Pearson

Exercises

Review Questions

1. How do the properties of compounds compare to the properties of the elements from which they are composed?
2. What is a chemical bond? Why do chemical bonds form?
3. Explain the difference between an ionic bond and a covalent bond.
4. List and describe the different ways to represent compounds. Why are there so many?
5. What is the difference between an empirical formula and a molecular formula?
6. How do you determine how many dots to put around the Lewis symbol of an element?
7. Describe the octet rule in the Lewis model.
8. According to the Lewis model, what is a chemical bond?
9. How can you use Lewis structures to determine the formula of ionic compounds? Give an example.
10. What is lattice energy?
11. Why is the formation of solid sodium chloride from solid sodium and gaseous chlorine exothermic, even though it takes more energy to form the Na^+ ion than the amount of energy released upon formation of Cl^-?
12. Explain how to write a formula for an ionic compound given the names of the metal and nonmetal (or polyatomic ion) in the compound.
13. Explain how to name binary ionic compounds. How do you name an ionic compound if it contains a polyatomic ion?
14. Why do the names of some ionic compounds include the charge of the metal ion while others do not?
15. Within a covalent Lewis structure, what is the difference between lone pair and bonding pair electrons?
16. In what ways are double and triple covalent bonds different from single covalent bonds?
17. How does the Lewis model for covalent bonding account for why certain combinations of atoms are stable while others are not?
18. How does the Lewis model for covalent bonding account for the relatively low melting and boiling points of molecular compounds (compared to ionic compounds)?
19. Explain how to name molecular inorganic compounds.
20. How many atoms are specified by each of these prefixes: mono, di, tri, tetra, penta, hexa?
21. What is the formula mass for a compound? Why is it useful?
22. Explain how the information in a chemical formula can be used to determine how much of a particular element is present in a given amount of a compound. Provide some examples of how this might be useful.
23. What is mass percent composition? Why is it useful?
24. Which kinds of conversion factors are inherent in chemical formulas? Provide an example.
25. Which kind of chemical formula can be obtained from experimental data showing the relative masses of the elements in a compound?
26. How can a molecular formula be obtained from an empirical formula? What additional

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

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

28. Which elements are normally present in organic compounds?

Problems by Topic

Note: Answers to all odd-numbered Problems 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. Because of their nature, Challenge Problems and Conceptual Problems are unpaired.

Types of Compounds and Chemical Formulas

29. Classify each compound as ionic or molecular.

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. Determine the empirical formula for the compound represented by each molecular formula.

a. N_2O_4

b. C_5H_{12}

c. C_4H_{10}

32. Determine the empirical formula for the compound represented by each molecular formula.

a. C_2H_4

b. $C_6H_{12}O_6$

c. NH_3

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

a. $Mg_3(PO_4)_2$

b. $BaCl_2$

c. $Fe(NO_2)_2$

d. $Ca(OH)_2$

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

a. $Ca(NO_2)_2$

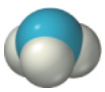
b. $CuSO_4$

c. $Al(NO_3)_3$

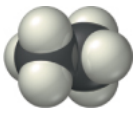
d. $Mg(HCO_3)_2$

35. Write a chemical formula for each molecular model. (See Appendix II A for color codes.)

a.



b.



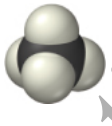
c.

36. Write a chemical formula for each molecular model. (See Appendix II A for color codes.)

a.

b.

c.



Valence Electrons and Lewis Dot Structures

37. Write an electron configuration for N. Then write a Lewis symbol for N and show which electrons from the electron configuration are included in the Lewis symbol.

38. Write an electron configuration for Ne. Then write a Lewis symbol for Ne and show which electrons from the electron configuration are included in the Lewis symbol.

39. Write a Lewis symbol for each atom or ion.

a. Al

b. Na^+

c. Cl

d. Cl^-

40. Write a Lewis symbol for each atom or ion.

a. S^{2-}

b. Mg

c. Mg^{2+}

d. P

Ionic Bonding and Lattice Energy

41. Write the Lewis symbols that represent the ions in each ionic compound.

a. NaF

b. CaO

c. $SrBr_2$

d. K_2O

42. Write the Lewis symbols that represent the ions in each ionic compound.

a. SrO

b. Li_2S

c. CaI_2

d. RbF

43. Use Lewis symbols to determine the formula for the compound that forms between each pair of elements.

a. Sr and Se

b. Ba and Cl

c. Na and S

d. Al and O

44. Use Lewis symbols to determine the formula for the compound that forms between each pair of elements.

a. Ca and N

b. Mg and I

c. Ca and S

d. Cs and F

45. The lattice energy of CsF is −744 kJ/mol, whereas that of BaO is −3029 kJ/mol. Explain this large difference in lattice energy.

46. Rubidium iodide has a lattice energy of −617 kJ/mol, while potassium bromide has a lattice energy of −671 kJ/mol. Why is the lattice energy of potassium bromide more exothermic than the lattice energy of rubidium iodide?

Formulas and Names for Ionic Compounds

47. Write a formula for the ionic compound that forms between each pair of elements.

a. calcium and oxygen

b. zinc and sulfur

c. rubidium and bromine

d. aluminum and oxygen

48. 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

49. Write a formula for the compound that forms between calcium and each polyatomic ion.

a. hydroxide

b. chromate

c. phosphate

d. cyanide

50. Write a formula for the compound that forms between potassium and each polyatomic ion.

a. carbonate

b. phosphate

c. hydrogen phosphate

d. acetate

51. Name each ionic compound.

a. Mg_3N_2

b. KF

c. Na_2O

d. Li_2S

e. CsF

f. KI

52. Name each ionic compound.

a. $SnCl_4$

b. PbI_2

c. Fe_2O_3

d. CuI_2

e. $HgBr_2$

f. $CrCl_2$

53. Name each ionic compound.

a. SnO

b. Cr_2S_3

c. RbI

d. $BaBr_2$

54. Name each ionic compound.

a. BaS

b. $FeCl_3$

c. PbI_4

d. $SrBr_2$

55. Name each ionic compound containing a polyatomic ion.

a. $CuNO_2$

b. $Mg(C_2H_3O_2)_2$

c. $Ba(NO_3)_2$

d. $Pb(C_2H_3O_2)_2$

56. Name each ionic compound containing a polyatomic ion.

a. $Ba(OH)_2$

b. NH_4I

c. $NaBrO_4$

d. $Fe(OH)_3$

57. Write the formula for each ionic compound.

a. sodium hydrogen sulfite

b. lithium permanganate

c. silver nitrate

d. potassium sulfate

e. rubidium hydrogen sulfate

f. potassium hydrogen carbonate

58. 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

59. Write the name from the formula or the formula from the name for each hydrated ionic compound.

a. $CoSO_4 \cdot 7H_2O$

b. iridium(III) bromide tetrahydrate

c. $Mg(BrO_3)_2 \cdot 6H_2O$

d. potassium carbonate dihydrate

60. Write the name from the formula or the formula from the name for each hydrated ionic compound.

a. cobalt(II) phosphate octahydrate

b. $BeCl_2 \cdot 2H_2O$

c. chromium(III) phosphate trihydrate

d. $LiNO_2 \cdot H_2O$

Simple Lewis Structures, Formulas, and Names for Molecular Compounds

61. Use covalent Lewis structures to explain why each element (or family of elements) occurs as

61. Use covalent Lewis structures to explain why each element (or family of elements) occurs as diatomic molecules.

- **a.** hydrogen
- **b.** the halogens
- **c.** oxygen
- **d.** nitrogen

62. Use covalent Lewis structures to explain why the compound that forms between nitrogen and hydrogen has the formula NH_3. Show why NH_2 and NH_4 are not stable.

63. Name each molecular compound.

- **a.** CO
- **b.** NI_3
- **c.** $SiCl_4$
- **d.** N_4Se_4

64. Name each molecular compound.

- **a.** SO_3
- **b.** SO_2
- **c.** BrF_5
- **d.** NO

65. Write a formula for each molecular compound.

- **a.** phosphorus trichloride
- **b.** chlorine monoxide
- **c.** disulfur tetrafluoride
- **d.** phosphorus pentafluoride

66. Write a formula for each molecular compound.

- **a.** boron tribromide
- **b.** dichlorine monoxide
- **c.** xenon tetrafluoride
- **d.** carbon tetrabromide

Naming Compounds (When the Type Is Not Specified)

67. Name each compound. (Refer to the nomenclature flowchart found in the Key Concepts section of the Chapter in Review.)

- **a.** $SrCl_2$
- **b.** SnO_2
- **c.** P_2S_5

68. Name each compound. (Refer to the nomenclature flowchart found in the Key Concepts section of the Chapter in Review.)

- **a.** B_2Cl_2
- **b.** $BaCl_2$
- **c.** $CrCl_3$

69. Name each compound. (Refer to the nomenclature flowchart found in the Key Concepts section of the Chapter in Review.)

- **a.** $KClO_3$
- **b.** I_2O_5
- **c.** $PbSO_4$

70. Name each compound. (Refer to the nomenclature flowchart found in the Key Concepts section of the Chapter in Review.)

- **a.** XeO_3
- **b.** KClO
- **c.** $CoSO_4$

Formula Mass and the Mole Concept for Compounds

71. Calculate the formula mass for each compound.

a. NO_2

b. C_4H_{10}

c. $C_6H_{12}O_6$

d. $Cr(NO_3)_3$

72. Calculate the formula mass for each compound.

a. $MgBr_2$

b. HNO_2

c. CBr_4

d. $Ca(NO_3)_2$

73. Calculate the number of moles in each sample.

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 of dinitrogen monoxide

74. 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

75. Determine the number of moles (of molecules or formula units) in each sample.

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

76. 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

77. How many molecules are in each sample?

a. 6.5 g H_2O

b. 389 g CBr_4

c. 22.1 g O_2

d. 19.3 g C_8H_{10}

78. 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

79. Calculate the mass (in g) of each sample.

a. 5.94×10^{20} SO_3 molecules

b. 2.8×10^{22} H_2O molecules

c. 1 glucose molecule ($C_6H_{12}O_6$)

80. 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

81. A sugar crystal contains approximately 1.8×10^{17}sucrose ($C_{12}H_{22}O_{11}$)molecules. What is its mass in mg?

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

Composition of Compounds

83. Calculate the mass percent composition of carbon in each carbon-containing compound.

a. CH_4

b. C_2H_6

c. C_2H_2

d. C_2H_5Cl

84. Calculate the mass percent composition of nitrogen in each nitrogen-containing compound.

a. N_2O

b. NO

c. NO_2

d. HNO_3

85. 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 named in this problem. Which fertilizer has the highest nitrogen content?

86. 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?

87. Copper(II) fluoride contains 37.42% F by mass. Calculate the mass of fluorine (in g) contained in 55.5 g of copper(II) fluoride.

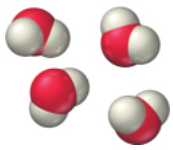
88. Silver chloride, often used in silver plating, contains 75.27% Ag by mass. Calculate the mass of silver chloride required to plate 155 mg of pure silver.

89. The iodide ion is a dietary mineral essential to good nutrition. In countries where potassium iodide is added to salt, iodine deficiency (goiter) has been almost completely eliminated. The recommended daily allowance (RDA) for iodine is 150 μg/day. How much potassium iodide (76.45% I) must you consume to meet the RDA?

90. 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?

91. Write a ratio showing the relationship between the molar amounts of each element for each compound.

a.



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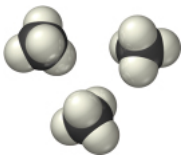
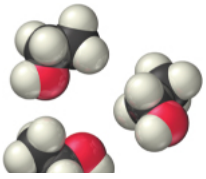
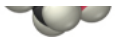


c.

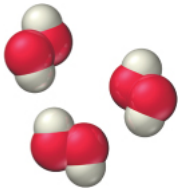




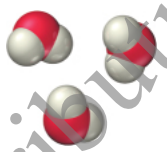
92. Write a ratio showing the relationship between the molar amounts of each element for each compound.

a.

b.



c.



93. Determine the number of moles of hydrogen atoms in each sample.

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}

94. 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

95. Calculate mass (in grams) of sodium in 8.5 g of each sodium-containing food additive.

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)

96. 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

Chemical Formulas from Experimental Data

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

are shown. Calculate the empirical formula for each compound.

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

98. A chemist decomposes samples of several compounds; the masses of their constituent elements are shown. 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

99. Calculate the empirical formula for each stimulant based on its elemental mass percent composition.

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%

100. 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%

101. The elemental mass percent composition of ibuprofen is 75.69% C, 8.80% H, and 15.51% O. Determine the empirical formula of ibuprofen.

102. 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.

103. 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.

104. 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.

105. The empirical formula and molar mass of several compounds are listed. Find the molecular formula of each compound.

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

106. The molar mass and empirical formula of several compounds are listed. 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

107. Combustion analysis of a hydrocarbon produced 33.01 g CO_2 and 13.51 g H_2O. Calculate the empirical formula of the hydrocarbon.

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

109. 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 for butyric acid.

110. 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 for tartaric acid.

Organic Compounds

111. Classify each compound as organic or inorganic.

a. $CaCO_3$

b. C_4H_8

c. $C_4H_6O_6$

d. LiF

a. LiF

112. Classify each compound as organic or inorganic.

a. C_8H_{18}

b. CH_3NH_2

c. CaO

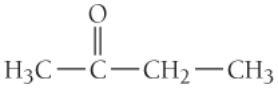
d. $FeCO_3$

113. Determine whether each compound is a hydrocarbon.

a. H_3C-CH_2OH

b. H_3C-CH_3

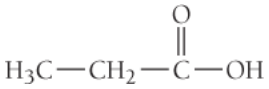
c.



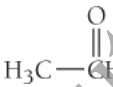
d. H_3C-NH_2

114. Determine whether each compound is a hydrocarbon.

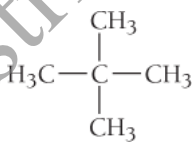
a.



b.



c.



d. $H_3C-CH_2-O-CH_3$

Cumulative Problems

115. 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.

116. 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.

117. Determine the chemical formula of each compound and use it to calculate the mass percent composition of each constituent element.

a. potassium chromate

b. lead(II) phosphate

c. cobalt(II) bromide

118. Determine the chemical formula of each compound and use it to calculate the mass percent composition of each constituent element.

a. phosphorus pentachloride

b. nitrogen triiodide

c. carbon dioxide

119. 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?

120. 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 are emitted into the atmosphere each year?

121. 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?

122. 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?

123. Estradiol is a female sexual hormone that causes 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.

124. 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.

125. 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.

126. Estrone, which contains only carbon, hydrogen, and oxygen, is a female sexual hormone that occurs 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.

127. 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 was heated to drive off the water of hydration. The mass of the sample after complete dehydration was 2.41 g. Find the number of waters of hydration (x) in Epsom salts.

128. 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.

129. A compound of molar mass 177 g/mol contains only carbon, hydrogen, bromine, and oxygen. Analysis reveals that the compound contains 8 times as much carbon as hydrogen by mass. Find the molecular formula.

130. Researchers obtain 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 sample of mass 2.35 g is found to contain 0.199 g of N. The molar mass of benzocaine is found to be 165 g/mol. Find the molecular formula of benzocaine.

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

132. 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 one of these oxides.

133. 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^{-3} mol Cl Find the atomic mass of M.

134. Write the structural formulas of two different compounds that each has the molecular formula C_4H_{10}.

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

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

137. 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?

138. 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

139. 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?

140. 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_3Z_3. Find the empirical formulas of the other two compounds.

141. 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.

142. 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. What mass of S_2Cl_2 forms?

143. Because of increasing evidence of damage to the ozone layer, chlorofluorocarbon (CFC) production was banned in 1996. However, there are about 100 million auto air conditioners in operation that still use CFC-12 (CF_2Cl_2). These air conditioners are recharged from stockpiled supplies of CFC-12. If each of the 100 million automobiles contains 1.1 kg of CFC-12 and leaks 25% of its CFC-12 into the atmosphere per year, how much chlorine, in kg, is added to the atmosphere each year due to auto air conditioners? (Assume two significant figures in your calculations.)

144. 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.)

145. 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.)

146. 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. (*Hint*: Use the first set of data to determine % C and % H by mass. Use the second and third sets of data to determine % S and % N by mass. Then determine % O by mass by difference from 100%.)

147. A compound of molar mass 229 contains only carbon, hydrogen, iodine, and sulfur. Analysis shows that a sample of the compound contains 6 times as much carbon as hydrogen, by mass. Calculate the molecular formula of the compound.

148. 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?

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

150. 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

151. 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?

152. Without doing any calculations, determine which element in each of the compounds will have the highest mass percent composition.

a. CO

b. N_2O

c. $C_6H_{12}O_6$

d. NH_3

153. Explain the problem with this statement and correct it: "The chemical formula for ammonia (NH_3) indicates that ammonia contains 3 grams of hydrogen to each gram of nitrogen."

154. 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.

155. Using group members to play 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.

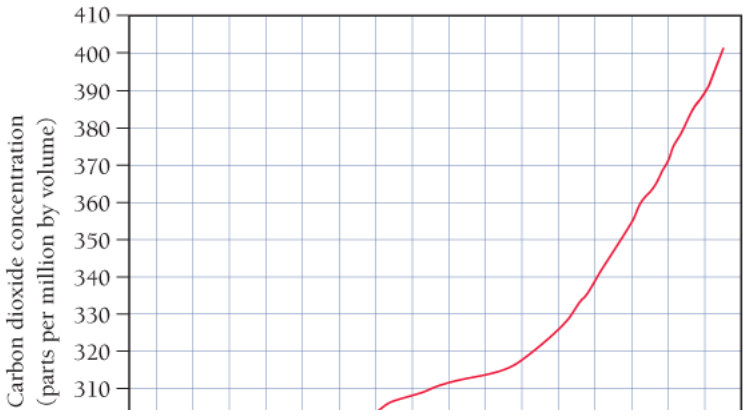
156. Create a flowchart with a series of simple questions that can be used to determine whether a chemical formula is that of an atomic element, a molecular element, a molecular compound, or an ionic compound. Use your flowchart to identify the correct category for P_4, KCl, CH_4, Ne, and NH_4NO_3.

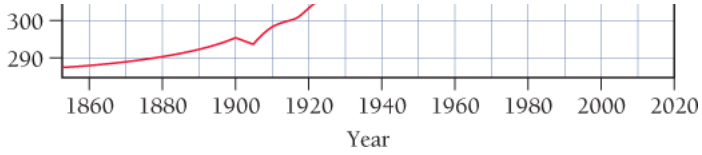
157. Have each member of your group list one similarity or difference between the naming conventions for ionic and the naming conventions of molecular compounds.

158. A compound isolated from the rind of lemons is 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 most challenging for the members of your group to remember?

Data Interpretation and Analysis

159. The amount of carbon dioxide in the atmosphere has been increasing over the past century as a result of the combustion of fossil fuels (coal, oil, and natural gas). Carbon dioxide is a greenhouse gas that plays a significant role in climate. The increase in carbon dioxide is correlated with changes in climate that have climate scientists concerned. The graph shown here illustrates the increase in atmospheric carbon dioxide from 1860 to the present. Study the graph and answer the questions that follow.





Atmospheric carbon dioxide concentration from 1850 to present.

a. By how much did the level of carbon dioxide (in ppmv) increase between 1880 and the present day?

b. What is the percent increase in the level of carbon dioxide between 1880 and the present day?

c. Assuming that the total volume of air in the atmosphere around Earth is 5.1×10^9 km^3 and that the concentration of CO_2 is uniform throught this volume, what is the present-day volume of CO_2 in the atmosphere?

d. Determine the percentage average yearly increase in atmospheric CO_2 from 1960 to the present day.

e. If atmospheric carbon dioxide continues to increase at the rate you determined in part d, what will its concentration (in ppmv) be in the year 2040?

Answers to Conceptual Connections

Cc 4.1 H–O–H

Cc 4.2 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—on this scale, the nucleus would be too small to see.

Cc 4.3 You would expect MgO to have the higher melting point because, in our bonding model, the magnesium and oxygen ions are held together in a crystalline lattice by charges of 2+ for magnesium and 2—for oxygen. In contrast, the NaCl lattice is held together by charges of 1+ for sodium and 1– for chlorine. According to Coulomb's law, as long as the spacing between the cation and the anion in the two compounds does not differ that much, the higher charges in MgO should result in lower potential energy (more stability), and therefore a higher melting point. The experimentally measured melting points of these compounds are 801 °C for NaCl and 2852 °C for MgO, in accordance with the model.

Cc 4.4 **(a)** NO_2^-; **(b)** SO_4^{2-}; **(c)** NO_3^-

Cc 4.5 The reasons that atoms form bonds are complex. One contributing factor is the lowering of their potential energy. The octet rule is just a handy way to predict the combinations of atoms that will have a lower potential energy when they bond together.

Cc 4.6 Choice **(a)** best describes the difference between ionic and molecular compounds. Answer **(b)** is incorrect because there are no "new" forces in bonding (just rearrangements that result in lower potential energy), and because ions do not group together in pairs in the solid phase. Answer **(c)** is incorrect because the main difference between ionic and molecular compounds is the way that the atoms bond. Answer **(d)** is incorrect because ionic compounds do not contain molecules.

Cc 4.7 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 or a molecular compound, and then name it accordingly. NCl_3 is a molecular compound (two or more nonmetals), and therefore you must use prefixes to indicate the number of each type of atom—so NCl_3 is nitrogen trichloride. The compound $AlCl_3$, in contrast, is an ionic compound (metal and nonmetal), and therefore does not require prefixes—so $AlCl_3$ is aluminum chloride.

Cc 4.8 **(c)** Atomic radii range in the hundreds of picometers, while the spheres in these models have radii of less than a centimeter. The scaling factor is therefore about 10^8(100 million).

Cc 4.9 $C > O > H$ 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 to every one oxygen atom.

Cc 4.10 **(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 2 H atoms to every 1 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 in water because these atoms have different masses. It also does not imply a two-to-one relationship between volumes.