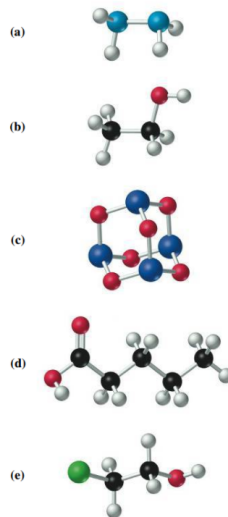
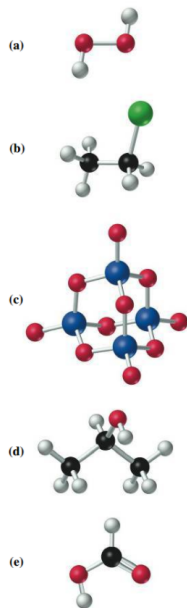


Exercises

Representing Molecules

1. Refer to the color scheme given in Figure 3-3, and give the molecular formulas for the molecules whose ball-and-stick models are given here.
2. Give the molecular formulas for the molecules whose ball-and-stick models are given here. Refer to the color scheme in Figure 3-3.



3. Give the structural formulas of the molecules shown in Exercise 1 (b), (d), and (e).
4. Give the structural formulas of the molecules shown in Exercise 2 (b), (d), and (e).

The Avogadro Constant and the Mole

5. Calculate the total number of (a) atoms in one molecule of trinitrotoluene (TNT), $\text{CH}_2\text{C}_6\text{H}_2(\text{NO}_2)_3$; (b) atoms in 0.00102 mol $\text{CH}_3(\text{CH}_2)_4\text{CH}_2\text{OH}$; (c) F atoms in 12.15 mol $\text{C}_2\text{H}_5\text{BrClF}_3$.
6. Determine the mass, in grams, of (a) 7.34 mol NO_2 ; (b) 4.220×10^{25} O_2 molecules; (c) 15.5 mol $\text{CuSO}_4 \cdot 5 \text{H}_2\text{O}$; (d) 2.25×10^{24} molecules of $\text{C}_2\text{H}_4(\text{OH})_2$.
7. The amino acid methionine, which is essential in human diets, has the molecular formula $\text{C}_5\text{H}_{11}\text{NO}_2\text{S}$. Determine (a) its molar mass; (b) the number of moles of H atoms per mole of methionine;

104 Chapter 3 Chemical Compounds

- (c) the number of grams of C per mole of methionine;
(d) the number of C atoms in 9.07 mol methionine.
8. Determine the number of moles of Br_2 in a sample consisting of (a) 4.04×10^{22} Br_2 molecules; (b) 5.78×10^{24} Br atoms (assuming that the Br atoms react completely to form Br_2); (c) 7.82 kg bromine; (d) 3.56 L liquid bromine ($d = 3.10 \text{ g/mL}$).
9. Without doing detailed calculations, explain which of the following has the greatest number of N atoms (a) 50.0 g N_2O ; (b) 17.0 g NH_3 ; (c) 150 mL of liquid pyridine, $\text{C}_5\text{H}_5\text{N}$ ($d = 0.983 \text{ g/mL}$); (d) 1.0 mol N_2 .
10. Without doing detailed calculations, determine which of the following has the greatest number of S atoms (a) 0.12 mol of solid sulfur, S_8 ; (b) 0.50 mol of gaseous S_2O ; (c) 65 g of gaseous SO_2 ; (d) 75 mL of liquid thiophene, $\text{C}_4\text{H}_4\text{S}$ ($d = 1.064 \text{ g/mL}$).
11. Determine the number of moles of
(a) N_2O_4 in a 115 g sample
(b) N atoms in 43.5 g of $\text{Mg}(\text{NO}_3)_2$
(c) N atoms in a sample of $\text{C}_7\text{H}_5(\text{NO}_2)_3$ that has the same number of O atoms as 12.4 g $\text{C}_6\text{H}_{12}\text{O}_6$
12. Determine the mass, in grams, of
(a) $2.10 \times 10^2 \text{ mol S}_8$
(b) 5.02×10^{22} molecules of palmitic acid, $\text{C}_{16}\text{H}_{32}\text{O}_2$
(c) a quantity of the amino acid histidine, $\text{C}_6\text{H}_9\text{N}_3\text{O}_2$, containing 2.95 mol N atoms
13. The hemoglobin content of blood is about 15.5 g/100 mL blood. The molar mass of hemoglobin is about 64,500 g/mol, and there are four iron (Fe) atoms in a hemoglobin molecule. Approximately how many Fe atoms are present in the 6 L of blood in a typical adult?
14. In white phosphorus, P atoms are joined into P_4 molecules (see Figure 3-5). White phosphorus is commonly supplied in chalk-like cylindrical form. Its density is 1.823 g/cm^3 . For a cylinder of white phosphorus 6.50 cm long and 1.22 cm in diameter, determine (a) the number of moles of P_4 present; (b) the total number of P atoms.

Chemical Formulas

15. Explain which of the following statement(s) is (are) correct concerning glucose (blood sugar), $\text{C}_6\text{H}_{12}\text{O}_6$.
(a) The percentages, by mass, of C and O are the same as in CO.
(b) The ratio of C:H:O atoms is the same as in dihydroxyacetone, $(\text{CH}_2\text{OH})_2\text{CO}$.
(c) The proportions, by mass, of C and O are equal.
(d) The highest percentage, by mass, is that of H.
16. Explain which of the following statement(s) is (are) correct for sorbic acid, $\text{C}_8\text{H}_8\text{O}_2$, an inhibitor of mold and yeast.
(a) It has a C:H:O mass ratio of 3:4:1.
(b) It has the same mass percent composition as the aquatic herbicide, acrolein, $\text{C}_3\text{H}_4\text{O}$.
(c) It has the same empirical formula as aspidinol, $\text{C}_{12}\text{H}_{16}\text{O}_4$, a drug used to kill parasitic worms.
- (d) It has four times as many H atoms as O atoms, but four times as much O as H by mass.
17. For the mineral torbernite, $\text{Cu}(\text{UO}_2)_2(\text{PO}_4)_2 \cdot 8 \text{H}_2\text{O}$, determine
(a) the total number of atoms in one formula unit
(b) the ratio, by number, of H atoms to O atoms
(c) the ratio, by mass, of Cu to P
(d) the element present in the greatest mass percent
(e) the mass required to contain 1.00 g P
18. For the compound $\text{Ge}[\text{S}(\text{CH}_2)_4\text{CH}_3]_4$, determine
(a) the total number of atoms in one formula unit
(b) the ratio, by number, of C atoms to H atoms
(c) the ratio, by mass, of Ge to S
(d) the number of g S in 1 mol of the compound
(e) the number of C atoms in 33.10 g of the compound

Percent Composition of Compounds

19. Determine the mass percent H in the hydrocarbon decane, $\text{C}_{10}\text{H}_{22}$.
20. Determine the mass percent O in the mineral malachite, $\text{Cu}_2(\text{OH})_2\text{CO}_3$.
21. Determine the mass percent H in the hydrocarbon isooctane, $\text{C}(\text{CH}_3)_3\text{CH}_2\text{CH}(\text{CH}_3)_2$.
22. Determine the mass percent H_2O in the hydrate $\text{Cr}(\text{NO}_3)_3 \cdot 9 \text{H}_2\text{O}$.
23. Determine the mass percent of each of the elements in the antimalarial drug quinine, $\text{C}_{20}\text{H}_{24}\text{N}_2\text{O}_2$.
24. Determine the mass percent of each of the elements in the fungicide copper(II) oleate, $\text{Cu}(\text{C}_{18}\text{H}_{33}\text{O}_2)_2$.
25. Determine the percent, by mass, of the indicated element:
(a) Pb in tetraethyl lead, $\text{Pb}(\text{C}_2\text{H}_5)_4$, once extensively used as an additive to gasoline to prevent engine knocking
(b) Fe in Prussian blue, $\text{Fe}_4[\text{Fe}(\text{CN})_6]_3$, a pigment used in paints and printing inks
(c) Mg in chlorophyll, $\text{C}_{55}\text{H}_{72}\text{MgN}_4\text{O}_5$, the green pigment in plant cells
26. All of the following minerals are semiprecious or precious stones. Determine the mass percent of the indicated element.
(a) Zr in zircon, ZrSiO_4
(b) Be in beryl (emerald), $\text{Be}_3\text{Al}_2\text{Si}_6\text{O}_{18}$
(c) Fe in almandine (garnet), $\text{Fe}_3\text{Al}_2\text{Si}_5\text{O}_{12}$
(d) S in lazurite (lapis lazuli), $\text{Na}_4\text{S}_3\text{Si}_3\text{Al}_3\text{O}_{12}$
27. Without doing detailed calculations, arrange the following in order of increasing % Cr, by mass, and explain your reasoning: CrO , Cr_2O_3 , CrO_2 , CrO_3 .
28. Without doing detailed calculations, explain which of the following has the greatest mass percent of sulfur: SO_2 , S_2Cl_2 , Na_2S , $\text{Na}_2\text{S}_2\text{O}_3$, or $\text{CH}_3\text{CS}_2\text{SH}$.

Chemical Formulas from Percent Composition

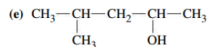
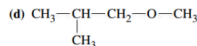
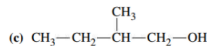
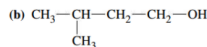
29. Two oxides of sulfur have nearly identical molecular masses. One oxide consists of 40.05% S. What are the simplest possible formulas for the two oxides?
30. An oxide of chromium used in chrome plating has a formula mass of 100.0 u and contains *four* atoms per formula unit. Establish the formula of this compound, with a *minimum of calculation*.
31. Diethylene glycol, used to de-ice aircraft, is a carbon-hydrogen-oxygen compound with 45.27% C and 9.50% H by mass. What is its empirical formula?
32. The food flavor enhancer monosodium glutamate (MSG) has the composition 13.6% Na, 35.5% C, 4.8% H, 8.3% N, 37.8% O, by mass. What is the empirical formula of MSG?
33. Determine the empirical formula of (a) the rodenticide (rat killer) warfarin, which consists of 74.01% C, 5.23% H, and 20.76% O, by mass; (b) the antibacterial agent sulfamethizole, which consists of 39.98% C, 3.73% H, 20.73% N, 11.84% O, and 23.72% S, by mass.
34. Determine the empirical formula of (a) benz[a]pyrene, a suspected carcinogen found in cigarette smoke, consisting of 95.21% C and 4.79% H, by mass; (b) hexachlorophene, used in germicidal soaps, which consists of 38.37% C, 1.49% H, 52.28% Cl, and 7.86% O by mass.
35. A compound of carbon and hydrogen consists of 94.34% C and 5.66% H, by mass. The molecular mass of the compound is found to be 178 u. What is its molecular formula?
36. Selenium, an element used in the manufacture of photoelectric cells and solar energy devices, forms two oxides. One has 28.8% O, by mass, and the other, 37.8% O. What are the formulas of these oxides? Propose acceptable names for them.
37. Indigo, the dye for blue jeans, has a percent composition, by mass, of 73.27% C, 3.84% H, 10.68% N, and the remainder is oxygen. The molecular mass of indigo is 262.3 u. What is the molecular formula of indigo?
38. Adenine, a component of nucleic acids, has the mass percent composition: 44.45% C, 3.73% H, 51.82% N. Its molecular mass is 135.14 u. What is its molecular formula?
39. The element X forms the chloride XCl_4 containing 75.0% Cl, by mass. What is element X?
40. The element X forms the compound XOCl_2 containing 59.6% Cl. What is element X?
41. Chlorophyll contains 2.72% Mg by mass. Assuming one Mg atom per chlorophyll molecule, what is the molecular mass of chlorophyll?
42. Two compounds of Cl and X are found to have molecular masses and % Cl, by mass, as follows: 137 u, 77.5% Cl; 208 u, 85.1% Cl. What is element X? What is the formula for each compound?

Combustion Analysis

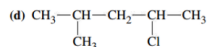
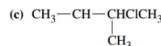
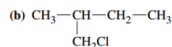
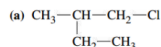
43. A 0.1888 g sample of a hydrocarbon produces 0.6260 g CO_2 and 0.1602 g H_2O in combustion analysis. Its molecular mass is found to be 106 u. For this hydrocarbon, determine its (a) mass percent composition; (b) empirical formula; (c) molecular formula.
44. *Para*-cresol (*p*-cresol) is used as a disinfectant and in the manufacture of herbicides. A 0.4039 g sample of this carbon-hydrogen-oxygen compound yields 1.1518 g CO_2 and 0.2694 g H_2O in combustion analysis. Its molecular mass is 108.1 u. For *p*-cresol, determine its (a) mass percent composition; (b) empirical formula; (c) molecular formula.
45. Dimethylhydrazine is a carbon-hydrogen-nitrogen compound used in rocket fuels. When burned in an excess of oxygen, a 0.312 g sample yields 0.458 g CO_2 and 0.374 g H_2O . The nitrogen content of a 0.486 g sample is converted to 0.226 g N_2 . What is the empirical formula of dimethylhydrazine?
46. The organic solvent thiophene is a carbon-hydrogen-sulfur compound that yields CO_2 , H_2O , and SO_2 when burned in an excess of oxygen. When subjected to combustion analysis, a 1.3020 g sample of thiophene produces 2.7224 g CO_2 , 0.5575 g H_2O , and 0.9915 g SO_2 . What is the empirical formula of thiophene?
47. *Without doing detailed calculations*, explain which of these compounds produces the *greatest* mass of CO_2 when 1.00 mol of the compound is burned in an excess of oxygen: CH_4 , $\text{C}_2\text{H}_6\text{OH}$, C_{10}H_8 , $\text{C}_6\text{H}_6\text{OH}$.
48. *Without doing detailed calculations*, explain which of these compounds produces the *greatest* mass of H_2O when 1.00 g of the compound is burned in an excess of oxygen: CH_4 , $\text{C}_2\text{H}_6\text{OH}$, C_{10}H_8 , $\text{C}_6\text{H}_6\text{OH}$.
49. A 1.562 g sample of the alcohol $\text{CH}_3\text{CHOHCH}_2\text{CH}_3$ is burned in an excess of oxygen. What masses of CO_2 and H_2O should be obtained?
50. Liquid ethyl mercaptan, $\text{C}_2\text{H}_6\text{S}$, has a density of 0.84 g/mL. Assuming that the combustion of this compound produces only CO_2 , H_2O , and SO_2 , what masses of each of these three products would be produced in the combustion of 3.15 mL of ethyl mercaptan?

Oxidation States

51. Indicate the oxidation state of the underlined element in (a) CH_4 ; (b) SF_4 ; (c) Na_2O_2 ; (d) $\text{C}_2\text{H}_3\text{O}_2^-$; (e) FeO_4^{2-} .
52. Indicate the oxidation state of S in (a) SO_3^{2-} ; (b) $\text{S}_2\text{O}_3^{2-}$; (c) $\text{S}_2\text{O}_8^{2-}$; (d) HSO_4^- ; (e) $\text{S}_4\text{O}_6^{2-}$.
53. Chromium forms three principal oxides. Write appropriate formulas for these compounds in which the oxidation states of Cr are +3, +4, and +6, respectively.
54. Nitrogen forms five oxides in which its oxidation states are +1, +2, +3, +4, and +5, respectively. Write appropriate formulas for these compounds.



78. Which of the following structures are isomers?



79. Write the condensed structural formulas for the organic compounds:

(a) heptane (b) propanoic acid

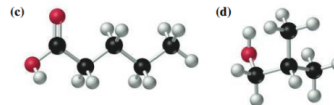
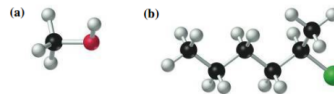
(c) 2-methylpentan-1-ol (d) fluoroethane

80. Write the condensed structural formulas for the organic compounds:

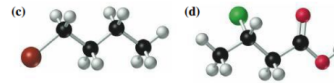
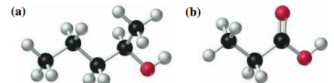
(a) octane (b) heptanoic acid

(c) hexan-3-ol (d) 2-chlorobutane

81. Give the name, condensed structural formula, and molecular mass of the molecule whose ball-and-stick model is shown. Refer to the color scheme in Figure 3-3.



82. Give the name, condensed structural formula, and molecular mass of the molecule whose ball-and-stick model is shown. Refer to the color scheme in Figure 3-3.



Integrative and Advanced Exercises

83. The mineral spodumene has the empirical formula $\text{LiAlSi}_2\text{O}_6$. Given that the percentage of lithium-6 atoms in naturally occurring lithium is 7.40%, how many lithium-6 atoms are present in a 518 g sample of spodumene?

84. A particular type of brass contains Cu, Sn, Pb, and Zn. A 1.1713 g sample is treated in such a way as to convert the Sn to 0.245 g SnO_2 , the Pb to 0.115 g PbSO_4 , and the Zn to 0.246 g $\text{Zn}_2\text{P}_2\text{O}_7$. What is the mass percent of each element in the sample?

85. A brand of lunchmeat contains 0.12% by mass of sodium benzoate, $\text{C}_6\text{H}_5\text{COONa}$. How many mg of Na does a person ingest by eating 3.50 oz of this meat?

86. The important natural sources of boron compounds are the minerals kernite, $\text{Na}_2\text{B}_4\text{O}_7 \cdot 4\text{H}_2\text{O}$ and borax, $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$. How much *additional* mass of mineral must be processed per kilogram of boron obtained if the mineral is borax rather than kernite?

87. To deposit exactly one mole of Ag from an aqueous solution containing Ag^+ requires a quantity of electricity known as one faraday (F). The electrodeposition requires that each Ag^+ ion gain one electron to become an Ag atom. Use appropriate physical constants listed on the inside back cover to obtain a precise value of the Avogadro constant, N_A .

88. By analysis, a compound was found to contain 26.58% K and 35.45% Cr by mass; the remainder was oxygen. What is the oxidation state of chromium in this compound? What is the name of the compound?

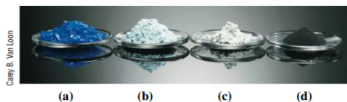
89. Is it possible to have a sample of S_8 that weighs 1.00×10^{-23} g? What is the smallest possible mass that a sample of S_8 can have? Express your answer to the second question in appropriate SI units so that your answer has a numerical value greater than 1. (See Table 1.2 for a list of SI prefixes.)

108 Chapter 3 Chemical Compounds

90. What is the molecular formula of a hydrocarbon containing n carbon atoms and only one double bond? Can such a hydrocarbon yield a greater mass of H_2O than CO_2 when burned in an excess of oxygen?
91. A hydrocarbon mixture consists of 60.0% by mass of C_3H_8 and 40.0% of C_4H_{10} . When 10.0 g of this mixture is burned, 29.0 g CO_2 and 18.8 g H_2O are the only products. What is the formula of the unknown hydrocarbon?
92. A 0.732 g mixture of methane, CH_4 , and ethane, C_2H_6 , is burned, yielding 2.064 g CO_2 . What is the percent composition of this mixture (a) by mass; (b) on a mole basis?
93. The density of a mixture of H_2SO_4 and water is 1.78 g/mL. The percent composition of the mixture is to be determined by converting H_2SO_4 to $(\text{NH}_4)_2\text{SO}_4$. If 32.0 mL of the mixture gives 65.2 g $(\text{NH}_4)_2\text{SO}_4$, then what is the percent composition of the mixture?
94. In 2013, the IUPAC recommended that the atomic masses of 12 elements be expressed as an atomic mass interval rather than as a single invariant value. (See Section 2-5 and Table 2.2.) For example, the IUPAC recommends that the atomic mass of Cl be given as [35.446, 35.457]. Consequently, the results of calculations involving the atomic mass of chlorine should, in principle, be reported as a range of values. Demonstrate this approach by calculating the range of values possible for the mass percent of silver in an impure sample if all the silver in a 26.39 g sample is converted to 31.56 g of silver chloride. [Hint: Perform two calculations, using first the lower bound and then the upper bound of the atomic mass interval of Cl.]
95. In the year 2000, the *Guinness Book of World Records* called ethyl mercaptan, $\text{C}_2\text{H}_6\text{S}$, the smelliest substance known. The average person can detect its presence in air at levels as low as $9 \times 10^{-4} \mu\text{mol}/\text{m}^3$. Express the limit of detectability of ethyl mercaptan in parts per billion (ppb). (Note: 1 ppb $\text{C}_2\text{H}_6\text{S}$ means there is 1 g $\text{C}_2\text{H}_6\text{S}$ per billion grams of air.) The density of air is approximately 1.2 g/L at room temperature.
96. Dry air is essentially a mixture of the following entities: N_2 , O_2 , Ar, and CO_2 . The composition of dry air, in *mole percent*, is 78.08% N_2 , 20.95% O_2 , 0.93% Ar, and 0.04% CO_2 . (a) What is the mass, in grams, of a sample of air that contains exactly one mole of the entities? (b) Dry air also contains other entities in much smaller amounts. For example, the mole percent of krypton (Kr) is about $1.14 \times 10^{-4}\%$. Given that the density of dry air is about 1.2 g/L at room temperature, what mass of krypton could be obtained from exactly one cubic meter of dry air?
97. A public water supply was found to contain 0.8 part per billion (ppb) by mass of chloroform, CHCl_3 . (a) How many CHCl_3 molecules would be present in a 350 mL glass of this water? (b) If the CHCl_3 in part (a) could be isolated, would this quantity be detectable on an ordinary analytical balance that measures mass with a precision of ± 0.0001 g?
98. A sample of the compound MSO_4 , weighing 0.1131 g reacts with barium chloride and yields 0.2193 g BaSO_4 . What must be the atomic mass of the metal M? [Hint: All the SO_4^{2-} from the MSO_4 appears in the BaSO_4 .]
99. The metal M forms the sulfate $\text{M}_2(\text{SO}_4)_3$. A 0.738 g sample of this sulfate is converted to 1.511 g BaSO_4 . What is the atomic mass of M? [Hint: Refer to Exercise 98.]
100. A 0.622 g sample of a metal oxide with the formula M_2O_3 is converted to 0.685 g of the sulfide, MS . What is the atomic mass of the metal M?
101. MgCl_2 often occurs in table salt (NaCl) and is responsible for caking of the salt. A 0.5200 g sample of table salt is found to contain 61.10% Cl, by mass. What is the % MgCl_2 in the sample? Why is the precision of this calculation so poor?
102. When 2.750 g of the oxide of lead Pb_3O_4 is strongly heated, it decomposes and produces 0.0640 g of oxygen gas and 2.686 g of a second oxide of lead. What is the empirical formula of this second oxide?
103. A 1.013 g sample of $\text{ZnSO}_4 \cdot x \text{H}_2\text{O}$ is dissolved in water and the sulfate ion precipitated as BaSO_4 . The mass of pure, dry BaSO_4 obtained is 0.8223 g. What is the formula of the zinc sulfate hydrate?
104. The iodide ion in a 1.552 g sample of the ionic compound MI is removed through precipitation. The precipitate is found to contain 1.186 g I. What is the element M?
105. An oxoacid with the formula $\text{H}_m\text{E}_n\text{O}_p$ has a formula mass of 178 u, has 13 atoms in its formula unit, contains 34.80% by mass, and 15.38% by number of atoms, of the element E. What is the element E, and what is the formula of this oxoacid?
106. The insecticide dieldrin contains carbon, hydrogen, oxygen, and chlorine. When burned in an excess of oxygen, a 1.510 g sample yields 2.094 g CO_2 and 0.286 g H_2O . The compound has a molecular mass of 381 u and has half as many chlorine atoms as carbon atoms. What is the molecular formula of dieldrin?
107. A thoroughly dried 1.271 g sample of Na_2SO_4 is exposed to the atmosphere and found to gain 0.387 g in mass. What is the percent, by mass, of $\text{Na}_2\text{SO}_4 \cdot 10 \text{H}_2\text{O}$ in the resulting mixture of anhydrous Na_2SO_4 and the decahydrate?
108. The atomic mass of Bi is to be determined by converting the compound $\text{Bi}(\text{C}_6\text{H}_5)_3$ to Bi_2O_3 . If 5.610 g of $\text{Bi}(\text{C}_6\text{H}_5)_3$ yields 2.969 g Bi_2O_3 , what is the atomic mass of Bi?
109. A piece of gold (Au) foil measuring 0.25 mm \times 15 mm \times 15 mm is treated with fluorine gas. The treatment converts all the gold in the foil to 1.400 g of a gold fluoride. What is the formula and name of the fluoride? The density of gold is 19.3 g/cm³.
110. In an experiment, 244 mL of chlorine gas (Cl_2 , $d = 2.898$ g/L) combines with iodine to give 1.553 g of a binary compound. In a separate experiment, the molar mass of the compound is found to be about 467 g/mol. What is the molecular formula of this compound?
111. Placing a 0.725 g copper strip in the presence of iodine vapor produced a yellowish-white coating on the metal strip. The mass of the copper strip and coating was 0.733 g. The coating was removed by rinsing the coated metal strip in a potassium thiocyanate (KSCN) solution, yielding a clean copper strip of mass 0.721 g. What is the empirical formula of the yellowish-white compound?

Feature Problems

- 112.** All-purpose fertilizers contain the essential elements nitrogen, phosphorus, and potassium. A typical fertilizer carries numbers on its label, such as “5-10-5”. These numbers represent the % N, % P_2O_5 , and % K_2O , respectively. The N is contained in the form of a nitrogen compound, such as $(NH_4)_2SO_4$, NH_4NO_3 , or $CO(NH_2)_2$ (urea). The P is generally present as a phosphate, and the K as KCl. The expressions % P_2O_5 and % K_2O were devised in the nineteenth century, before the nature of chemical compounds was fully understood. To convert from % P_2O_5 to % P and from % K_2O to % K, the factors 2 mol P/mol P_2O_5 and 2 mol K/mol K_2O must be used, together with molar masses.
- (a) Assuming three-significant-figure precision, what is the percent composition of the “5-10-5” fertilizer in % N, % P and % K?
- (b) What is the % P_2O_5 in the following compounds (both common fertilizers)? (i) $Ca(H_2PO_4)_2$; (ii) $(NH_4)_2HPO_4$.
- (c) In a similar manner to the “5-10-5” fertilizer described in this exercise, how would you describe a fertilizer in which the mass ratio of $(NH_4)_2HPO_4$ to KCl is 5.00:1.00?
- (d) Can a “5-10-5” fertilizer be prepared in which $(NH_4)_2HPO_4$ and KCl are the sole fertilizer components, with or without inert nonfertilizer additives? If so, what should be the proportions of the constituents of the fertilizer mixture? If this “5-10-5” fertilizer cannot be prepared, why not?
- 113.** A hydrate of copper(II) sulfate, when heated, goes through the succession of changes suggested by the photograph. In this photograph, (a) is the original fully hydrated copper(II) sulfate; (b) is the product obtained by heating the original hydrate to 140 °C; (c) is the product obtained by further heating to 400 °C; and (d) is the product obtained at 1000 °C.



A 2.574 g sample of $CuSO_4 \cdot x H_2O$ was heated to 140 °C, cooled, and reweighed. The resulting solid was reheated to 400 °C, cooled, and reweighed. Finally, this solid was heated to 1000 °C, cooled, and reweighed for the last time.

| | |
|----------------------------|---------|
| Original sample | 2.574 g |
| After heating to 140 °C | 1.833 g |
| After reheating to 400 °C | 1.647 g |
| After reheating to 1000 °C | 0.812 g |

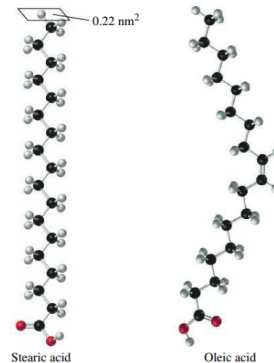
- (a) Assuming that all the water of hydration is driven off at 400 °C, what is the formula of the original hydrate?
- (b) What is the formula of the hydrate obtained when the original hydrate is heated to only 140 °C?

(c) The black residue obtained at 1000 °C is an oxide of copper. What is its percent composition and empirical formula?

- 114.** Some substances that are only very slightly soluble in water will spread over the surface of water to produce a film that is called a *monolayer* because it is only one molecule thick. A practical use of this phenomenon is to cover ponds to reduce the loss of water by evaporation. Stearic acid forms a monolayer on water. The molecules are arranged upright and in contact with one another, rather like pencils tightly packed and standing upright in a coffee mug. The model below represents an individual stearic acid molecule in the monolayer.
- (a) How many square meters of water surface would be covered by a monolayer made from 10.0 g of stearic acid?
- [Hint: What is the formula of stearic acid?]
- (b) If stearic acid has a density of 0.85 g/cm³, estimate the length (in nanometers) of a stearic acid molecule. [Hint: What is the thickness of the monolayer described in part (a)?]
- (c) A very dilute solution of oleic acid in liquid pentane is prepared in the following way:

- 1.00 mL oleic acid + 9.00 mL pentane → solution (1);
 1.00 mL solution (1) + 9.00 mL pentane → solution (2);
 1.00 mL solution (2) + 9.00 mL pentane → solution (3);
 1.00 mL solution (3) + 9.00 mL pentane → solution (4).

A 0.10 mL sample of solution (4) is spread in a monolayer on water. The area covered by the monolayer is 85 cm². Assume that oleic acid molecules are arranged in the same way as described for stearic acid, and that the cross-sectional area of the molecule is 4.6×10^{-18} cm². The density of oleic acid is 0.895 g/mL. Use these data to obtain an approximate value of Avogadro's number.



Stearic acid

Oleic acid

Self-Assessment Exercises

115. In your own words, define or explain the following terms or symbols: (a) formula unit; (b) P_4 ; (c) molecular compound; (d) binary compound; (e) hydrate.
116. Briefly describe each of the following ideas or methods: (a) mole of a compound; (b) structural formula; (c) oxidation state; (d) carbon-hydrogen-oxygen determination by combustion analysis.
117. Explain the important distinctions between each pair of terms: (a) molecular mass and molar mass; (b) empirical and molecular formulas; (c) systematic and trivial, or common, name; (d) hydroxyl and carboxyl functional group.
118. Explain each term as it applies to the element nitrogen: (a) atomic mass; (b) molecular mass; (c) molar mass.
119. Which answer is correct? One mole of liquid bromine, Br_2 , (a) has a mass of 79.9 g; (b) contains 6.022×10^{23} Br atoms; (c) contains the same number of atoms as in 12.01 g H_2O ; (d) has twice the mass of 0.500 mole of gaseous Cl_2 .
120. Three of the following formulas might be either an empirical or a molecular formula. The formula that must be a molecular formula is (a) N_2O ; (b) N_2H_4 ; (c) NaCl; (d) NH_3 .
121. The compound $C_7H_7NO_2$ contains (a) 17 atoms per mole; (b) equal percents by mass of C and H; (c) about twice the percent by mass of O as of N; (d) about twice the percent by mass of N as of H.
122. The greatest number of N atoms is found in (a) 50.0 g N_2O ; (b) 17.0 g NH_3 ; (c) 150 mL of liquid pyridine, C_5H_5N ($d = 0.983$ g/mL); (d) 1.0 mol N_2 .
123. Iron is present in red blood cells and acts to carry oxygen to the organs. Without oxygen, these organs will die. There are about 2.6×10^{15} red blood cells in the blood of an adult human, and the blood contains a total of 2.9 g of iron. How many atoms are there in each blood cell?
124. XF_3 consists of 65% F by mass. The atomic mass of the element X must be (a) 8 u; (b) 11u; (c) 31 u; (d) 35 u.
125. The oxidation state of I in the ion $H_4IO_6^-$ is (a) -1; (b) +1; (c) +7; (d) +8.
126. The oxidation state of Mn in $MgMnO_4$ is (a) +2; (b) +7; (c) +6; (d) +4; (e) +3.
127. The name of which compound ends with *-ite*? (a) HIO_4 ; (b) Na_2SO_3 ; (c) $KClO_2$; (d) HFO ; (e) NO_2 .
128. The name of $Sr(HCO_3)_2$ is (a) strontium oxalate; (b) strontium carbonate; (c) sodium bicarbonate; (d) strontium bicarbonate; (e) none of these.
129. The formula for calcium chlorite is (a) $CaClO_2$; (b) $Ca(ClO_2)_2$; (c) $CaClO_3$; (d) $Ca(ClO_4)_2$.
130. Which compound has a molar mass of 51.79 g mol^{-1} ? (a) NaCl; (b) KF; (c) MgS ; (d) Li_3P ; (e) none of these.
131. A formula unit of the compound $[Cu(NH_3)_4]SO_4$ has nearly equal masses of (a) S and O; (b) N and O; (c) H and N; (d) Cu and O.
132. An isomer of the compound $CH_3CH_2CHOHCH_3$ is (a) $C_4H_{10}O$; (b) $CH_3CHOHCH_2CH_3$; (c) $CH_3(CH_2)_2OH$; (d) $CH_3CH_2OCH_2CH_3$.
133. A hydrate of Na_2SO_3 contains almost exactly 50% H_2O by mass. What is the formula of this hydrate?
134. Malachite is a common copper-containing mineral with the formula $CuCO_3 \cdot Cu(OH)_2$. (a) What is the mass percent copper in malachite? (b) When malachite is strongly heated, carbon dioxide and water are driven off, yielding copper(II) oxide as the sole product. What mass of copper(II) oxide is produced per kg of malachite?
135. Acetaminophen, an analgesic and antipyretic drug, has a molecular mass of 151.2 u and a mass percent composition of 63.56% C, 6.00% H, 9.27% N, and 21.17% O. What is the molecular formula of acetaminophen?
136. Ibuprofen is a compound used in painkillers. When a 2.174 g sample is burned in an excess of oxygen, it yields 6.029 g CO_2 and 1.709 g H_2O as the sole products. (a) What is the percent composition, by mass, of ibuprofen? (b) What is the empirical formula of ibuprofen?
137. Appendix E describes a useful study aid known as concept mapping. Using the method presented in Appendix E, construct a concept map illustrating the different concepts in Sections 3-2 and 3-3.