CHAPTER 10

Study Guide

Key Concepts

10.1 The Mole: A Measurement of Matter

- Three methods for measuring the amount of a substance are by count, by mass, and by volume.
- A mole of any substance always contains Avogadro's number of representative particles, or 6.02×10^{23} representative particles.
- The atomic mass of an element expressed in grams is the mass of a mole of the element.
- To calculate the molar mass of a compound, find the number of grams of each element contained in one mole of the compound. Then add the masses of the elements in the compound.

10.2 Mole–Mass and Mole–Volume Relationships

- The molar mass of an element or compound is the conversion factor for converting between the mass and the number of moles of a substance.
- One mole of any gas occupies a volume of 22.4 L at standard temperature and pressure. One mole of any substance contains Avogadro's number of particles, so 22.4 L of any gas at STP contains 6.02×10^{23} representative particles of that gas.

10.3 Percent Composition and Chemical Formulas

- To determine the percent by mass of any element in a given compound, divide the element's mass by the mass of the compound and multiply by 100%.
- An empirical formula of a compound is the simplest whole-number ratio of atoms of the elements in the compound.
- The molecular formula of a compound is either the same as its experimentally determined empirical formula, or it is a simple whole-number multiple of it.

Vocabulary

- Avogadro's hypothesis (p. 300)
- Avogadro's number (p. 290)
- empirical formula (p. 309)
- molar mass (p. 294)
- molar volume (p. 300)
- mole (mol) (p. 290)
- percent composition (p. 305)
- representative particle (p. 290)
- standard temperature and pressure (STP) (p. 300)

Key Equations

- $\text{moles} = \text{representative particles} \times \dfrac{1\ \text{mole}}{6.02 \times 10^{23}\ \text{representative particles}}$
- $\text{representative particles} = \text{moles} \times \dfrac{6.02 \times 10^{23}\ \text{representative particles}}{1\ \text{mole}}$
- $\text{mass (grams)} = \text{number of moles} \times \dfrac{\text{mass (grams)}}{1\ \text{mole}}$
- $\text{moles} = \text{mass (grams)} \times \dfrac{1\ \text{mole}}{\text{mass (grams)}}$
- $\dfrac{\text{grams}}{\text{mole}} = \dfrac{\text{grams}}{\text{L}} \times \dfrac{22.4\ \text{L}}{1\ \text{mole}}$
- $\text{volume of gas} = \text{moles of gas} \times \dfrac{22.4\ \text{L}}{1\ \text{mol}}$
- $\%\ \text{mass of element} = \dfrac{\text{mass of element}}{\text{mass of compound}} \times 100\%$

Organizing Information

Organize the major ideas of the chapter.

Interactive Textbook

Concept Map 10 Solve the Concept Map with the help of an interactive tutorial.

with ChemASAP

Avogadro's number | Empirical formula | Molar volume | Molar mass | Mole (mol) | Percent composition | Representative particle | Standard temperature and pressure (STP)

314 Chapter 10

CHAPTER 10

Assessment

Reviewing Content

10.1 The Mole: A Measurement of Matter

47. List three common ways that matter is measured. Give examples of each.

48. Name the representative particle (atom, molecule, or formula unit) of each substance.
a. oxygen gas **b.** sodium sulfide
c. sulfur dioxide **d.** potassium

49. How many hydrogen atoms are in a representative particle of each substance?
a. $Al(OH)_3$ **b.** $H_2C_2O_4$
c. $(NH_4)_2HPO_4$ **d.** $C_4H_{10}O$

50. Which contains more molecules: 1.00 mol H_2O_2, 1.00 mol C_2H_6, or 1.00 mol CO?

51. Which contains more atoms: 1.00 mol H_2O_2, 1.00 mol C_2H_6, or 1.00 mol CO?

52. Find the number of representative particles in each substance.
a. 3.00 mol Sn **b.** 0.400 mol KCl
c. 7.50 mol SO_2 **d.** 4.80×10^{-3} mol NaI

53. Calculate the molar mass of each substance.
a. H_3PO_4 **b.** N_2O_3 **c.** $CaCO_3$
d. $(NH_4)_2SO_4$ **e.** $C_4H_9O_2$ **f.** Br_2

54. Calculate the mass of 1.00 mol of each of these substances.
a. silicon dioxide (SiO_2)
b. diatomic nitrogen (N_2)
c. iron(III) hydroxide ($Fe(OH)_3$)
d. copper (Cu)

55. List the steps you would take to calculate the molar mass of any compound.

56. What is the molar mass of chlorine?

57. Construct a numerical problem to illustrate the size of Avogadro's number. Exchange problems with a classmate and then compare your answers.

10.2 Mole–Mass and Mole–Volume Relationships

58. How many moles is each of the following?
a. 15.5 g SiO_2 **b.** 0.0688 g AgCl
c. 79.3 g Cl_2 **d.** 5.96 g KOH
e. 937 g $Ca(C_2H_3O_2)_2$ **f.** 0.800 g Ca

59. Find the mass of each substance.
a. 1.50 mol C_5H_{12} **b.** 14.4 mol F_2
c. 0.780 mol $Ca(CN)_2$ **d.** 7.00 mol H_2O_2
e. 5.60 mol NaOH **f.** 3.21×10^{-2} mol Ni

60. Calculate the volume of each of the following gases at STP.
a. 7.6 mol Ar **b.** 0.44 mol C_2H_6

61. What is the density of each of the following gases at STP?
a. C_3H_8 **b.** Ne **c.** NO_2

62. Find each of the following quantities.
a. the volume, in liters, of 835 g SO_3 at STP
b. the mass, in grams, of a molecule of aspirin ($C_9H_8O_4$)
c. the number of atoms in 5.78 mol NH_4NO_3

10.3 Percent Composition and Chemical Formulas

63. Calculate the percent composition of each compound.
a. H_2S **b.** $(NH_4)_2C_2O_4$
c. $Mg(OH)_2$ **d.** Na_3PO_4

64. Using your answers from Problem 63, calculate the number of grams of these elements.
a. sulfur in 3.54 g H_2S
b. nitrogen in 25.0 g $(NH_4)_2C_2O_4$
c. magnesium in 97.4 g $Mg(OH)_2$
d. phosphorus in 804 g Na_3PO_4

65. Which of the following compounds has the highest iron content?
a. $FeCl_2$ **b.** $Fe(C_2H_3O_2)_3$
c. $Fe(OH)_2$ **d.** FeO

66. You find that 7.36 g of a compound has decomposed to give 6.93 g of oxygen. The only other element in the compound is hydrogen. If the molar mass of the compound is 34.0 g/mol, what is its molecular formula?

67. Which of the following can be classified as an empirical formula?
a. S_2Cl_2 **b.** $C_6H_{10}O_4$ **c.** Na_2SO_3

68. What is the molecular formula for each compound? Each compound's empirical formula and molar mass is given.
a. CH_2O, 90 g/mol **b.** HgCl, 472.2 g/mol

69. Determine the molecular formula for each compound.
a. 94.1% O and 5.9% H; molar mass = 34 g
b. 50.7% C, 4.2% H, and 45.1% O; molar mass = 142 g

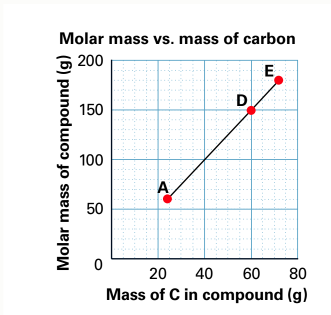
CHAPTER 10

Assessment *continued*

Understanding Concepts

70. How can you determine the molar mass of a gaseous compound if you do not know its molecular formula?

71. A series of compounds has the empirical formula CH_2O. The graph shows the relationship between the molar mass of the compounds and the mass of carbon in each compound.



a. What are the molecular formulas for the compounds represented by data points A, D, and E?

b. Find the slope of the line. Is this value consistent with the empirical formula? Explain.

c. Two other valid data points fall on the line between points A and D. What are the *x, y* values for these data points?

72. Explain what is wrong with each statement.

a. One mole of any substance contains the same number of atoms.

b. A mole and a molecule of a substance are identical in amount.

c. One molar mass of CO_2 contains Avogadro's number of atoms.

73. Which of the following contains the largest number of atoms?

a. 82.0 g Kr **b.** 0.842 mol C_2H_4

c. 36.0 g N_2

74. What is the total mass of a mixture of 3.50×10^{22} formula units Na_2SO_4, 0.500 mol H_2O, and 7.23 g AgCl?

75. Determine the empirical formulas of compounds with the following percent compositions.

a. 42.9% C and 57.1% O

b. 32.00% C, 42.66% O, 18.67% N, and 6.67% H

c. 71.72% Cl, 16.16% O, and 12.12% C

76. An imaginary "atomic balance" is shown below. Fifteen atoms of boron on the left side of the balance are balanced by six atoms of an unknown element E on the right side.

a. What is the atomic mass of element E?

b. What is the identity of element E?

77. A typical virus is 5×10^{-6} cm in diameter. If Avogadro's number of these virus particles were laid in a row, how many kilometers long would the line be?

78. Calculate the empirical formula for each compound.

a. compound consisting of 0.40 mol Cu and 0.80 mol Br

b. compound with 4 atoms of carbon for every 12 atoms of hydrogen

79. Muscle fatigue can result from the buildup of lactic acid resulting from overexercising. The percent composition of lactic acid is 40.0% C, 6.67% H, and 53.3% O. What is the molecular formula of lactic acid if its molar mass is 90.0 g/mol?

80. How many water molecules are in a 1.00-L bottle of water? The density of water is 1.00 g/mL.

81. The molecular formula of an antibacterial drug is $C_{17}H_{18}FN_3O_3$. How many fluorine atoms are in a 150-mg tablet of this drug?

82. What mass of helium is needed to inflate a balloon to a volume of 5.50 L at STP?

316 Chapter 10

Critical Thinking

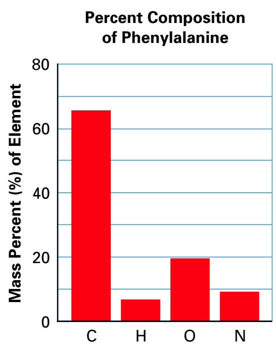
83. What is the empirical formula of a compound that has three times as many hydrogen atoms as carbon atoms, but only half as many oxygen atoms as carbon atoms?

84. How are the empirical and molecular formulas of a compound related?

85. Why does one mole of carbon have a smaller mass than one mole of sulfur? How are the atomic structures of these elements different?

86. One mole of any gas at STP equals 22.4 L of that gas. It is also true that different elements have different atomic volumes, or diameters. How can you reconcile these two statements?

87. The graph shows the percent composition of phenylalanine.



a. What is the empirical formula for phenylalanine?

b. If the molar mass of phenylalanine is 165.2 g/mol, what is its molecular formula?

Concept Challenge

88. Nitroglycerine contains 60% as many carbon atoms as hydrogen atoms, three times as many oxygen atoms as nitrogen atoms, and the same number of carbon and nitrogen atoms. The number of moles of nitroglycerine in 1.00 g is 0.00441. What is the molecular formula of nitroglycerine?

89. The density of nickel is 8.91 g/cm^3. How large a cube, in cm^3, would contain 2.00×10^{24} atoms of nickel?

90. Dry air is about 20.95% oxygen by volume. Assuming STP, how many oxygen molecules are in a 75.0-g sample of air? The density of air is 1.19 g/L.

91. The table below gives the molar mass and density of seven gases at STP.

Substance	Molar mass (g)	Density (g/l)
Oxygen	32.0	1.43
Carbon dioxide	44.0	1.96
Ethane	30.0	1.34
Hydrogen	2.0	0.089
Sulfur dioxide	64.1	2.86
Ammonia	17.0	0.759
Fluorine	38.0	1.70

a. Plot these data, with density on the *x*-axis.

b. What is the slope of the straight-line plot?

c. What is the molar mass of a gas at STP that has a density of 1.10 g/L?

d. A mole of a gas at STP has a mass of 56.0 g. Use the graph to determine its density.

92. A cubic meter of seawater contains 6×10^{-6} g gold. If the total mass of the water in Earth's oceans is 4×10^{20} kg, how many kilograms of gold are distributed throughout the oceans? (Assume that the density of seawater is 1 g/cm^3.) How many liters of seawater would have to be processed to recover 1 kg of gold (which has a value of about $12,500 at 2003 prices)? Do you think this recovery operation is feasible?

93. Avogadro's number has been determined by about 20 different methods. In one approach, the spacing between ions in an ionic substance is determined by using a technique called X-ray diffraction. X-ray diffraction studies of sodium chloride have shown that the distance between adjacent Na^+ and Cl^- ions is 2.819×10^{-8} cm. The density of solid NaCl is 2.165 g/cm^3. By calculating the molar mass to four significant figures, you can determine Avogadro's number. What value do you obtain?

CHAPTER 10

Assessment *continued*

Cumulative Review

94. Identify at least one chemical change and two physical changes that are occurring in the photo. (*Chapter 2*)

95. Classify each of the following as a physical change or a chemical change. (*Chapter 2*)
- **a.** an aspirin tablet is crushed to a powder
- **b.** a red rose turns brown
- **c.** grape juice turns to wine
- **d.** fingernail polish remover evaporates
- **e.** a bean seed sprouts
- **f.** a piece of copper is beaten into a thin sheet

96. Which of these statements are true about every solution? (*Chapter 2*)
- **a.** Solutions are in the liquid state.
- **b.** Solutions are homogeneous.
- **c.** Solutions are mixtures.
- **d.** Solutions are composed of at least two compounds.

97. A student writes down the density of table sugar as 1.59 g/cm^3 and the density of carbon dioxide as 1.83 g/L. Can these values be correct? Explain. (*Chapter 3*)

98. A block of wood measuring 2.75 cm $\times$ 4.80 cm $\times$ 7.50 cm has a mass of 84.0 g. Will the block of wood sink or float in water? (*Chapter 3*)

99. Convert each of the following. (*Chapter 3*)
- **a.** 4.72 g to mg
- **b.** 2.7×10^3 cm/s to km/h
- **c.** 4.4 mm to dm

100. How many protons, electrons, and neutrons are in each isotope? (*Chapter 4*)
- **a.** zirconium-90
- **b.** palladium-108
- **c.** bromine-81
- **d.** antimony-123

101. Write the complete electron configuration for each atom. (*Chapter 5*)
- **a.** fluorine
- **b.** lithium
- **c.** rubidium

102. Why do the elements magnesium and barium have similar chemical and physical properties? (*Chapter 6*)

103. Which of the following are transition metals: Cr, Cd, Ca, Cu, Co, Cs, Ce? (*Chapter 6*)

104. How can the periodic table be used to infer the number of valence electrons in an atom? (*Chapter 7*)

105. How does a molecule differ from an atom? (*Chapter 8*)

106. Draw electron dot structures and predict the shapes of the following molecules. (*Chapter 8*)
- **a.** PH_3
- **b.** CO
- **c.** CS_2
- **d.** CF_4

107. How are single, double, and triple bonds indicated in electron dot structures? (*Chapter 8*)

108. Give an example of each of the following. (*Chapter 8*)
- **a.** coordinate covalent bonding
- **b.** resonance structures
- **c.** exceptions to the octet rule

109. Explain how you can use electronegativity values to classify a bond as nonpolar covalent, polar covalent, or ionic. (*Chapter 8*)

110. Identify any incorrect formulas among the following. (*Chapter 9*)
- **a.** H_2O_2
- **b.** $NaIO_4$
- **c.** SrO
- **d.** CaS_2
- **e.** $CaHPO_4$
- **f.** BaOH

111. Name these compounds. (*Chapter 9*)
- **a.** $Fe(OH)_3$
- **b.** NH_4I
- **c.** Na_2CO_3
- **d.** CCl_4

112. Write formulas for these compounds. (*Chapter 9*)
- **a.** potassium nitrate
- **b.** copper(II) oxide
- **c.** magnesium nitride
- **d.** silver fluoride

318 Chapter 10

Standardized Test Prep

Test-Taking Tip

Wear a Watch. Be aware of how many questions you have to answer and how much time you have to answer them. Look at your watch or a clock frequently to keep track of your progress.

1. Choose the term that best completes the second relationship.
   a. dozen: eggs
   mole: ____
   (A) atoms (B) 6.02×10^{23}
   (C) size (D) grams
   b. mole: Avogadro's number
   molar volume: ____
   (A) mole (B) water
   (C) STP (D) 22.4 L

Select the choice that best answers each question or completes each statement.

2. Calculate the molar mass of ammonium phosphate, $(NH_4)_3PO_4$.
   a. 149.0 g/mol **b.** 113.0 g/mol
   c. 242.0 g/mol **d.** 121.0 g/mol
3. Based on the structural formula below, what is the empirical formula for tartaric acid, a compound found in grape juice?

$$\begin{array}{l} HO-CH-COOH \\ \quad\quad\ \ | \\ HO-CH-COOH \end{array}$$

   a. $C_2H_3O_3$ **b.** $C_4H_6O_6$
   c. CHO **d.** $C_1H_{1.5}O_{1.5}$
4. How many hydrogen atoms are in six molecules of ethylene glycol, $HOCH_2CH_2OH$?
   a. 6 **b.** 36
   c. $6 \times 6.02 \times 10^{23}$ **d.** $36 \times 6.02 \times 10^{23}$
5. Which of these statements is true of a balloon filled with 1.00 mol $N_2(g)$ at STP?
   I. The balloon has a volume of 22.4 L.
   II. The contents of the balloon have a mass of 14.0 g.
   III. The balloon contains 6.02×10^{23} molecules.
   a. I only **b.** I and II only
   c. I and III only **d.** II and III only
   e. I, II, and III
6. Which of these compounds has the largest percent by mass of nitrogen?
   a. N_2O **b.** NO **c.** NO_2
   d. N_2O_3 **e.** N_2O_4
7. Allicin, $C_6H_{10}S_2O$, is the compound that gives garlic its odor. A sample of allicin contains 3.0×10^{21} atoms of carbon. How many atoms of hydrogen does this sample contain?
   a. 1.8×10^{21} atoms **b.** 10 atoms
   c. 5.0×10^{21} atoms **d.** 1.0×10^{21} atoms

The lettered choices below refer to Questions 8–12. A lettered choice may be used once, more than once, or not at all.

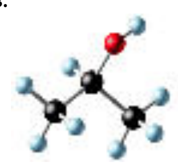
(A) CH (B) CH_2 (C) C_2H_5
(D) CH_3 (E) C_2H_3

Which of the formulas is the empirical formula for each of the following compounds?

8. C_8H_{12} **9.** C_6H_6 **10.** $C_{12}H_{24}$
11. C_2H_6 **12.** C_4H_{10}

Use the ball-and-stick models to answer Questions 13–15. In the models, carbon is black, hydrogen is light blue, oxygen is red, and nitrogen is dark blue. Write the molecular formula for each compound. Then calculate its molar mass.

13.



14.

15.