Understanding Concepts

1. The following equation represents the "rusting" of aluminum:

$$4\ Al_{(s)} + 3\ O_{2(g)} \rightarrow 2\ Al_2O_{3(s)}$$

   (a) List the coefficients in the equation.
   (b) Describe the reaction in words. (2.1)

2. (a) How many doughnuts are in one dozen doughnuts? How many doughnuts are in one mole of doughnuts?
   (b) Calculate the mass, in grams, of one mole of doughnuts, if one doughnut has a mass of 70 g.
   (c) Is one mole of doughnuts a reasonable number of doughnuts? Explain. (2.1)

3. (a) How many atoms of mercury are in one mole of mercury atoms?
   (b) What is the mass, in grams, of one mole of mercury atoms?
   (c) Is one mole of mercury atoms a reasonable number of mercury atoms? Explain. (2.1)

4. Why do we use the value of Avogadro's constant, 6.02×10^{23}, when working with atoms or molecules? (2.1)

5. The term "carat" is used to indicate the mass of a diamond. This term comes from the name of the carob bean. In the past, gem dealers used carob beans to balance their scales because all carob beans have approximately the same mass. A one-carat diamond (pure carbon) has a mass of 0.2 g. The term "karat" is used to indicate the purity of gold. Pure gold is 24 karats. The ring in **Figure 1** consists of a 0.50-carat diamond and 6.50 g of 18-karat gold.
   (a) How many moles of carbon are in the diamond in **Figure 1**? How many atoms?
   (b) How many moles of gold are in the ring in **Figure 1**? How many atoms? (2.2)

6. (a) Calculate the molar mass of 1,4-benzenedicarboxylic acid, $C_8H_6O_{4(aq)}$, a raw material that is used to make Dacron. Dacron is a synthetic fibre that is found in many types of clothing.

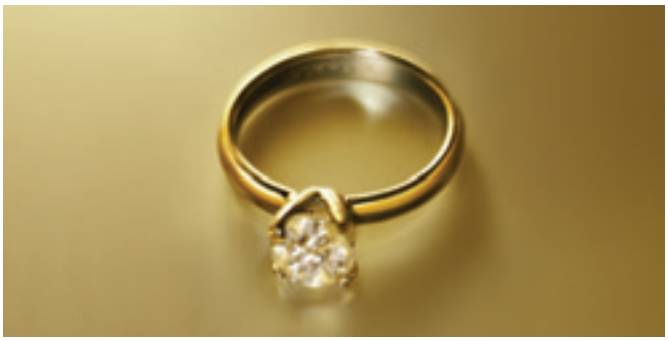

Figure 1

   (b) A patient is prescribed 1.5×10^{-3} mol of acetaminophen (Tylenol), $C_8H_9NO_{2(s)}$. How many grams of Tylenol should the patient take?
   (c) How many moles of butane, $C_4H_{10(l)}$, are in a lighter (**Figure 2**), if the butane has a mass of 0.95 g?
   (d) How many atoms of carbon are in a vitamin C tablet (ascorbic acid), $C_6H_8O_{6(s)}$, that contains 0.5 g of ascorbic acid? (2.2)

7. Distinguish between molecular elements and compounds. Provide an example of each. (2.2)

8. (a) What information does a mass spectrometer provide for determining the molecular formula of a compound?
   (b) How are the carbon dioxide and water traps in a combustion analyzer used to measure the masses of carbon and hydrogen in a sample of a hydrocarbon? (2.3)

Figure 2

9. A compound is found to contain 38.72% carbon, 9.72% hydrogen, and 51.56% oxygen.
   (a) Calculate the empirical formula of the compound.
   (b) State two possible molecular formulas for the compound.
   (c) What additional information do you need to determine the molecular formula of the compound? (2.3)

10. Calculate the molecular formulas of organic compounds A and B, given the information in **Table 1**. (2.3)

11. Why is the molar concentration of an aqueous solution measured as moles of solute per litre of solution, instead of moles of solute per litre of water? (2.5)

12. Distinguish between a dilute solution and a concentrated solution. (2.5)

13. A sample of drinking water has a nitrate concentration of 2.3 ppm (a level that is considered safe for drinking). Calculate the mass, in grams, of nitrate ions in a 250-mL glass of this water. (2.5)

14. Calculate the molar concentration of each of the following aqueous solutions:
   (a) 12.0 g of sodium hydroxide dissolved in water to make 2.5 L of solution
   (b) 2.28 g of potassium hydrogen tartrate, $KC_4H_5O_{6(s)}$, dissolved in water to form 100.0 mL of solution
   (c) 0.08 g ethanol, $C_2H_6O_{(l)}$, in 100 mL of blood (the legal limit of blood alcohol concentration in Canada when driving a car) (2.5)

15. A sodium hydroxide solution was prepared by transferring 0.40 g of sodium hydroxide, $NaOH_{(s)}$, to a 100-mL volumetric flask and filling the flask with water to the 100-mL mark.
   (a) Calculate the molar concentration and the weight by volume (W/V) concentration of the sodium hydroxide solution.
   (b) A 10-mL sample of the sodium hydroxide solution was transferred to a 50-mL volumetric flask, and the solution was diluted to the 50-mL mark. Calculate the molar concentration and weight by volume concentration of the final sodium hydroxide solution. (2.5)

16. Balance each of the following unbalanced equations:
   (a) $Fe + H_2O \rightarrow Fe_3O_4 + H_2$
   (b) $H_2SO_4 + NaOH \rightarrow H_2O + Na_2SO_4$
   (c) $Cu + O_2 \rightarrow Cu_2O$
   (d) $Fe_2(SO_4)_3 + KSCN \rightarrow K_3Fe(SCN)_6 + K_2SO_4$ (2.9)

17. (a) Write a balanced chemical equation to represent the complete combustion of ethanol, $C_2H_6O_{(l)}$.
   (b) Nitroglycerine (a drug used for heart conditions), $C_3H_5N_3O_9$, is produced by mixing glycerine, $C_3H_8O_3$, and nitric acid, HNO_3. Water is also a product. Write a balanced chemical equation to represent this reaction. (2.9)

18. The conversion of iron ore, $Fe_2O_{3(s)}$, into iron occurs in several steps. The first step involves the partial combustion of coal, $C_{(s)}$, to give carbon monoxide:

$$2\,C_{(s)} + O_{2(g)} \rightarrow 2\,CO_{(g)}$$

In a number of additional steps, carbon monoxide acts on iron ore, with the following overall result:

$$Fe_2O_{3(s)} + 3\,CO_{(g)} \rightarrow 2\,Fe_{(s)} + 3\,CO_{2(g)}$$

Table 1 Percent Composition and Molar Mass for Compounds A and B

Compound	Percentage composition (%)				Molar mass (g/mol)
	Carbon	Hydrogen	Oxygen	Nitrogen	
A	64.6	10.8	24.6	none	260.0
B	38.67	16.22	none	45.11	31.06

(a) In a small-scale laboratory test of the conversion process, a 300-g sample of iron ore is converted into iron. How many moles of iron are produced? How many grams of iron are produced?
(b) The actual yield of iron in this test is 178 g. What is the percentage yield? (2.12)

19. Aluminum oxide (a polishing powder), $Al_2O_{3(s)}$, is made by combining 5.00 g of aluminum with oxygen. Calculate how much oxygen is needed, in moles and in grams. (2.10)

20. The thermite reaction (**Figure 3**) has been used to weld railroad rails, to make certain bombs, and to ignite solid-fuel rocket motors. The balanced chemical equation for this reaction is

$$Fe_2O_{3(s)} + 2\,Al_{(s)} \rightarrow 2\,Fe_{(l)} + Al_2O_{3(s)}$$

(a) What is the maximum mass of aluminum oxide that can be produced with 135.0 g of aluminum?
(b) How much aluminum oxide is produced if the yield is 87%? (2.10, 2.12)

Figure 3
The thermite reaction is used to weld railroad rails.

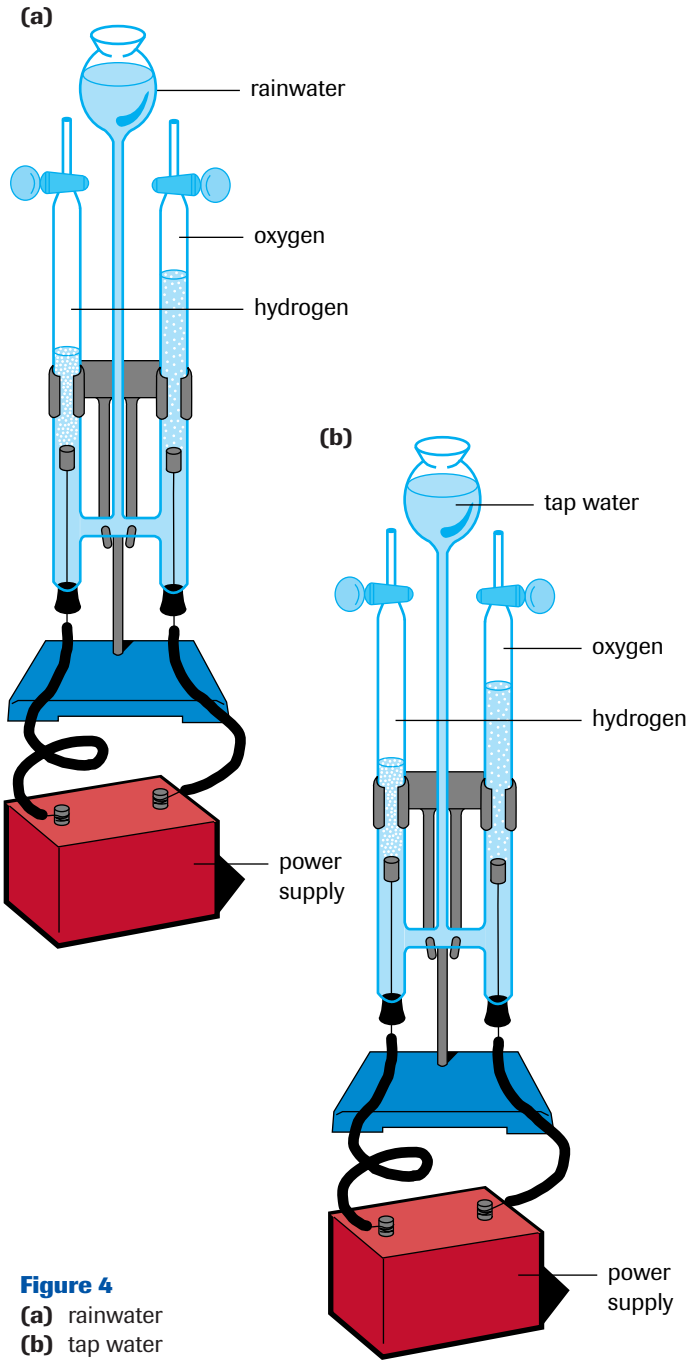

Figure 4
(a) rainwater
(b) tap water

Applying Inquiry Skills

21. To test the law of constant composition, a student uses a Hoffman apparatus to decompose a sample of tap water and a sample of rainwater into hydrogen and oxygen, under the same environmental conditions (**Figure 4**). (A Hoffman apparatus uses electricity to decompose water into its elements.) The volumes of hydrogen gas and oxygen gas that are formed in the reactions are measured directly on the calibrated gas collection tubes. Complete the Analysis and Evaluation in the following lab report.

Question
Does the law of constant composition hold for water molecules?

Prediction
All water molecules have the same composition.

Observations

Table 1

Sample	rainwater	tap water
Volume of $H_{2(g)}$ produced (mL)	23.72	8.39
Volume of $O_{2(g)}$ produced (mL)	11.80	4.18

Analysis

(a) Calculate the hydrogen-to-oxygen ratio for rainwater and tap water.

(b) Answer the Question.

Evaluation

(c) What assumptions, if any, must be made in order to answer the Question?

(d) Evaluate the Prediction. (2.3)

22. Calcium is a silvery white metal (**Figure 5(a)**) that burns readily in air to produce calcium oxide, $CaO_{(s)}$ (**Figure 5(b)**), as the only product.

(a) Describe an experimental design that may be used to determine the percentage composition by mass of calcium oxide.

(b) Octane, $C_8H_{18(l)}$, is a liquid that burns readily in air to produce carbon dioxide and water. Can you use the same experimental design to determine the percentage composition by mass of octane? Explain. (2.13)

23. (a) Describe the steps in a procedure for preparing 100 mL of a 0.15-mol/L copper(II) nitrate solution, including safety precautions.

(b) Describe the steps in a procedure for diluting the solution you prepared in (a) to form 1.0 L of a copper(II) nitrate solution with a concentration of 0.03 mol/L. (2.5)

24. The percent absorbance of several dilutions of the heart drug atropine was measured on a spectrophotometer. The data are listed in **Table 3**.

Table 3 Spectrophotometer Data for Atropine

Absorbance (%)	[Atropine] (μg/L)
0	0
0.10	0.62
0.14	1.2
0.23	1.9
0.37	3.1
0.64	5.5
0.76	6.3
1.0	8.0

(a)

(b)

Figure 5
(a) Calcium is a silvery white metal.
(b) Calcium oxide is the only product that is formed when calcium burns in air.

(a) Prepare a standard curve by graphing the data in **Table 3**, with percent absorbance plotted on the vertical axis and concentration plotted on the horizontal axis.
(b) Determine the concentration of an atropine solution whose percent absorbance is 0.50%.
(c) Can the standard curve you sketched in (a) be used to determine the concentration of a solution of digitalis, a different heart medication? Explain. (2.7)

25. When lead(II) nitrate solution reacts with sodium sulfate solution, a black precipitate of lead(II) sulfate is formed (**Figure 6**). The balanced chemical equation for the double displacement reaction is

$$Pb(NO_3)_{2(aq)} + Na_2SO_{4(aq)} \rightarrow PbSO_{4(s)} + 2\,NaNO_{3(aq)}$$

A student adds 10.0 mL of the sodium sulfate solution to 4.60 mL of the lead(II) nitrate solution. The student filters and dries the precipitate and measures its mass. Can the student use this mass to calculate the concentration of the lead(II) nitrate solution? Explain. (2.7)

Figure 6
When lead(III) nitrate solution and sodium sulfate solution are mixed, a precipitate of lead(II) sulfate is formed. Sodium nitrate remains dissolved in water.

Making Connections

26. A Breathalyzer is a portable breath alcohol testing device that is used by police officers to determine a driver's blood alcohol concentration (BAC). Many drivers who are charged with drunk driving challenge the results of the Breathalyzer test in court. Conduct library and/or Internet research to answer the following questions about Breathalyzers and Breathalyzer testing:
(a) Briefly explain how a Breathalyzer works.
(b) What is the legal BAC limit for drivers in Ontario?
(c) Distinguish between a portable Breathalyzer and a stationary Breathalyzer.
(d) What reasons do drivers use to challenge the results of Breathalyzer tests in court?
(e) Write a one-page paper, stating your position on the reliability of Breathalyzer tests. (2.5)

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27. The Haber process requires hydrogen and nitrogen as reactants.
(a) Suggest sources for each of these reactants.
(b) Research how modern ammonia production facilities obtain pure hydrogen and pure nitrogen for the Haber process. (2.14)

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