Name ____________________ Date ______________ Class ______________

12 STOICHIOMETRY

SECTION 12.1 THE ARITHMETIC OF EQUATIONS (pages 353–358)

This section explains how to calculate the amount of reactants required or product formed in a nonchemical process. It teaches you how to interpret chemical equations in terms of interacting moles, representative particles, masses, and gas volume at STP.

▶ Using Everyday Equations (pages 353–355)

1. How can you determine the quantities of reactants and products in a chemical reaction?

____

____

2. Quantity usually means the ________________ of a substance expressed in grams or moles.

3. A bookcase is to be built from 3 shelves (Sh), 2 side boards (Sb), 1 top (T), 1 base (B), and 4 legs (L). Write a "balanced equation" for the construction of this bookcase.

____

▶ Using Balanced Chemical Equations (page 354)

4. Is the following sentence true or false? Stoichiometry is the calculation of quantities in chemical reactions. ________________

5. Calculations using balanced equations are called ____________________.

▶ Interpreting Chemical Equations (pages 356–357)

6. From what elements is ammonia produced? How is it used?

____

____

7. Circle the letter of the term that tells what kind of information you CANNOT get from a chemical equation.

a. moles

b. mass

c. size of particles

d. volume

e. number of particles

8. The coefficients of a balanced chemical equation tell you the relative number of moles of ____________________ and ____________________ in a chemical reaction.

9. Why is the relative number of moles of reactants and products the most important information that a balanced chemical equation provides?

____

____

▶ Mass Conservation in Chemical Reactions (pages 357–358)

10. Is the following sentence true or false? A balanced chemical equation must obey the law of conservation of mass. ____________________

11. Use Figure 12.3 on page 357. Complete the table about the reaction of nitrogen and hydrogen.

$N_2(g)$	$+$ $3H_2(g)$	$\rightarrow$ $2NH_3(g)$
☐ atoms N	$+$ 6 atoms H	$\rightarrow$ ☐ atoms N and ☐ atoms H
1 molecule N_2	$+$ ☐ molecules H_2	$\rightarrow$ ☐ molecules NH_3
☐ $\times$ (6.02×10^{23} molecules N_2)	$+$ $3 \times$ (6.02×10^{23} molecules H_2)	$\rightarrow$ ☐ $\times$ (6.02×10^{23} molecules NH_3)
1 mol N_2	$+$ ☐ mol H_2	$\rightarrow$ 2 mol NH_3
28 g N_2	$+ 3 \times$ ☐ g H_2	$\rightarrow$ $2 \times$ ☐ g NH_3
	☐ g reactants	$\rightarrow$ 34 g products
Assume STP 22.4 L N_2	$+$ 67.2 L H_2	$\rightarrow$ ☐ L NH_3

12. Circle the letter(s) of the items that are ALWAYS conserved in every chemical reaction.

a. volume of gases

b. mass

c. formula units

d. moles

e. molecules

f. atoms

13. What reactant combines with oxygen to form sulfur dioxide? Where can this reactant be found in nature?

____

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SECTION 12.2 CHEMICAL CALCULATIONS (pages 359–366)

This section shows you how to construct mole ratios from balanced chemical equations. It then teaches you how to calculate stoichiometric quantities from balanced chemical equations using units of moles, mass, representative particles, and volumes of gases at STP.

▶ Writing and Using Mole Ratios (pages 359–362)

1. What is essential for all calculations involving amounts of reactants and products? ______________________________

2. Is the following sentence true or false? If you know the number of moles of one substance in a reaction, you need more information than the balanced chemical equation to determine the number of moles of all the other substances in the reaction.

____

3. The coefficients from a balanced chemical equation are used to write conversion factors called ______________ .

4. What are mole ratios used for?

____

____

____

____

5. The equation for the formation of potassium chloride is given by the equation

$2K(s) + Cl_2(g) \longrightarrow 2KCl(s)$

Write the six possible mole ratios for this equation.

______________ ______________

______________ ______________

______________ ______________

6. Is the following sentence true or false? Laboratory balances are used to measure moles of substances directly. ______________

7. The amount of a substance is *usually* determined by measuring its mass in ______________________________ .

CHAPTER 12, Stoichiometry *(continued)*

8. Is the following sentence true or false? If a sample is measured in grams, molar mass can be used to convert the mass to moles. ______________________

9. Complete the flow chart to show the steps for the mass–mass conversion of any given mass of *G* to any wanted mass of *W*. In the chemical equation, *a* moles of *G* react with *b* moles of *W*.

$$\text{mass of } G \times \frac{\boxed{}}{\text{molar mass } G} = \text{mol } G$$

$$\downarrow$$

$$\text{mol } G \times \frac{b \text{ mol } W}{a \text{ mol } G} = \boxed{}$$

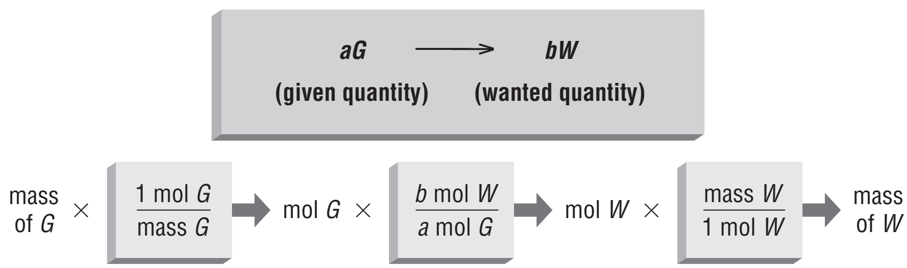
$$\downarrow$$

$$\text{mol } W \times \frac{\text{molar mass } W}{\boxed{}} = \text{mass } W$$

10. Use the diagram below. Describe the steps needed to solve a mass–mass stoichiometry problem.

____

____



▶ Other Stoichiometric Calculations (pages 363–366)

11. Is the following sentence true or false? Stoichiometric calculations can be expanded to include any unit of measurement that is related to the mole.

____

12. List two or three types of problems that can be solved with stoichiometric calculations.

____

____

13. In any problem relating to stoichiometric calculations, the given quantity is first converted to ______________ .

14. The combustion of methane produces carbon dioxide and water. The chemical equation for this reaction is

$CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(g)$

Write the three conversion factors you would use to find the volume of carbon dioxide obtained from 1.5 L of oxygen.

______________ ______________ ______________

Reading Skill Practice

Sometimes information you read is easier to remember if you write it in a different format. For example, the paragraph on page 363 and Figure 12.8 both explain how to solve stoichiometric problems. Use these explanations to make a diagram or flow chart for solving a particle–mass stoichiometry problem. Do your work on a separate sheet of paper.

SECTION 12.3 LIMITING REAGENT AND PERCENT YIELD (pages 368–375)

This section helps you identify and use the limiting reagent in a reaction to calculate the maximum amount of product(s) produced and the amount of excess reagent. It also explains how to calculate theoretical yield, actual yield, or percent yield, given appropriate information.

▶ Limiting and Excess Reagents (pages 368–371)

1. What is a limiting reagent? ______________

____

2. Is the following sentence true or false? A chemical reaction stops before the limiting reagent is used up. ______________

3. Circle the letter of the term that correctly completes the sentence. The reactant that is not completely used up in a chemical reaction is called the ______ .

a. spectator reagent

b. limiting reagent

c. excess reagent

d. catalyst

CHAPTER 12, Stoichiometry *(continued)*

4. If the quantities of reactants are given in units other than moles, what is the first step for determining the amount of product?

a. Determine the amount of product from the given amount of limiting reagent.

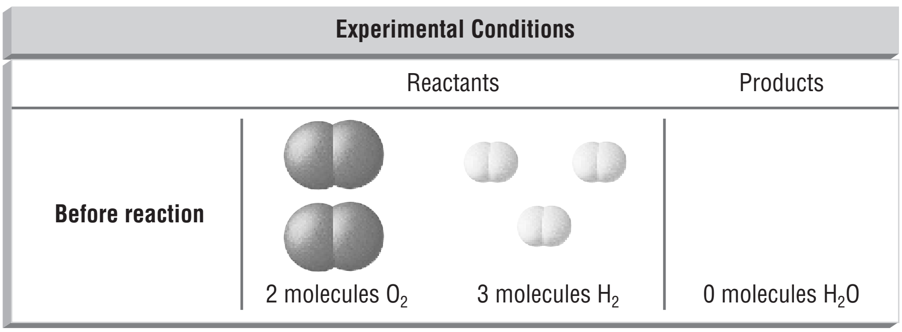
b. Convert each given quantity of reactant to moles.

c. Identify the limiting reagent.

5. In the diagram below, which reactant is the limiting reagent and why? The chemical equation for the formation of water is $2H_2 + O_2 \longrightarrow 2H_2O$.

____

____



▶ Percent Yield (pages 372–375)

6. What is the theoretical yield?

____

____

7. The amount of product that actually forms when a chemical reaction is carried out in a laboratory is called the ____________________ yield.

8. Is the following sentence true or false? The actual yield is usually greater than the theoretical yield. ____________________

9. Complete the equation for the percent yield of a chemical reaction.

$$\text{Percent yield} = \frac{\boxed{}\ \text{yield}}{\boxed{}\ \text{yield}} \times 100\%$$

10. Describe four factors that may cause percent yields to be less than 100%.

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GUIDED PRACTICE PROBLEMS

GUIDED PRACTICE PROBLEM 11 (page 360)

11. This equation shows the formation of aluminum oxide.

$$4Al(s) + 3O_2(g) \longrightarrow 2Al_2O_3(s)$$

a. How many moles of oxygen are required to react completely with 14.8 moles of aluminum?

Analyze

1. What is the given information? ______________________

2. What is the unknown? ______________________

3. What conversion factor will you need to use? ______________________

Calculate

4. Complete the solution. $14.8 \_\_\_\_\_\_ \times \frac{3 \text{ mol } O_2}{\boxed{}} = \_\_\_\_\_\_ \text{ mol } O_2$

Evaluate

5. Why does the answer have three significant figures?

____

____

____

b. How many moles of aluminum oxide are formed when 0.78 moles of oxygen react with an excess of aluminum?

Analyze

6. What information is given? ______________________

7. What information is unknown? ______________________

Calculate

8. Complete the solution. $\_\_\_\_\_\_ \text{ mol } O_2 \times \frac{\boxed{} \text{ mol } Al_2O_3}{\boxed{}}$

$= \_\_\_\_\_\_ \text{ mol } Al_2O_3$

Evaluate

9. Why does the answer have two significant figures?

____

____

EXTRA PRACTICE (similar to Practice Problem 15, page 364)

15. How many molecules of oxygen are produced by the decomposition of 1225 grams of potassium chlorate ($KClO_3$)?

$2KClO_3(s) \longrightarrow 2KCl(s) + 3O_2(g)$

EXTRA PRACTICE (similar to Practice Problem 17, page 365)

17. The equation for the combustion of carbon monoxide is

$2CO(g) + O_2(g) \longrightarrow 2CO_2(g)$

How many liters of oxygen are needed to burn 10 liters of carbon monoxide?

GUIDED PRACTICE PROBLEM 25 (page 370)

25. The equation for the complete combustion of ethene (C_2H_4) is

$C_2H_4(g) + 3O_2(g) \longrightarrow 2CO_2(g) + 2H_2O(g)$

a. If 2.70 moles of ethene reacted with 6.30 moles of oxygen, identify the limiting reagent.

Step 1. Calculate the number of moles of oxygen needed to react with 2.70 moles of ethane. Multiply by the mole ratio.	2.70 ____________ $\times \dfrac{\boxed{}\ \text{mol } O_2}{1 \text{ mol } C_2H_4}$ $=$ _______ mol O_2
Step 2. Compare the number of moles of oxygen needed to the number given.	__________ O_2 given is less than _______ mol O_2 needed
Step 3. Identify the limiting reagent.	Because ________ mol O_2 are needed to react with the 2.70 mol C_2H_4 and only ________ mol O_2 are available, __________ is the limiting reagent.

b. Calculate the number of moles of water produced.

Step 1. Identify the mole ratio needed.	$\dfrac{\square \text{ mol } H_2O}{3 \text{ mol } O_2}$
Step 2. Calculate the given number of moles of oxygen.	6.30 ________ $\times \dfrac{\square \text{ mol } H_2O}{3 \text{ mol } O_2}$ $=$ ________ mol H_2O

GUIDED PRACTICE PROBLEM 29 (page 374)

29. When 84.8 grams of iron(III) oxide reacts with an excess of carbon monoxide, 54.3 grams of iron are produced.

$Fe_2O_3(s) + 3CO(g) \longrightarrow 2Fe(s) + 3CO_2(g)$

What is the percent yield of this reaction?

Step 1. First calculate the theoretical yield. Begin by finding the molar mass of Fe_2O_3.	2 mol Fe $\times$ (________ g Fe/mol Fe) $+$ 3 mol O_3 $\times$ (________ g O_3/mol O_3) $=$ ________ g $+$ 48.0 g $=$ ________ g
Step 2. Calculate the number of moles of iron(III) oxide. Multiply by the mole/mass conversion factor.	________ g $Fe_2O_3 \times \dfrac{1 \text{ mol } Fe_2O_3}{159.6 \text{ g } Fe_2O_3}$ $=$ ________ mol
Step 3. Find the number of moles of Fe expected. Multiply by the mole ratio.	0.531 ____________ $\times \dfrac{\square \text{ mol Fe}}{1 \text{ mol } Fe_2O_3}$ $=$ ________ mol Fe
Step 4. Find the mass of iron that should be produced. Multiply by the mole/mass conversion factor.	1.062 ____________ $\times \dfrac{\square \text{ g Fe}}{1 \text{ mol Fe}} = 59.3$ g Fe
Step 5. Compare the actual yield to the theoretical yield by dividing.	$\dfrac{\text{actual yield}}{\text{theoretical yield}} = \dfrac{\square \text{ g Fe}}{\square \text{ g Fe}} = 0.916$
Step 6. Write the answer as a percent, with the correct number of significant figures.	0.916 $=$ ____________