measure out molar quantities of various samples.

Materials copper wire, aluminum foil, water, sodium chloride, hydrogen peroxide, wire snips, metal spatulas, beakers, balances

Class Time 10 minutes

Procedure Have students use the periodic table to determine the molar mass of Cu, Al, H_2O, NaCl, and H_2O_2. Ask them to calculate the mass of the following quantities: 0.5 mol Cu, 2 mol Al, 3 mol H_2O, 0.75 mol NaCl, and 1 mol H_2O_2. Have students wear goggles and work in groups to measure out each quantity. If supplies are limited, assign one quantity to each group.

Expected Outcome The molar mass for Cu is 63.55 g, for Al is 26.98 g, for H_2O is 18.02 g, for NaCl is 58.44 g, and for H_2O_2 is 34.02 g. Students should measure out 32 g Cu, 54 g Al, 54 g H_2O, 44 g NaCl, and 34 g H_2O_2.
Logical, Group

Chemical Calculations

Build Reading Literacy L1

Summarize Refer to page **598D** in **Chapter 20**, which provides the guidelines for a summary.

Have students read the text on pp. 197 and 198 related to chemical calculations. Then, have students summarize the steps required to determine the number of grams of oxygen needed to make 144 grams of water.
Logical

Facts and Figures

Baking Reactions The reaction of sodium bicarbonate ($NaHCO_3$) under heat is one of the chemical reactions that make cakes and muffins rise. Cake recipes may call for baking soda (the common name for sodium bicarbonate) or baking powder (a mixture that contains sodium bicarbonate). When sodium bicarbonate is heated, it breaks down into simpler products according to the following equation.

$$2NaHCO_3 \longrightarrow Na_2CO_3 + H_2O + CO_2$$

The carbon dioxide produced by this reaction causes the cake to rise as it bakes. The CO_2 bubbles that become trapped give baked goods their spongy texture.

Answer to . . .

Figure 6 *Carbon and sulfur have different atomic masses. Therefore, the mass of one mole of carbon is different from the mass of one mole of sulfur.*

Figure 7 *A cake recipe tells you what ingredients and what amounts of each are required to make a cake. Similarly, a balanced chemical equation tells you what reactants and what relative amounts of each are required to form a product or set of products.*

Reading Checkpoint *You can convert moles of a substance into mass by multiplying by the molar mass of the substance.*

3 ASSESS

Evaluate Understanding

L2

Give students a chemical equation to analyze. Ask them to determine whether the equation is balanced, and to explain how conservation of mass applies. Then, have students write a problem that requires converting from mass of a reactant to mass of a product. Have students exchange their problem with a partner for him or her to solve.

Reteach

L1

Use Figure 2 to summarize the key concepts in this section, such as identifying reactants and products, balancing equations, understanding conservation of mass, and determining mole ratios. Have students determine the mole ratio of carbon to carbon dioxide in the balanced equation. *(1:1)*

Math Practice

Solutions

9. $2K + Br_2 \longrightarrow 2KBr$
10. $2Mg + O_2 \longrightarrow 2MgO$

Interactive Textbook

If your class subscribes to the Interactive Textbook, use it to review key concepts in Section 7.1.

Go Online SCIENCE NEWS

Science News provides students with current information on chemical reactions.

Go Online SCIENCE NEWS

For: Articles on chemical reactions
Visit: PHSchool.com
Web Code: cce-1071

Using Mole Ratios Remember the balanced chemical equation for the formation of water. You can read it as, "Two moles of hydrogen react with one mole of oxygen and form two moles of water." Because each mole of oxygen that reacts will yield two moles of water, you can write the following conversion factors, or mole ratios.

$$\frac{1 \text{ mol } O_2}{2 \text{ mol } H_2O} \qquad \frac{2 \text{ mol } H_2O}{1 \text{ mol } O_2}$$

The mole ratio on the left allows you to convert moles of water to moles of oxygen. Now you can calculate how many moles of oxygen are required to produce eight moles of water:

$$8.00 \text{ mol } H_2O \times \frac{1 \text{ mol } O_2}{2 \text{ mol } H_2O} = 4.00 \text{ mol } O_2$$

Converting Moles to Mass The last step is to convert moles of O_2 to grams of O_2 by using the molar mass of O_2 as a conversion factor.

$$4.00 \text{ mol } O_2 \times \frac{32.0 \text{ g } O_2}{1 \text{ mol } O_2} = 128 \text{ g } O_2$$

So, in order to produce 144 grams of H_2O, you must supply 128 grams of O_2. Notice that you used the concept of a mole in two ways to solve this problem. In the first and last step, you used a molar mass to convert between mass and moles. In the middle step, you used the mole ratio to convert moles of a product into moles of a reactant.

Section 7.1 Assessment

Reviewing Concepts

1. What is the law of conservation of mass?
2. Why does a chemical equation need to be balanced?
3. Why do chemists use the mole as a counting unit?
4. What information do you need to predict the mass of a reactant or product in a chemical reaction?
5. What is a mole ratio?

Critical Thinking

6. **Applying Concepts** The following equation describes how sodium and chlorine react to produce sodium chloride.

$$2Na + Cl_2 \longrightarrow 2NaCl$$

Is the equation balanced? Explain your answer.

7. **Calculating** Ammonia, NH_3, can be made by reacting nitrogen with hydrogen.

$$N_2 + 3H_2 \longrightarrow 2NH_3$$

How many moles of NH_3 can be made if 7.5 moles of H_2 react with enough N_2?

8. **Calculating** What mass of NH_3 can be made from 35.0 g of N_2?

Math Practice

9. Balance the following equation.

$$K + Br_2 \longrightarrow KBr$$

10. Write a balanced chemical equation for the formation of magnesium oxide, MgO, from magnesium and oxygen.

Section 7.1 Assessment

1. The law of conservation of mass states that mass is neither created nor destroyed.
2. A chemical equation must be balanced in order to demonstrate that mass is conserved.
3. Because chemical reactions often involve large numbers of small particles, the mole (6.02×10^{23} particles) is a practical counting unit for scientists to use.
4. In order to calculate the mass of a reactant or product in a chemical reaction, you need the molar mass of the reactant, the molar mass of the product, and a balanced chemical equation (which tells you the mole ratio between the reactant and product).
5. A mole ratio is a conversion factor that relates two substances that take part in a chemical reaction. A mole ratio can be determined from a balanced chemical equation.
6. Yes, there are two sodium atoms and two chlorine atoms on each side of the equation.
7. $7.5 \text{ mol } H_2 \times \frac{2 \text{ mol } NH_3}{3 \text{ mol } H_2} = 5.0 \text{ mol } NH_3$
8. Molar mass of N_2 is 28.0 g.
$35.0 \text{ g } N_2 \times \frac{1 \text{ mol } N_2}{28.0 \text{ g } N_2} = 1.25 \text{ mol } N_2$
Mole ratio of NH_3:N_2 is 2:1.
$1.25 \text{ mol } N_2 \times \frac{2 \text{ mol } NH_3}{1 \text{ mol } N_2} = 2.50 \text{ mol } NH_3$
Molar mass of NH_3 is 17.0 grams.
$2.50 \text{ mol } NH_3 \times \frac{17.0 \text{ g } NH_3}{1 \text{ mol } NH_3} = 42.5 \text{ g } NH_3$