CHAPTER 3 IN REVIEW

TERMS

Section 3.2
ionic bond (93)
ionic compound (93)
covalent bond (94)
molecular compound (94)

Section 3.3
chemical formula (94)
empirical formula (94)
molecular formula (94)
structural formula (95)
ball-and-stick molecular model (96)
space-filling molecular model (96)

Section 3.4
atomic element (96)
molecular element (96)
formula unit (98)
polyatomic ion (99)

Section 3.5
common name (101)
systematic name (101)
binary compound (102)
oxyanion (104)
hydrate (105)

Section 3.6
acid (107)
binary acid (108)
oxyacid (108)

Section 3.8
formula mass (111)

Section 3.9
mass percent composition (mass percent) (113)

Section 3.10
empirical formula molar mass (120)
combustion analysis (121)

Section 3.11
organic compound (123)
hydrocarbon (124)
alkane (124)
alkene (124)
alkyne (124)
functional group (125)
alcohol (125)
family (126)

CONCEPTS

Chemical Bonds (3.2)
- Chemical bonds, the forces that hold atoms together in compounds, arise from the interactions between nuclei and electrons in atoms.
- In an ionic bond, one or more electrons are *transferred* from one atom to another, forming a cation (positively charged) and an anion (negatively charged). The two ions are drawn together by the attraction between the opposite charges.
- In a covalent bond, one or more electrons are *shared* between two atoms. The atoms are held together by the attraction between their nuclei and the shared electrons.

Representing Molecules and Compounds (3.3, 3.4)
- A compound is represented with a chemical formula, which indicates the elements present and the number of atoms of each.
- An empirical formula gives only the *relative* number of atoms, while a molecular formula gives the *actual* number of atoms present in the molecule.
- Structural formulas show how atoms are bonded together, while molecular models portray the geometry of the molecule.
- Compounds can be divided into two types: molecular compounds, formed between two or more covalently bonded nonmetals, and ionic compounds, usually formed between a metal ionically bonded to one or more nonmetals. The smallest identifiable unit of a molecular compound is a molecule, and the smallest identifiable unit of an ionic compound is a formula unit: the smallest electrically neutral collection of ions.
- Elements can also be divided into two types: molecular elements, which occur as (mostly diatomic) molecules, and atomic elements, which occur as individual atoms.

Naming Inorganic Ionic and Molecular Compounds and Acids (3.5–3.7)
- A flowchart for naming simple inorganic compounds is provided in Section 3.7.

Formula Mass and Mole Concept for Compounds (3.8)
- The formula mass of a compound is the sum of the atomic masses of all the atoms in the chemical formula. Like the atomic masses of elements, the formula mass characterizes the average mass of a molecule (or a formula unit).
- The mass of one mole of a compound is the molar mass of that compound and equals its formula mass (in grams).

Chemical Composition (3.9, 3.10)
- The mass percent composition of a compound indicates each element's percentage of the total compound's mass. We can determine the mass percent composition from the compound's chemical formula and the molar masses of its elements.
- The chemical formula of a compound provides the relative number of atoms (or moles) of each element in a compound, and we can therefore use it to determine numerical relationships between moles of the compound and moles of its constituent elements. We can extend this relationship to mass by using the molar masses of the compound and its constituent elements.
- If the mass percent composition and molar mass of a compound are known, we can determine its empirical and molecular formulas.

Organic Compounds (3.11)
- Organic compounds are composed of carbon, hydrogen, and a few other elements such as nitrogen, oxygen, and sulfur.

- The simplest organic compounds are hydrocarbons, compounds composed of only carbon and hydrogen.
- Hydrocarbons are categorized into three types based on the bonds they contain: alkanes contain single bonds, alkenes contain double bonds, and alkynes contain triple bonds.
- All other organic compounds can be thought of as hydrocarbons with one or more functional groups—characteristic atoms or groups of atoms.
- Common functionalized hydrocarbons include alcohols, ethers, aldehydes, ketones, carboxylic acids, esters, and amines.

EQUATIONS AND RELATIONSHIPS

Formula Mass (**3.8**)

$$\left(\begin{array}{c}\text{No. of atoms of 1st element}\\ \text{in chemical formula}\end{array} \times \begin{array}{c}\text{atomic mass}\\ \text{of 1st element}\end{array}\right) + \left(\begin{array}{c}\text{No. of atoms of 2nd element}\\ \text{in chemical formula}\end{array} \times \begin{array}{c}\text{atomic mass}\\ \text{of 2nd element}\end{array}\right) + \ldots$$

Mass Percent Composition (**3.9**)

$$\text{Mass \% of element X} = \frac{\text{mass of X in 1 mol compound}}{\text{mass of 1 mol compound}} \times 100\%$$

Empirical Formula Molar Mass (**3.10**)

$$\text{Molecular formula} = n \times (\text{empirical formula})$$

$$n = \frac{\text{molar mass}}{\text{empirical formula molar mass}}$$

LEARNING OUTCOMES

Chapter Objectives	Assessment
Analyze substances by bond type (covalent or ionic), compound type (molecular or ionic), and formula (chemical, molecular, and structural) (**3.2–3.4**)	Examples 3.1, 3.2 **For Practice** 3.1, 3.2 **Exercises** 27–32
Write formulas and names for ionic compounds (**3.5**)	Examples 3.3, 3.4, 3.5, 3.6, 3.7 **For Practice** 3.3, 3.4, 3.5, 3.6, 3.7 **For More Practice** 3.5, 3.6, 3.7 **Exercises** 33–44, 55–58
Write formulas and names for hydrated ionic compounds (**3.5**)	Exercises 45–46
Write formulas and names for molecular compounds (**3.6**)	Example 3.8 **For Practice** 3.8 **For More Practice** 3.8 **Exercises** 47–50, 55–58
Write formulas and names for acids and oxyacids (**3.6**)	Examples 3.9, 3.10 **For Practice** 3.9, 3.10, 3.11 **For More Practice** 3.10 **Exercises** 51–54, 55–58
Analyze the composition of compounds in terms of formula mass, mass percent, and moles (**3.8–3.9**)	Examples 3.12, 3.13, 3.14, 3.15, 3.16 **For Practice** 3.12, 3.13, 3.14, 3.15, 3.16 **For More Practice** 3.13, 3.14, 3.15 **Exercises** 59–86
Write chemical formulas from experimental data (**3.10**)	Examples 3.17, 3.18, 3.19, 3.20, 3.21 **For Practice** 3.17, 3.18, 3.19, 3.20, 3.21 **Exercises** 87–100
Write formulas and names for organic compounds (**3.11**)	**Exercises** 101–108

EXERCISES

Mastering Chemistry provides end-of-chapter exercises, feedback-enriched tutorial problems, animations, and interactive activities to encourage problem-solving practice and deeper understanding of key concepts and topics.

REVIEW QUESTIONS

1. How do the properties of compounds compare to the properties of the elements from which the compounds are composed?
2. What is a chemical bond? Explain the difference between an ionic bond and a covalent bond.
3. Explain the different ways to represent compounds. Why are there so many?
4. What is the difference between an empirical formula and a molecular formula?
5. Define and provide an example for each of the following: atomic element, molecular element, ionic compound, molecular compound.
6. Explain how to write a formula for an ionic compound given the names of the metal and nonmetal (or polyatomic ion) in the compound.
7. Explain how to name binary ionic compounds. How do you name an ionic compound if it contains a polyatomic ion?
8. Why do the names of some ionic compounds include the charge of the metal ion while others do not?

9. Explain how to name molecular inorganic compounds.

10. How many atoms are specified by each of these prefixes: *mono-*, *di-*, *tri-*, *tetra-*, *penta-*, *hexa-*?

11. Explain how to name binary acids and oxyacids.

12. What is the formula mass for a compound? Why is it useful?

13. Explain how you can use the information in a chemical formula to determine how much of a particular element is present in a given amount of a compound. Provide some examples of why this might be important.

14. What is mass percent composition? Why is it useful?

15. What kinds of conversion factors are inherent in chemical formulas? Provide an example.

16. What kind of chemical formula can be obtained from experimental data showing the relative masses of the elements in a compound?

17. How can a molecular formula be obtained from an empirical formula? What additional information is required?

18. What is combustion analysis? What is it used for?

19. Which elements are normally present in organic compounds?

20. What is the difference between an alkane, an alkene, and an alkyne?

21. What are functionalized hydrocarbons? Cite an example of a functionalized hydrocarbon.

22. Write a generic formula for each of the families of organic compounds.

a. alcohols **b.** ethers
c. aldehydes **d.** ketones
e. carboxylic acids **f.** esters
g. amines

PROBLEMS BY TOPIC

Note: Answers to all odd-numbered Problems, numbered in blue, can be found in Appendix III. Exercises in the Problems by Topic section are paired, with each odd-numbered problem followed by a similar even-numbered problem. Exercises in the Cumulative Problems section are also paired, but somewhat more loosely. (Challenge Problems and Conceptual Problems, because of their nature, are unpaired.)

Chemical Formulas and Molecular View of Elements and Compounds

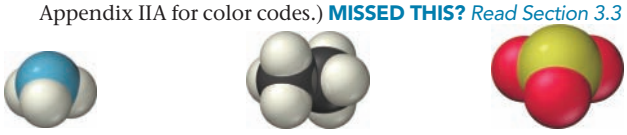
23. Determine the number of each type of atom in each formula.
MISSED THIS? *Read Section 3.3*

a. $Mg_3(PO_4)_2$
b. $BaCl_2$
c. $Fe(NO_2)_2$
d. $Ca(OH)_2$

24. Determine the number of each type of atom in each formula.

a. $Ca(NO_2)_2$
b. $CuSO_4$
c. $Al(NO_3)_3$
d. $Mg(HCO_3)_2$

25. Write a chemical formula for each molecular model. (See Appendix IIA for color codes.) **MISSED THIS?** *Read Section 3.3*



a. **b.** **c.**

26. Write a chemical formula for each molecular model. (See Appendix IIA for color codes.)

a. **b.** **c.**

27. Classify each element as atomic or molecular.
MISSED THIS? *Read Section 3.4*

a. neon
b. fluorine
c. potassium
d. nitrogen

28. Identify the elements that have molecules as their basic units.

a. hydrogen
b. iodine
c. lead
d. oxygen

29. Classify each compound as ionic or molecular.
MISSED THIS? *Read Section 3.2*

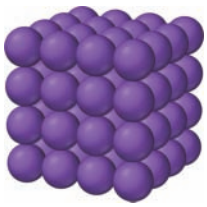
a. CO_2
b. $NiCl_2$
c. NaI
d. PCl_3

30. Classify each compound as ionic or molecular.

a. CF_2Cl_2
b. CCl_4
c. PtO_2
d. SO_3

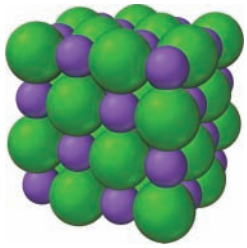
31. Based on the molecular views, classify each substance as an atomic element, a molecular element, an ionic compound, or a molecular compound. **MISSED THIS?** *Read Section 3.4*

a. **b.**

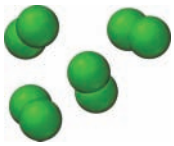


c.

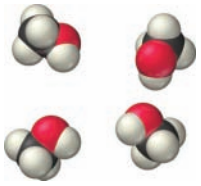
32. Based on the molecular views, classify each substance as an atomic element, a molecular element, an ionic compound, or a molecular compound.



a.



b.



c.

Formulas and Names for Ionic Compounds

33. Write a formula for the ionic compound that forms between each pair of elements.
MISSED THIS? *Read Section 3.5; Watch KCV 3.5, IWE 3.3*
a. calcium and oxygen
b. zinc and sulfur
c. rubidium and bromine
d. aluminum and oxygen

34. Write a formula for the ionic compound that forms between each pair of elements.
a. silver and chlorine
b. sodium and sulfur
c. aluminum and sulfur
d. potassium and chlorine

35. Write a formula for the compound that forms between calcium and each polyatomic ion.
MISSED THIS? *Read Section 3.5; Watch KCV 3.5, IWE 3.3*
a. hydroxide
b. chromate
c. phosphate
d. cyanide

36. Write a formula for the compound that forms between potassium and each polyatomic ion.
a. carbonate
b. phosphate
c. hydrogen phosphate
d. acetate

37. Name each ionic compound.
MISSED THIS? *Read Section 3.5; Watch KCV 3.5, IWE 3.11*
a. Mg_3N_2 **b.** KF **c.** Na_2O
d. Li_2S **e.** CsF **f.** KI

38. Name each ionic compound.
a. $SnCl_4$ **b.** PbI_2 **c.** Fe_2O_3
d. CuI_2 **e.** $HgBr_2$ **f.** $CrCl_2$

39. Give each ionic compound an appropriate name.
MISSED THIS? *Read Section 3.5; Watch KCV 3.5, IWE 3.11*
a. SnO **b.** Cr_2S_3 **c.** RbI **d.** $BaBr_2$

40. Give each ionic compound an appropriate name.
a. BaS **b.** $FeCl_3$ **c.** PbI_4 **d.** $SrBr_2$

41. Name each ionic compound containing a polyatomic ion.
MISSED THIS? *Read Section 3.5; Watch KCV 3.5, IWE 3.11*
a. $CuNO_2$ **b.** $Mg(C_2H_3O_2)_2$
c. $Ba(NO_3)_2$ **d.** $Pb(C_2H_3O_2)_2$

42. Name each ionic compound containing a polyatomic ion.
a. $Ba(OH)_2$ **b.** NH_4I **c.** $NaBrO_4$ **d.** $Fe(OH)_3$

43. Write the formula for each ionic compound.
MISSED THIS? *Read Section 3.5; Watch KCV 3.5, IWE 3.11*
a. sodium hydrogen sulfite
b. lithium permanganate
c. silver nitrate
d. potassium sulfate
e. rubidium hydrogen sulfate
f. potassium hydrogen carbonate

44. Write the formula for each ionic compound.
a. copper(II) chloride
b. copper(I) iodate
c. lead(II) chromate
d. calcium fluoride
e. potassium hydroxide
f. iron(II) phosphate

45. Write the name from the formula or the formula from the name for each hydrated ionic compound.
MISSED THIS? *Read Section 3.5; Watch KCV 3.5, IWE 3.11*
a. $CoSO_4 \cdot 7\ H_2O$
b. iridium(III) bromide tetrahydrate
c. $Mg(BrO_3)_2 \cdot 6\ H_2O$
d. potassium carbonate dihydrate

46. Write the name from the formula or the formula from the name for each hydrated ionic compound.
a. cobalt(II) phosphate octahydrate
b. $BeCl_2 \cdot 2\ H_2O$
c. chromium(III) phosphate trihydrate
d. $LiNO_2 \cdot H_2O$

Formulas and Names for Molecular Compounds and Acids

47. Name each molecular compound.
MISSED THIS? *Read Section 3.6; Watch KCV 3.6, IWE 3.11*
a. CO **b.** NI_3 **c.** $SiCl_4$ **d.** N_4Se_4

48. Name each molecular compound.
a. SO_3 **b.** SO_2 **c.** BrF_5 **d.** NO

49. Write the formula for each molecular compound.
MISSED THIS? *Read Section 3.6; Watch KCV 3.6, IWE 3.11*
a. phosphorus trichloride
b. chlorine monoxide
c. disulfur tetrafluoride
d. phosphorus pentafluoride

50. Write the formula for each molecular compound.
a. boron tribromide
b. dichlorine monoxide
c. xenon tetrafluoride
d. carbon tetrabromide

51. Name each acid.
MISSED THIS? *Read Section 3.6; Watch IWE 3.11*
a. HI(*aq*)
b. $HNO_3(aq)$
c. $H_2CO_3(aq)$

52. Name each acid.
a. HCl(*aq*) **b.** $HClO_2(aq)$ **c.** $H_2SO_4(aq)$

53. Write the formula for each acid.
MISSED THIS? *Read Section 3.6; Watch IWE 3.11*
a. hydrofluoric acid
b. hydrobromic acid
c. sulfurous acid

54. Write the formula for each acid.
a. phosphoric acid
b. hydrocyanic acid
c. chlorous acid

Using the Nomenclature Flowchart

55. Refer to the nomenclature flowchart (Figure 3.11) to name each compound.
MISSED THIS? *Read Section 3.7; Watch IWE 3.11*
a. $SrCl_2$ **b.** SnO_2
c. P_2S_5 **d.** $HC_2H_3O_2(aq)$

56. Refer to the nomenclature flowchart (Figure 3.11) to name each compound.
a. $HNO_2(aq)$ **b.** B_2Cl_2
c. $BaCl_2$ **d.** $CrCl_3$

57. Refer to the nomenclature flowchart (Figure 3.11) to name each compound.
MISSED THIS? *Read Section 3.7; Watch IWE 3.11*
a. $KClO_3$ **b.** I_2O_5 **c.** $PbSO_4$

58. Refer to the nomenclature flowchart (Figure 3.11) to name each compound.
a. XeO_3 **b.** KClO **c.** $CoSO_4$

Formula Mass and the Mole Concept for Compounds

59. Calculate the formula mass for each compound.
MISSED THIS? *Read Section 3.8*
a. NO_2 **b.** C_4H_{10}
c. $C_6H_{12}O_6$ **d.** $Cr(NO_3)_3$

60. Calculate the formula mass for each compound.
a. $MgBr_2$ **b.** HNO_2
c. CBr_4 **d.** $Ca(NO_3)_2$

61. Calculate the number of moles in each sample.
MISSED THIS? *Read Section 3.8; Watch IWE 3.13*
a. 72.5 g CCl_4
b. 12.4 g $C_{12}H_{22}O_{11}$
c. 25.2 kg C_2H_2
d. 12.3 g dinitrogen monoxide

62. Calculate the mass of each sample.
a. 15.7 mol HNO_3
b. 1.04×10^{-3} mol H_2O_2
c. 72.1 mmol SO_2
d. 1.23 mol xenon difluoride

63. Determine the number of moles (of molecules or formula units) in each sample.
MISSED THIS? *Read Section 3.8; Watch IWE 3.13*
a. 25.5 g NO_2
b. 1.25 kg CO_2
c. 38.2 g KNO_3
d. 155.2 kg Na_2SO_4

64. Determine the number of moles (of molecules or formula units) in each sample.
a. 55.98 g CF_2Cl_2
b. 23.6 kg $Fe(NO_3)_2$
c. 0.1187 g C_8H_{18}
d. 195 kg CaO

65. How many molecules are in each sample?
MISSED THIS? *Read Section 3.8; Watch IWE 3.13*
a. 6.5 g H_2O
b. 389 g CBr_4
c. 22.1 g O_2
d. 19.3 g C_8H_{10}

66. How many molecules (or formula units) are in each sample?
a. 85.26 g CCl_4
b. 55.93 kg $NaHCO_3$
c. 119.78 g C_4H_{10}
d. 4.59×10^5 g Na_3PO_4

67. Calculate the mass (in g) of each sample.
MISSED THIS? *Read Section 3.8; Watch IWE 3.13*
a. 5.94×10^{20} SO_3 molecules
b. 2.8×10^{22} H_2O molecules
c. 1 glucose molecule ($C_6H_{12}O_6$)

68. Calculate the mass (in g) of each sample.
a. 4.5×10^{25} O_3 molecules
b. 9.85×10^{19} CCl_2F_2 molecules
c. 1 water molecule

69. A sugar crystal contains approximately 1.8×10^{17} sucrose ($C_{12}H_{22}O_{11}$) molecules. What is its mass in mg?
MISSED THIS? *Read Section 3.8; Watch IWE 3.13*

70. A salt crystal has a mass of 0.12 mg. How many NaCl formula units does it contain?

Composition of Compounds

71. Calculate the mass percent composition of carbon in each carbon-containing compound.
MISSED THIS? *Read Section 3.9*
a. CH_4 **b.** C_2H_6 **c.** C_2H_2 **d.** C_2H_5Cl

72. Calculate the mass percent composition of nitrogen in each nitrogen-containing compound.
a. N_2O **b.** NO **c.** NO_2 **d.** HNO_3

73. Most fertilizers consist of nitrogen-containing compounds such as NH_3, $CO(NH_2)_2$, NH_4NO_3, and $(NH_4)_2SO_4$. Plants use the nitrogen content in these compounds for protein synthesis. Calculate the mass percent composition of nitrogen in each of the fertilizers listed. Which fertilizer has the highest nitrogen content?
MISSED THIS? *Read Section 3.9*

74. Iron in the earth is in the form of iron ore. Common ores include Fe_2O_3 (hematite), Fe_3O_4 (magnetite), and $FeCO_3$ (siderite). Calculate the mass percent composition of iron for each of these iron ores. Which ore has the highest iron content?

75. Copper(II) fluoride contains 37.42% F by mass. Calculate the mass of fluorine (in g) in 55.5 g of copper(II) fluoride.
MISSED THIS? *Read Section 3.9; Watch IWE 3.15*

76. Silver chloride, often used in silver plating, contains 75.27% Ag by mass. Calculate the mass of silver chloride required to plate 155 mg of pure silver.

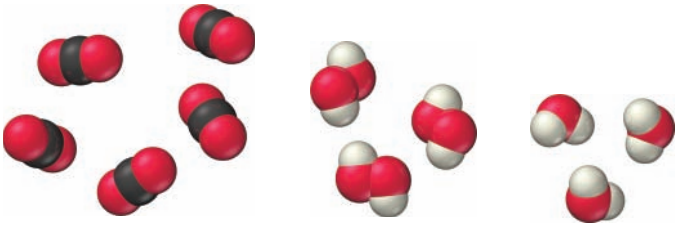
77. The iodide ion is a dietary mineral essential to good nutrition. In countries where potassium iodide is added to salt, iodine deficiency (or goiter) has been almost completely eliminated. The recommended daily allowance (RDA) for iodine is 150 μg/day. How much potassium iodide (76.45% I) should you consume if you want to meet the RDA?
MISSED THIS? *Read Section 3.9; Watch IWE 3.15*

78. The American Dental Association recommends that an adult female should consume 3.0 mg of fluoride (F^-) per day to prevent tooth decay. If the fluoride is consumed in the form of sodium fluoride (45.24% F), what amount of sodium fluoride contains the recommended amount of fluoride?

79. Write a ratio showing the relationship between the molar amounts of each element for each compound. (See Appendix IIA for color codes.) **MISSED THIS?** *Read Section 3.9*

a. **b.** **c.**

80. Write a ratio showing the relationship between the molar amounts of each element for each compound. (See Appendix IIA for color codes.)



a. **b.** **c.**

81. Determine the number of moles of hydrogen atoms in each sample. **MISSED THIS?** *Read Section 3.9; Watch IWE 3.16*

a. 0.0885 mol C_4H_{10} **b.** 1.3 mol CH_4
c. 2.4 mol C_6H_{12} **d.** 1.87 mol C_8H_{18}

82. Determine the number of moles of oxygen atoms in each sample.

a. 4.88 mol H_2O_2 **b.** 2.15 mol N_2O
c. 0.0237 mol H_2CO_3 **d.** 24.1 mol CO_2

83. Calculate the mass (in grams) of sodium in 8.5 g of each sodium-containing food additive.
MISSED THIS? *Read Section 3.9; Watch IWE 3.16*

a. NaCl (table salt)
b. Na_3PO_4 (sodium phosphate)
c. $NaC_7H_5O_2$ (sodium benzoate)
d. $Na_2C_6H_6O_7$ (sodium hydrogen citrate)

84. Calculate the mass (in kilograms) of chlorine in 25 kg of each chlorofluorocarbon (CFC).

a. CF_2Cl_2 **b.** $CFCl_3$ **c.** $C_2F_3Cl_3$ **d.** CF_3Cl

85. How many fluorine atoms are present in 5.85 g of C_2F_4?
MISSED THIS? *Read Section 3.9; Watch IWE 3.16*

86. How many bromine atoms are present in 35.2 g of CH_2Br_2?

Chemical Formulas from Experimental Data

87. A chemist decomposes samples of several compounds; the masses of their constituent elements are listed. Calculate the empirical formula for each compound.
MISSED THIS? *Read Section 3.10; Watch IWE 3.18*

a. 1.651 g Ag, 0.1224 g O
b. 0.672 g Co, 0.569 g As, 0.486 g O
c. 1.443 g Se, 5.841 g Br

88. A chemist decomposes samples of several compounds; the masses of their constituent elements are listed. Calculate the empirical formula for each compound.

a. 1.245 g Ni, 5.381 g I
b. 2.677 g Ba, 3.115 g Br
c. 2.128 g Be, 7.557 g S, 15.107 g O

89. Calculate the empirical formula for each stimulant based on its elemental mass percent composition.
MISSED THIS? *Read Section 3.10; Watch IWE 3.18*

a. nicotine (found in tobacco leaves): C 74.03%, H 8.70%, N 17.27%
b. caffeine (found in coffee beans): C 49.48%, H 5.19%, N 28.85%, O 16.48%

90. Calculate the empirical formula for each natural flavor based on its elemental mass percent composition.

a. methyl butyrate (component of apple taste and smell): C 58.80%, H 9.87%, O 31.33%
b. vanillin (responsible for the taste and smell of vanilla): C 63.15%, H 5.30%, O 31.55%

91. The elemental mass percent composition of ibuprofen (a non-steroidal anti-inflammatory drug [NSAID]) is 75.69% C, 8.80% H, and 15.51% O. Determine the empirical formula of ibuprofen.
MISSED THIS? *Read Section 3.10; Watch IWE 3.18*

92. The elemental mass percent composition of ascorbic acid (vitamin C) is 40.92% C, 4.58% H, and 54.50% O. Determine the empirical formula of ascorbic acid.

93. A 0.77-mg sample of nitrogen reacts with chlorine to form 6.61 mg of the chloride. Determine the empirical formula of nitrogen chloride.
MISSED THIS? *Read Section 3.10; Watch IWE 3.18*

94. A 45.2-mg sample of phosphorus reacts with selenium to form 131.6 mg of the selenide. Determine the empirical formula of phosphorus selenide.

95. From the given empirical formula and molar mass, find the molecular formula of each compound.
MISSED THIS? *Read Section 3.10*

a. C_6H_7N,186.24 g/mol **b.** C_2HCl,181.44 g/mol
c. $C_5H_{10}NS_2$, 296.54 g/mol

96. From the given molar mass and empirical formula of several compounds, find the molecular formula of each compound.

a. C_4H_9,114.22 g/mol **b.** CCl, 284.77 g/mol
c. C_3H_2N, 312.29 g/mol

97. Combustion analysis of a hydrocarbon produces 33.01 g CO_2 and 13.51 g H_2O. Calculate the empirical formula of the hydrocarbon. **MISSED THIS?** *Read Section 3.10; Watch IWE 3.21*

98. Combustion analysis of naphthalene, a hydrocarbon used in mothballs, produces 8.80 g CO_2 and 1.44 g H_2O. Calculate the empirical formula of naphthalene.

99. The foul odor of rancid butter is due largely to butyric acid, a compound containing carbon, hydrogen, and oxygen. Combustion analysis of a 4.30-g sample of butyric acid produces 8.59 g CO_2 and 3.52 g H_2O. Determine the empirical formula of butyric acid. **MISSED THIS?** *Read Section 3.10; Watch IWE 3.21*

100. Tartaric acid is the white, powdery substance that coats tart candies such as Sour Patch Kids. Combustion analysis of a 12.01-g sample of tartaric acid—which contains only carbon, hydrogen, and oxygen—produces 14.08 g CO_2 and 4.32 g H_2O. Determine the empirical formula of tartaric acid.

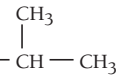
Organic Compounds

101. Classify each compound as organic or inorganic.
MISSED THIS? *Read Section 3.11*

a. $CaCO_3$
b. C_4H_8
c. $C_4H_6O_6$
d. LiF

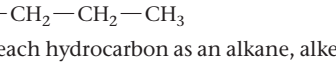
102. Classify each compound as organic or inorganic.
a. C_8H_{18}
b. CH_3NH_2
c. CaO
d. $FeCO_3$

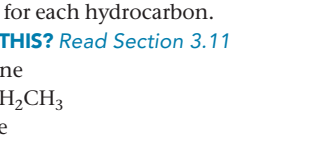
103. Classify each hydrocarbon as an alkane, alkene, or alkyne.
MISSED THIS? *Read Section 3.11*
a. $H_2C{=}CH{-}CH_3$
b. $H_3C{-}CH_2{-}CH_3$
c. $HC{\equiv}C{-}CH_3$
d. $H_3C{-}CH_2{-}CH_2{-}CH_3$

104. Classify each hydrocarbon as an alkane, alkene, or alkyne.
a. $HC{\equiv}CH$
b. $H_3C{-}CH{=}CH{-}CH_3$
c. 
d. $H_3C{-}C{\equiv}C{-}CH_3$

105. Write the formula based on the name, or the name based on the formula, for each hydrocarbon.
MISSED THIS? *Read Section 3.11*
a. propane
b. $CH_3CH_2CH_3$
c. octane
d. $CH_3CH_2CH_2CH_2CH_3$

106. Write the formula based on the name, or the name based on the formula, for each hydrocarbon.
a. CH_3CH_3
b. pentane
c. $CH_3CH_2CH_2CH_2CH_2CH_3$
d. heptane

107. Classify each organic compound as a hydrocarbon or a functionalized hydrocarbon. For functionalized hydrocarbons, identify the compound's family.
MISSED THIS? *Read Section 3.11*
a. $H_3C{-}CH_2OH$
b. $H_3C{-}CH_3$
c. 
d. $H_3C{-}NH_2$

108. Classify each organic compound as a hydrocarbon or a functionalized hydrocarbon. For functionalized hydrocarbons, identify the compound's family.
a. 
b.
c. 
d. $H_3C{-}CH_2{-}O{-}CH_3$

CUMULATIVE PROBLEMS

109. How many molecules of ethanol (C_2H_5OH) (the alcohol in alcoholic beverages) are present in 145 mL of ethanol? The density of ethanol is 0.789 g/cm^3.

110. A drop of water has a volume of approximately 0.05 mL. How many water molecules does it contain? The density of water is 1.0 g/cm^3.

111. Determine the chemical formula of each compound and then use it to calculate the mass percent composition of each constituent element.
a. potassium chromate
b. lead(II) phosphate
c. sulfurous acid
d. cobalt(II) bromide

112. Determine the chemical formula of each compound and then use it to calculate the mass percent composition of each constituent element.
a. perchloric acid
b. phosphorus pentachloride
c. nitrogen triiodide
d. carbon dioxide

113. A Freon leak in the air-conditioning system of an old car releases 25 g of CF_2Cl_2 per month. What mass of chlorine does this car emit into the atmosphere each year?

114. A Freon leak in the air-conditioning system of a large building releases 12 kg of CHF_2Cl per month. If the leak is allowed to continue, how many kilograms of Cl will be emitted into the atmosphere each year?

115. A metal (M) forms a compound with the formula MCl_3. If the compound contains 65.57% Cl by mass, what is the identity of the metal?

116. A metal (M) forms an oxide with the formula M_2O. If the oxide contains 16.99% O by mass, what is the identity of the metal?

117. Estradiol is a female sexual hormone that is responsible for the maturation and maintenance of the female reproductive system. Elemental analysis of estradiol gives the following mass percent composition: C 79.37%, H 8.88%, O 11.75%. The molar mass of estradiol is 272.37 g/mol. Find the molecular formula of estradiol.

118. Fructose is a common sugar found in fruit. Elemental analysis of fructose gives the following mass percent composition: C 40.00%, H 6.72%, O 53.28%. The molar mass of fructose is 180.16 g/mol. Find the molecular formula of fructose.

119. Combustion analysis of a 13.42-g sample of equilin (which contains only carbon, hydrogen, and oxygen) produces 39.61 g CO_2 and 9.01 g H_2O. The molar mass of equilin is 268.34 g/mol. Find its molecular formula.

120. Estrone, which contains only carbon, hydrogen, and oxygen, is a female sexual hormone in the urine of pregnant women. Combustion analysis of a 1.893-g sample of estrone produces 5.545 g of CO_2 and 1.388 g H_2O. The molar mass of estrone is 270.36 g/mol. Find its molecular formula.

121. Epsom salts is a hydrated ionic compound with the following formula: $MgSO_4 \cdot x\,H_2O$. A 4.93-g sample of Epsom salts is heated to drive off the water of hydration. The mass of the sample after complete dehydration is 2.41 g. Find the number of waters of hydration (x) in Epsom salts.

122. A hydrate of copper(II) chloride has the following formula: $CuCl_2 \cdot x\,H_2O$. The water in a 3.41-g sample of the hydrate is driven off by heating. The remaining sample has a mass of 2.69 g. Find the number of waters of hydration (x) in the hydrate.

123. A compound of molar mass 177 g/mol contains only carbon, hydrogen, bromine, and oxygen. Analysis reveals that the compound contains eight times as much carbon as hydrogen by mass. Find the molecular formula.

124. Researchers obtained the following data from experiments to find the molecular formula of benzocaine, a local anesthetic, which contains only carbon, hydrogen, nitrogen, and oxygen. Complete combustion of a 3.54-g sample of benzocaine with excess O_2 forms 8.49 g of CO_2 and 2.14 g H_2O. Another 2.35-g sample contains 0.199 g of N. The molar mass of benzocaine is 165 g/mol. Find the molar formula of benzocaine.

125. Find the total number of atoms in a sample of cocaine hydrochloride, $C_{17}H_{22}ClNO_4$, of mass 23.5 mg.

126. Vanadium forms four different oxides in which the percent by mass of vanadium is, respectively, (a) 76%, (b) 68%, (c) 61%, and (d) 56%. Determine the formula and the name of each oxide.

127. The chloride of an unknown metal is believed to have the formula MCl_3. A 2.395-g sample of the compound contains 3.606×10^{-2} mol Cl. Find the atomic mass of M.

128. Write the structural formulas of three different compounds that each have the molecular formula C_5H_{12}.

129. A chromium-containing compound has the formula $Fe_xCr_yO_4$ and is 28.59% oxygen by mass. Find x and y.

130. A phosphorus compound that contains 34.00% phosphorus by mass has the formula X_3P_2. Identify the element X.

131. A particular brand of beef jerky contains 0.0552% sodium nitrite by mass and is sold in an 8.00-oz bag. What mass of sodium does the sodium nitrite contribute to the sodium content of the bag of beef jerky?

132. Phosphorus is obtained primarily from ores containing calcium phosphate. If a particular ore contains 57.8% calcium phosphate, what minimum mass of the ore must be processed to obtain 1.00 kg of phosphorus?

CHALLENGE PROBLEMS

133. A mixture of NaCl and NaBr has a mass of 2.00 g and contains 0.75 g of Na. What is the mass of NaBr in the mixture?

134. Three pure compounds form when 1.00-g samples of element X combine with, respectively, 0.472 g, 0.630 g, and 0.789 g of element Z. The first compound has the formula X_2Z_3. Find the empirical formulas of the other two compounds.

135. A mixture of $CaCO_3$ and $(NH_4)_2CO_3$ is 61.9% CO_3 by mass. Find the mass percent of $CaCO_3$ in the mixture.

136. A mixture of 50.0 g of S and 1.00×10^2 g of Cl_2 reacts completely to form S_2Cl_2 and SCl_2. Find the mass of S_2Cl_2 formed.

137. Because of increasing evidence of damage to the ozone layer, chlorofluorocarbon (CFC) production was banned in 1996. However, many older cars still have air conditioners that use CFC-12 (CF_2Cl_2). These air conditioners are recharged from stockpiled supplies of CFC-12. Suppose that 100 million automobiles each contain 1.1 kg of CFC-12 and leak 25% of their CFC-12 into the atmosphere per year. How much chlorine, in kg, is added to the atmosphere each year due to these air conditioners? (Assume two significant figures in your calculations.)

138. A particular coal contains 2.55% sulfur by mass. When the coal is burned, it produces SO_2 emissions, which combine with rainwater to produce sulfuric acid. Use the formula of sulfuric acid to calculate the mass percent of S in sulfuric acid. Then determine how much sulfuric acid (in metric tons) is produced by the combustion of 1.0 metric ton of this coal. (A metric ton is 1000 kg.)

139. Lead is found in Earth's crust as several different lead ores. Suppose a certain rock is 38.0% PbS (galena), 25.0% $PbCO_3$ (cerussite), and 17.4% $PbSO_4$ (anglesite). The remainder of the rock is composed of substances containing no lead. How much of this rock (in kg) must be processed to obtain 5.0 metric tons of lead? (A metric ton is 1000 kg.)

140. A 2.52-g sample of a compound containing only carbon, hydrogen, nitrogen, oxygen, and sulfur is burned in excess oxygen to yield 4.23 g of CO_2 and 1.01 g of H_2O. Another sample of the same compound, of mass 4.14 g, yields 2.11 g of SO_3. A third sample, of mass 5.66 g, yields 2.27 g of HNO_3. Calculate the empirical formula of the compound.

141. A compound of molar mass 229 g/mol contains only carbon, hydrogen, iodine, and sulfur. Analysis shows that a sample of the compound contains six times as much carbon as hydrogen, by mass. Calculate the molecular formula of the compound.

142. The elements X and Y form a compound that is 40% X and 60% Y by mass. The atomic mass of X is twice that of Y. What is the empirical formula of the compound?

143. A compound of X and Y is $\frac{1}{3}$ X by mass. The atomic mass of element X is $\frac{1}{3}$ the atomic mass of element Y. Find the empirical formula of the compound.

144. A mixture of carbon and sulfur has a mass of 9.0 g. Complete combustion with excess O_2 gives 23.3 g of a mixture of CO_2 and SO_2. Find the mass of sulfur in the original mixture.

CONCEPTUAL PROBLEMS

145. When molecules are represented by molecular models, what does each sphere represent? How big is the nucleus of an atom in comparison to the sphere used to represent an atom in a molecular model?

146. Without doing any calculations, determine which element in each compound has the highest mass percent composition.

a. CO
b. N_2O
c. $C_6H_{12}O_6$
d. NH_3

147. Explain the problem with the following statement and correct it: "The chemical formula for ammonia (NH_3) indicates that ammonia contains three grams of hydrogen for each gram of nitrogen."

148. Element A is an atomic element, and element B is a diatomic molecular element. Using circles to represent atoms of A and squares to represent atoms of B, draw molecular-level views of each element.

149. Without doing any calculations, arrange the elements in H_2SO_4 in order of decreasing mass percent composition.

QUESTIONS FOR GROUP WORK

Active Classroom Learning

Discuss these questions with the group and record your consensus answer.

150. With group members playing the roles of nuclei and electrons, demonstrate the formation of an ionic bond between Na and Cl. Demonstrate the formation of the covalent bonds in H_2O.

151. Create a flowchart with a series of simple questions that can be used to determine whether a chemical formula is that of an atomic element, a molecular element, a molecular compound, or an ionic compound. Use your flowchart to identify the correct category for P_4, KCl, CH_4, Ne, and NH_4NO_3.

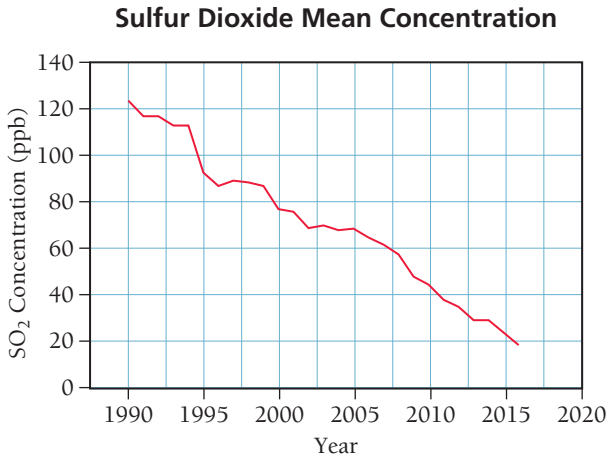
152. Have each member of your group list one similarity or difference between the naming conventions for ionic and molecular compounds.

153. A compound isolated from the rind of lemons is found to be 88.14% carbon and 11.86% hydrogen by mass. How many grams of C and H are there in a 100.0-g sample of this substance? How many moles of C and H? What is the empirical formula? The molar mass is determined to be 136.26 g/mol. What is the molecular formula? Which step of the process just described does your group understand the least? Which step will be hardest for the members of your group to remember?

DATA INTERPRETATION AND ANALYSIS

Sulfur Dioxide Air Pollution

154. Sulfur dioxide is a pollutant emitted primarily by coal-burning power plants and industrial smelters. Sulfur dioxide in air affects the respiratory system in humans and is the main cause of acid rain. Thanks to the Clean Air Act and its amendments, sulfur dioxide levels in the United States have dramatically fallen over the last 30 years. The graph below shows the mean sulfur dioxide levels from 136 measuring sites in the United States for the period 1990 to 2016. Examine the graph and answer the questions that follow.



a. On its website, the EPA claims that sulfur dioxide levels have fallen by 85% between 1990 and 2016. Is this claim accurate?

b. The EPA air quality standard for SO_2 is 75 ppm. In what year did the average U.S. SO_2 concentration begin to meet this standard?

c. What is the percent by mass of S in SO_2?

d. A 100 m^3 room with an SO_2 concentration of 75 ppb contains about 0.021 g SO_2. How many sulfur atoms does it contain?

Cc ANSWERS TO CONCEPTUAL CONNECTIONS

Types of Chemical Bonds

3.1 **(b)** The bond is covalent because it is forming between two nonmetals.

Structural Formulas

3.2 **(c)** H—O—H

Representing Molecules

3.3 **(b)** The spheres represent the electron cloud of the atom. It would be nearly impossible to draw a nucleus to scale on any of the space-filling molecular models in this book—the nucleus would be too small to see.

A Molecular View of Elements and Compounds

3.4 **(b)** A molecular element has molecules made of the same atoms as its basic unit.

Ionic and Molecular Compounds

3.5 **(a)** Only molecular compounds contain discrete molecules. Ionic compounds result in extended networks of alternating cations and anions.

Types of Metals

3.6 **(d)** Sr is a group II metal and forms a cation with a 2+ charge in all its compounds.

Polyatomic Ions

3.7 **(a)** Only this choice contains the polyatomic ions in the formulas.

Nomenclature

3.8 **(b)** This conceptual connection addresses one of the main errors you can make in nomenclature: the failure to correctly categorize the compound. Remember that you must first determine whether the compound is an ionic compound, a molecular compound, or an acid, and then you must name it accordingly. NCl_3 is a molecular compound (two or more nonmetals), and therefore in its name prefixes indicate the number of each type of atom—so NCl_3 is nitrogen trichloride. The compound $AlCl_3$, however, is an ionic compound (metal and nonmetal), and therefore does not require prefixes—so $AlCl_3$ is aluminum chloride.

Molecular Models and the Size of Molecules

3.9 **(c)** Atomic radii range in the hundreds of picometers, while the spheres in these models have radii of about a centimeter. The scaling factor is therefore about 10^8 (100 million).

Chemical Formula and Mass Percent Composition

3.10 **(a)** C > O > H Since carbon and oxygen differ in atomic mass by only 4 amu, and since there are six carbon atoms in the formula, we can conclude that carbon constitutes the greatest fraction of the mass. Oxygen is next because its mass is 16 times that of hydrogen and there are only six hydrogen atoms for every one oxygen atom.

Chemical Formulas and Elemental Composition

3.11 **(c)** The chemical formula for a compound gives relationships between *atoms* or *moles of atoms*. The chemical formula for water states that water molecules contain two H atoms to every one O atom or 2 mol H to every 1 mol H_2O. This *does not* imply a two-to-one relationship between *masses* of hydrogen and oxygen because these atoms have different masses. It also does not imply a two-to-one relationship between volumes.