CHAPTER 7 Review

Reflecting on Chapter 7

Summarize this chapter in the format of your choice. Here are a few ideas to use as guidelines:

- Use the coefficients of a balanced chemical equation to determine the mole ratios between reactants and products.
- Predict quantities required or produced in a chemical reaction.
- Calculate the limiting reactant in cases where the amount of various reactants was given.
- Calculate the percentage yield of a chemical reaction based on the amount of product(s) obtained relative to what was predicted by stoichiometry.
- Use the percentage yield of a reaction to predict the amount of product(s) formed.
- Determine the percentage purity of a reactant based on the actual yield of a reaction.

Reviewing Key Terms

For each of the following terms, write a sentence that shows your understanding of its meaning.

actual yield	competing reaction
excess reactant	limiting reactant
mole ratios	percentage purity
percentage yield	stoichiometric amounts
stoichiometric coefficients	stoichiometry
	theoretical yield

Knowledge/Understanding

1. Explain the different interpretations of the coefficients in a balanced chemical equation.
2. Why is a *balanced* chemical equation needed for stoichiometric calculations?
3. In what cases would it not be necessary to determine the limiting reactant before beginning any stoichiometric calculations?
4. Why was the concept of percentage yield introduced?
5. A student is trying to determine the mass of aluminum oxide that is produced when aluminum reacts with excess oxygen.
$$4Al_{(s)} + 3O_{2(g)} \rightarrow 2Al_2O_{3(s)}$$
The student states that 4 g of aluminum reacts with 3 g of oxygen to produce 2 g of aluminum oxide. Is the student's reasoning correct? Explain your answer.

Inquiry

6. A freshly exposed aluminum surface reacts with oxygen to form a tough coating of aluminum oxide. The aluminum oxide protects the metal from further corrosion.
$$4Al_{(s)} + 3O_{2(g)} \rightarrow 2Al_2O_{3(s)}$$
How many grams of oxygen are needed to react with 0.400 mol of aluminum?
7. Calcium metal reacts with chlorine gas to produce calcium chloride.
$$Ca_{(s)} + Cl_{2(g)} \rightarrow CaCl_{2(s)}$$
How many formula units of $CaCl_2$ are expected from 5.3 g of calcium and excess chlorine?
8. Propane is a gas at room temperature, but it exists as a liquid under pressure in a propane tank. It reacts with oxygen in the air to form carbon dioxide and water vapour.
$$C_3H_{8(\ell)} + 5O_{2(g)} \rightarrow 3CO_{2(g)} + 4H_2O_{(g)}$$
What mass of carbon dioxide gas is expected when 97.5 g of propane reacts with sufficient oxygen?
9. Powdered zinc and sulfur react in an extremely rapid, exothermic reaction. The zinc sulfide that is formed can be used in the phosphor coating on the inside of a television tube.
$$Zn_{(s)} + S_{(s)} \rightarrow ZnS_{(s)}$$
A 6.00 g sample of Zn is allowed to react with 3.35 g of S.
   (a) Determine the limiting reactant.
   (b) Calculate the mass of ZnS expected.
   (c) How many grams of the excess reactant will remain after the reaction?
10. Titanium(IV) chloride reacts violently with water vapour to produce titanium(IV) oxide and hydrogen chloride gas. Titanium(IV) oxide, when finely powdered, is extensively used in paint as a white pigment.
$$TiCl_{4(s)} + H_2O_{(\ell)} \rightarrow TiO_{2(s)} + 4HCl_{(g)}$$
The reaction has been used to create smoke screens. In moist air, the $TiCl_4$ reacts to produce a thick smoke of suspended TiO_2 particles. What mass of TiO_2 can be expected when 85.6 g of $TiCl_4$ is reacted with excess water vapour?

11. Silver reacts with hydrogen sulfide gas, which is present in the air. (Hydrogen sulfide has the odour of rotten eggs.) The silver sulfide, Ag_2S, that is produced forms a black tarnish on the silver.

$$4Ag_{(s)} + 2H_2S_{(g)} + O_{2(g)} \rightarrow 2Ag_2S_{(s)} + 2H_2O_{(g)}$$

How many grams of silver sulfide are formed when 1.90 g of silver reacts with 0.280 g of hydrogen sulfide and 0.160 g of oxygen?

12. 20.8 g of calcium phosphate, $Ca_3(PO_4)_2$, 13.3 g of silicon dioxide, SiO_2, and 3.90 g of carbon react according to the following equation:

$$2Ca_3(PO_4)_{2(s)} + 6SiO_{2(s)} + 10C_{(s)} \rightarrow P_{4(s)} + 6CaSiO_{3(s)} + 10CO_{(g)}$$

Determine the mass of calcium silicate, $CaSiO_3$, that is produced.

13. 1.56 g of As_2S_3, 0.140 g of H_2O, 1.23 g of HNO_3, and 3.50 g of $NaNO_3$ are reacted according to the equation below:

$$3As_2S_{3(s)} + 4H_2O_{(\ell)} + 10HNO_{3(aq)} + 18NaNO_{3(aq)} \rightarrow 9Na_2SO_{4(aq)} + 6H_3AsO_{4(aq)} + 28NO_{(g)}$$

What mass of H_3AsO_4 is produced?

14. 2.85×10^2 g of pentane, C_5H_{12}, reacts with 3.00 g of oxygen gas, according to the following equation:

$$C_5H_{12(\ell)} + 8O_{2(g)} \rightarrow 5CO_{2(g)} + 6H_2O_{(\ell)}$$

What mass of carbon dioxide gas, is produced?

15. Silica (also called silicon dioxide), along with other silicates, makes up about 95% of Earth's crust—the outermost layer of rocks and soil. Silicon dioxide is also used to manufacture transistors. Silica reacts with hydrofluoric acid to produce silicon tetrafluoride and water vapour.

$$SiO_{2(s)} + 4HF_{(aq)} \rightarrow SiF_{4(g)} + 2H_2O_{(g)}$$

   (a) 12.2 g of SiO_2 is reacted with a small excess of HF. What is the theoretical yield, in grams, of H_2O?
   (b) If the actual yield of water is 2.50 g, what is the percentage yield of the reaction?
   (c) Assuming the yield obtained in part (b), what mass of SiF_4 is formed?

16. An impure sample of barium chloride, $BaCl_2$, with a mass of 4.36 g, is added to an aqueous solution of sodium sulfate, Na_2SO_4.

$$BaCl_{2(s)} + Na_2SO_{4(aq)} \rightarrow BaSO_{4(s)} + 2NaCl_{(aq)}$$

After the reaction is complete, the solid barium sulfate, $BaSO_4$, is filtered and dried. Its mass is found to be 2.62 g. What is the percentage purity of the original barium chloride?

17. Benzene reacts with bromine to form bromobenzene, C_6H_5Br.

$$C_6H_{6(\ell)} + Br_{2(\ell)} \rightarrow C_6H_5Br_{(\ell)} + HBr_{(g)}$$

   (a) What is the maximum amount of C_6H_5Br that can be formed from the reaction of 7.50 g of C_6H_6 with excess Br_2?
   (b) A competing reaction is the formation of dibromobenzene, $C_6H_4Br_2$.

$$C_6H_{6(\ell)} + 2Br_{2(\ell)} \rightarrow C_6H_4Br_{2(\ell)} + 2HBr_{(g)}$$

   If 1.25 g of $C_6H_4Br_2$ was formed by the competing reaction, how much C_6H_6 was *not* converted to C_6H_5Br?
   (c) Based on your answer to part (b), what was the actual yield of C_6H_5Br? Assume that all the C_6H_5Br that formed was collected.
   (d) Calculate the percentage yield of C_6H_5Br.

18. Refer to Practice Problem 39. Design an experiment to determine the mole to mole ratio of pure malachite to copper(II) oxide. Include an outline of the procedure and any safety precautions. Clearly indicate which data need to be recorded.

19. A chemist wishes to prepare a compound called compound E. The molar mass of compound E is 100 g/mol. The synthesis requires four consecutive reactions, each with a yield of 60%.

$A \rightarrow B$ $\qquad$ $C \rightarrow D$
$B \rightarrow C$ $\qquad$ $D \rightarrow E$

   (a) The chemist begins the synthesis with 50 g of starting material, called compound A. If the molar mass of compound A is 200 g/mol, how many grams of compound E will be produced?
   (b) How many grams of compound A are needed to produce 70 g of compound E?

Communication

20. Develop a new analogy for the concept of limiting and excess reactant.

21. Examine the balanced chemical "equation"

$$2A + B \rightarrow 3C + D$$

Using a concept map, explain how to calculate the number of grams of C that can be obtained when a given mass of A reacts with a certain number of molecules of B. Assume that you know the molar mass of A and C. Include proper units. For simplicity, assume that A is limiting, but don't forget to show how to determine the limiting reactant.

22. Assume that your friend has missed several chemistry classes and that she has asked you to help her prepare for a stoichiometry test. Unfortunately, because of other commitments, you do not have time to meet face to face. You agree to email your friend a set of point-form instructions on how to solve stoichiometry problems, including those that involve a limiting reactant. She also needs to understand the concept of percentage yield. Write the text of this email. Assume that your friend has a good understanding of the mole concept.

Making Connections

23. How many grams of air are required for an automobile to travel from Thunder Bay, Ontario, to Smooth Rock Falls, Ontario? This is a distance of 670 km. Assume the following:
    - Gasoline is pure octane, C_8H_{18}. (Gasoline is actually a mixture of hydrocarbons.)
    - The average fuel consumption is 10 L per 100 km.
    - Air has a density of 1.21 g/L.
    - Air is 21% O_2 (v/v).
    - 1.00 mol of any gas occupies 24 L at 20°C and 100 kPa.
    - The density of the gasoline is 0.703 g/mL.

    The balanced chemical equation for the complete combustion of octane is

    $$2C_8H_{18(\ell)} + 25O_{2(g)} \rightarrow 16CO_{2(g)} + 18H_2O_{(g)}$$

24. You must remove mercury ions present as mercury(II) nitrate in the waste water of an industrial facility. You have decided to use sodium sulfide in the reaction below. Write a short essay that addresses the following points. Include a well-organized set of calculations where appropriate.

    $$Hg(NO_3)_{2(aq)} + Na_2S_{(aq)} \rightarrow HgS_{(s)} + 2NaNO_{3(aq)}$$

    (a) Explain why the chemical reaction above can be used to remove mercury ions from the waste water. What laboratory technique must be used in order that this reaction is as effective as possible for removing mercury from the waste stream?

    (b) Why is mercury(II) sulfide less of an environmental concern than mercury(II) nitrate?

    (c) What assumptions are being made regarding the toxicity of sodium sulfide and sodium nitrate relative to either mercury nitrate or mercury sulfide?

    (d) Every litre of waste water contains approximately 0.03 g of $Hg(NO_3)_2$. How many kg of Na_2S will be required to remove the soluble mercury ions from 10 000 L of waste water?

    (e) What factors would a company need to consider in adopting any method of cleaning its wastewater?

Answers to Practice Problems and Short Answers to Section Review Questions

Practice Problems: **1.(a)** 2:1:2 **(b)** 50 **(c)** 4956 **(d)** 1.20×10^{24} **2.(a)** 2 **(b)** 150 **(c)** 1.806×10^{24} **(d)** 1.204×10^{24} **3.(a)** 3.4×10^{25} **(b)** 6.7×10^{25} **4.** 7.5 mol **5.(a)** 1.8 mol **(b)** 37.5 mol **6.(a)** 48.7 mol **(b)** 1.20 mol **7.(a)** 8.3×10^{24} **(b)** 4.2×10^{24} **8.(a)** 7.47 mol **(b)** 7.19 mol **9.(a)** 4.68×10^{-2} mol **(b)** 0.187 mol **10.(a)** 0.708 mol **(b)** 1.06 mol **11.** 9.32 g **12.** 137 g **13.** 4.65 g **14.** 0.814 g **15.** 97.2 g **16.** 2.31×10^{-2} g **17.** 37.6 g **18.** 20.7 g **19.(a)** 124 g **(b)** 1.14×10^{24} **20.(a)** 120 g **(b)** 1.49×10^{21} **21.(a)** 2.39×10^{22} **(b)** 1.45×10^{24} **(c)** 1.21×10^{22} **22.(a)** 1.50×10^{24} **(b)** 357 g **23.** $CuCl_2$ **24.** CaF_2 **25.** C_3H_6 **26.** HCl **27.(a)** ClO_2 **(b)** 74.1 g **(c)** 1.06×10^{23} **28.(a)** H_2O_2 **(b)** 63.5 g **(c)** 104 g **29.** 4.23×10^4 g **30.(a)** 0.446 g **(b)** 4.80×10^{21} **(c)** F_2, 24.0 g **31.(a)** 74.4 g **(b)** 63.6% **32.(a)** 31.3 g **(b)** 95.2% **33.** 26.7% **34.** 14.1 g **35.(a)** 15.0 g **(b)** 10.5 g **(c)** 12.8 g **36.** 5.63 g **37.** 129 g **38.** 0.252 g **39.(a)** 187 g **(b)** 146 g **40.** 23.5 g

Section Review: **7.1:** **4.(a)** $S + O_2 \rightarrow SO_2$ **(b)** $2S + 3O_2 \rightarrow 2SO_3$ **(c)** 1.5 mol **(d)** 48.0 g **5.(a)** 1:5:3:4 **(b)** 2.50 mol **(c)** 6.02×10^{24} **(d)** 9.00 mol **6.(a)** 49.9 g **(b)** 4.48×10^{22} **7.(a)** $Pb(NO_3)_{2(aq)} + 2NaI_{(aq)} \rightarrow PbI_{2(s)} + 2NaNO_{3(aq)}$ **(b)** 1.03 g **7.2:** **2.(a)** oxygen **3.** 18.1 g **4.** 8.04 g **5.** 5.34 g **6.** 22.2 g **7.(a)** $Zn_{(s)} + CuCl_{2(aq)} \rightarrow ZnCl_{2(aq)} + Cu_{(s)}$ **(b)** zinc gone **(c)** zinc **(d)** less than 1.52 g Zn **7.3:** **2.** 73.6%