

FUNDAMENTALS

A.2 The boiling point and melting point are physical properties. The flammability of acetone is a chemical property.

A.4 The red-brown color of copper is a physical property. The formation of copper from copper sulfide ores, the formation of copper oxide from copper, the formation of impure copper from copper oxide and carbon, and the purification of copper by electrolysis are chemical properties.

A.6 (a) extensive; (b) intensive; (c) intensive; (d) intensive

A.8
$$d = \frac{m}{V}$$
$$= \left(\frac{10.00 \text{ g}}{9.87 \text{ mL} - 8.75 \text{ mL}} \right) \left(\frac{1 \text{ mL}}{1 \text{ cm}^3} \right)$$
$$= 8.93 \text{ g} \cdot \text{cm}^{-3}$$

A.10 $m = Vd$
mass of lead, m_l , equals mass of redwood, m_r
 $m_l = V_l d_l = m_r = V_r d_r$
 $V_l d_l = V_r d_r$
 $V_l = \frac{V_r d_r}{d_l} = \frac{(375 \text{ cm}^3)(0.38 \text{ g} \cdot \text{cm}^{-3})}{(11.3 \text{ g} \cdot \text{cm}^{-3})}$
 $= 13 \text{ cm}^3$

A.12 The average of the four density determinations is

$$d_{\text{avg}} = \frac{(1.68 + 1.67 + 1.69 + 1.69) \text{ g} \cdot \text{cm}^{-3}}{4} = 1.68 \text{ g} \cdot \text{cm}^{-3}$$

or $0.06 \text{ g} \cdot \text{cm}^{-3}$ below the accepted value. The standard deviation of these four values is

$$s = \sqrt{\frac{(1.68 - 1.68)^2 + (1.67 - 1.68)^2 + (1.69 - 1.68)^2 + (1.69 - 1.68)^2}{3}}$$

$$= 0.01 \text{ g} \cdot \text{cm}^{-3}$$

So the accuracy of the data, as measured by the difference between the average and an accepted value, is poor compared to the precision (reproducibility) of the data as measured by the standard deviation. The data is precise to within $0.01 \text{ g} \cdot \text{cm}^{-3}$ but only accurate to within $0.06 \text{ g} \cdot \text{cm}^{-3}$.

A.14 (a) $d = \frac{m}{V}$

$$= \left(\frac{2.0 \times 10^{-23} \text{ g}}{\frac{4}{3}\pi(1.5 \times 10^{-5} \text{ pm})^3} \right) \left(\frac{1 \text{ pm}}{1 \times 10^{-10} \text{ cm}} \right)^3$$

$$= 1.4 \times 10^{21} \text{ g} \cdot \text{cm}^{-3}$$

(b) From A.14a, density of a carbon nucleus is $1.4 \times 10^{21} \text{ g} \cdot \text{cm}^{-3}$

$$d = \frac{m}{V} = \frac{m}{\frac{4}{3}\pi r^3}$$

$$r = \sqrt[3]{\frac{3m}{4\pi d}} \quad m = d_1 V_1 = d_1 \left(\frac{4}{3}\pi r_1^3 \right)$$

$$r = \sqrt[3]{\frac{3d_1 \left(\frac{4}{3}\pi r_1^3 \right)}{4\pi d}}$$

$$= \sqrt[3]{\frac{d_1 r_1^3}{d}}$$

$$= \sqrt[3]{\frac{(5.5 \text{ g} \cdot \text{cm}^{-3})(6.4 \times 10^3 \text{ km})^3}{(1.4 \times 10^{21} \text{ g} \cdot \text{cm}^{-3})} \left(\frac{1 \text{ m}}{1 \times 10^{-3} \text{ km}} \right)^3}$$

$$= 1.0 \text{ m}$$

$$\begin{aligned}
\text{A.16} \quad E_K &= \frac{1}{2}mv^2 \\
&= \frac{1}{2}(2.5 \times 10^5 \text{ kg})(25 \text{ km} \cdot \text{s}^{-1})^2 \left(\frac{1000 \text{ m}}{1 \text{ km}} \right)^2 \\
&= 7.8 \times 10^{13} \text{ kg} \cdot \text{m}^2 \cdot \text{s}^{-2} \\
&= 7.8 \times 10^{13} \text{ J}
\end{aligned}$$

$$\begin{aligned}
\text{A.18} \quad E_p &= mgh \\
&= (0.51 \text{ kg})(9.81 \text{ m} \cdot \text{s}^{-2})(3.0 \text{ m}) \\
&= 15 \text{ kg} \cdot \text{m}^2 \cdot \text{s}^{-2} \\
&= 15 \text{ J}
\end{aligned}$$

A.20 When the skier is at rest at the top of the slope, the kinetic energy is 0. The total energy is equal to the potential energy. At the bottom of the slope, the potential energy is 0; it has been converted into kinetic energy.

$$\begin{aligned}
E &= E_K + E_p \\
&= E_p \\
&= mgh \\
&= (99.5 \text{ kg})(9.81 \text{ m} \cdot \text{s}^{-2})(244 \text{ m}) \\
&= 2.38 \times 10^5 \text{ kg} \cdot \text{m}^2 \cdot \text{s}^{-2} \\
&= 2.38 \times 10^5 \text{ J} \\
&= 238 \text{ kJ}
\end{aligned}$$

A.22 Since $R = R_E + h$,

$$\begin{aligned}
E_p = \Delta E_p &= \frac{-Gm_E m}{R_E + h} - \left(\frac{-Gm_E m}{R_E} \right) \\
&= \frac{-Gm_E m}{R_E} \left(\frac{1}{1 + \frac{h}{R_E}} - 1 \right) = \frac{Gm_E m}{R_E} \left(1 - \frac{1}{1 + \frac{h}{R_E}} \right)
\end{aligned}$$

If $x = \frac{h}{R_E}$, then $\frac{1}{1 + \frac{h}{R_E}} = 1 - \frac{h}{R_E}$ from the expansion in x .

Then

$$E_p = \frac{Gm_E m}{R_E} \left(1 - \left(1 - \frac{h}{R_E} \right) \right) = \frac{Gm_E m h}{R_E^2} = mgh$$

where $g = \frac{Gm_E}{R_E^2}$

A.24 $F = ma$

$$\begin{aligned} &= (9.1 \times 10^{-31} \text{ kg})(1.2 \times 10^6 \text{ m} \cdot \text{s}^{-2}) \\ &= 1.1 \times 10^{-24} \text{ kg} \cdot \text{m} \cdot \text{s}^{-2} \\ &= 1.1 \times 10^{-24} \text{ N} \end{aligned}$$

A.26 $P = \frac{F}{A}$

units of force = N = kg · m · s⁻²

units of area = m²

$$\begin{aligned} \text{units of pressure} &= \frac{\text{kg} \cdot \text{m} \cdot \text{s}^{-2}}{\text{m}^2} \\ &= \text{kg} \cdot \text{m}^{-1} \cdot \text{s}^{-2} \\ &= \text{Pa} \end{aligned}$$

A.28 (See Appendix 1)

$$\begin{aligned} \text{energy} &= \text{power} \cdot \text{time} = I^2 R \cdot \text{time} \quad V = IR \\ &= \frac{V}{R} \cdot I \cdot R \cdot \text{time} = V \cdot I \cdot \text{time} = V \cdot \left(\frac{\text{C}}{\text{s}} \right) \cdot \text{s} \\ &= V \cdot \left(\frac{\text{J}}{\text{V}} \right) = \text{J} \end{aligned}$$

A.30 First find the actual mass of the sample, then multiply by Earth gravity.

$$m_{planet} = \frac{5.70 \text{ lome} \left(\frac{1.3 \text{ N}}{1 \text{ lome}} \right) \left(\frac{1 \text{ kg} \cdot \text{m} \cdot \text{s}^{-2}}{1 \text{ N}} \right) \left(\frac{1 \text{ coburg}}{2.78 \text{ m} \cdot \text{s}^{-2}} \right)}{9.8 \text{ coburg}}$$

$$= 0.27 \text{ kg}$$

$$m_{Earth}g = (0.27 \text{ kg})(9.8 \text{ m} \cdot \text{s}^{-2}) = 2.7 \text{ N}$$

B.2 (a) Part one of Dalton's hypothesis – that all atoms of a given element are identical – has been disproved. (b) Mass spectrometry revealed that some atoms with the same atomic number have different masses.

B.4 In an evacuated tube, we would expect these particles to be electrons from the metal cathode (as discussed on p. F15). In that case, the ratio of charge to mass would be

$$\frac{q}{m} = \frac{-1.60218 \times 10^{-19} \text{ C}}{9.10939 \times 10^{-31} \text{ kg}} = -1.759 \times 10^{11} \text{ C} \cdot \text{kg}^{-1}.$$

Since this ratio for an electron is much larger than the one given for the “canal rays” in this helium-filled tube, we can reason that these particles are about 10,000 times as massive as an electron. It turns out that He^+ has the right mass:

$$\frac{q}{m} = \frac{1.60218 \times 10^{-19} \text{ C}}{(4.00)(1.66054 \times 10^{-27} \text{ kg})} = 2.41 \times 10^7 \text{ C} \cdot \text{kg}^{-1}$$

B.6 (a) A deuterium atom has 1 proton, 1 neutron, and 1 electron. (b) A ^{127}I atom has 53 protons, 74 neutrons, and 53 electrons. (c) A ^{15}N atom has 7 protons, 8 neutrons, and 7 electrons. (d) A ^{209}Bi atom has 83 protons, 126 neutrons, and 83 electrons.

B.8 (a) ^{175}Lu ; (b) ^{118}Sn ; (c) ^6Li

B.10 (a) ^{12}C , ^{13}C , and ^{14}C all have 6 protons and 6 electrons. (b) They have different numbers of neutrons: an atom of ^{12}C has 6 neutrons, an atom of ^{13}C has 7 neutrons, and an atom of ^{14}C has 8 neutrons.

B.12 (a) Atoms of ^{55}Mn , ^{56}Fe , and ^{58}Ni all have 30 neutrons. (b) They have different masses, numbers of protons, and numbers of electrons.

B.14 (a) In NH_3 , the nitrogen atom contributes 7 protons, 7 neutrons, and 7 electrons. Each hydrogen atom contributes 1 proton and 1 electron. There are 10 protons, 7 neutrons, and 10 electrons total.

(b) mass of protons = $(10)(1.673 \times 10^{-24} \text{ g}) = 1.673 \times 10^{-23} \text{ g}$

mass of neutrons = $(7)(1.675 \times 10^{-24} \text{ g}) = 1.172 \times 10^{-23} \text{ g}$

mass of electrons = $(10)(9.109 \times 10^{-28} \text{ g}) = 9.109 \times 10^{-27} \text{ g}$

B.16 (a) Silicon is a Group 14 metalloid. (b) Strontium is a Group 2 metal.
(c) Tin is a Group 14 metal. (d) Antimony is a Group 15 metalloid.

B.18 (a) Ag, metal; (b) Ge, metalloid; (c) Kr, nonmetal

B.20 lithium, Li, 3; sodium, Na, 11; potassium, K, 19; rubidium, Rb, 37; cesium, Cs, 55. All the alkali metals react with water to produce hydrogen. Lithium reacts gently; the reaction becomes more vigorous down the periodic table. The melting points decrease down the periodic table.

B.22 (a) Metals are malleable, conduct electricity, and have luster. (b) Nonmetals are neither malleable nor ductile and do not conduct electricity.

C.2 An element is made up of the same kinds of atoms. These atoms can bond together to form molecules, making a molecular substance that is still an element. One example is oxygen, O_2 .

- C.4** Since $x:y:z$ is 1:2:2 and $x = 3$, $C_xH_yN_z$ becomes $C_3H_6N_6$.
- C.6** (a) Sulfur is a Group 16 nonmetal and will form 2[−] anions, S^{2-} . (b) Lithium is a Group 1 metal and will form 1⁺ cations, Li^+ . (c) Phosphorus is a Group 15 nonmetal and will form 3[−] anions, P^{3-} . (d) Oxygen is a Group 16 nonmetal and will form 2[−] anions, O^{2-} .
- C.8** (a) $^{107}Ag^+$ has 47 protons, 60 neutrons, and 46 electrons. (b) $^{140}Ce^{4+}$ has 58 protons, 82 neutrons, and 54 electrons. (c) $^{17}O^{2-}$ has 8 protons, 9 neutrons, and 10 electrons. (d) $^{40}Ca^{2+}$ has 20 protons, 20 neutrons, and 18 electrons.
- C.10** (a) $^{24}Na^+$; (b) $^{27}Al^{3+}$; (c) $^{79}Se^{2-}$; (d) $^{52}Cr^{2+}$
- C.12** (a) Sodium forms Na^+ ions. Phosphorus forms P^{3-} ions. Three sodium ions produce a charge of $3 \times (+1) = +3$. One phosphorus ion balances the charge. The formula for sodium phosphide is Na_3P . (b) Aluminum forms Al^{3+} ions and chloride forms Cl^- ions. Since three chloride ions are needed to balance the charge on the aluminum cation, the empirical formula for aluminum chloride is $AlCl_3$. (c) Strontium forms Sr^{2+} . Fluorine forms F^- . Since two fluoride ions will balance the charge on the strontium cation, the formula for strontium fluoride is SrF_2 . (d) Lithium forms +1 cations and selenium forms -2 anions. Two Li^+ ions are needed to balance the charge on every one Se^{2-} , so the formula for lithium selenide is Li_2Se .
- C.14** (a) Element E belongs to Group 16 (VI, VIA). (b) Selenium, Se.

C.16 (a) $1 + 1 + 8 = 10$ protons and an equal number of electrons; $0 + 0 + 8 = 8$ neutrons

(b) $10(1.67262 \times 10^{-27} \text{ kg}) = 1.67262 \times 10^{-26} \text{ kg}$ protons

$8(1.67439 \times 10^{-27} \text{ kg}) = 1.33994 \times 10^{-26} \text{ kg}$ neutrons

$10(9.10939 \times 10^{-31} \text{ kg}) = 9.10939 \times 10^{-30} \text{ kg}$ electrons

(c)
$$\frac{1.33994 \times 10^{-26} \text{ kg}}{1.33994 \times 10^{-26} \text{ kg} + 1.67262 \times 10^{-26} \text{ kg} + 9.10939 \times 10^{-30} \text{ kg}}$$

 $= 0.444649$

So about 44% of my body mass is due to neutrons.

C.18 (a) $\text{Ca}_3(\text{PO}_4)_2$

(b) $(\text{NH}_4)_2\text{SO}_4$

(c) Since two silver ions have the same charge as one magnesium ion, each silver ion carries a charge of +1.

(d) Since one lead ion has the same charge as two potassium ions, each lead ion carries a charge of +2.

D.2 (a) $\text{Ba}(\text{OH})_2$; (b) AlPO_4 ; (c) ZnCl_2 ; (d) FeCl_3

D.4 (a) sodium bicarbonate or sodium hydrogen carbonate; (b) mercury(I) chloride; (c) sodium hydroxide; (d) zinc(II) oxide

D.6 (a) N_2O_4 ; (b) H_2S ; (c) Cl_2O_7 ; (d) NI_3 ; (e) SO_2 ; (f) HF ; (g) I_2Cl_6

D.8 (a) silicon dioxide; (b) silicon carbide; (c) dinitrogen oxide or nitrous oxide; (d) phosphorus(V) oxide; (e) carbon disulfide; (f) sulfur dioxide; (g) ammonia

D.10 (a) HClO_4 ; (b) HClO ; (c) HIO ; (d) HF ; (e) H_3PO_3 ;

(f) HIO_4

D.12 (a) CaCl_2 ; (b) $\text{Fe}_2(\text{SO}_4)_3$; (c) NH_4I ; (d) Li_2S ; (e) Ca_3P_2

D.14 (a) chromium(III) chloride hexahydrate; (b) cobalt(II) nitrate hexahydrate; (c) thallium(I) chloride; (d) bromine chloride; (e) manganese(IV) oxide; (f) mercury(II) nitrate; (g) nickel(II) perchlorate; (h) calcium hypochlorite; (i) niobium(V) oxide

D.16 (a) methane; (b) fluoromethane; (c) bromomethane; (d) iodomethane

D.18 BaTiO_3 ; hydrogen sulfate(VI) or dihydrogen sulfate

D.20 $\text{E} = \text{Sr}$; strontium bromide; strontium oxide

D.22 Oxygen is present as a molecular anion in each case. (a) potassium superoxide, ionic, K^+ , O_2^- ; (b) sodium peroxide, ionic, 2Na^+ , O_2^{2-} ; (c) cesium ozonide, ionic, Cs^+ , O_3^-

D.24 (a) uranyl chloride; (b) sodium azide; (c) calcium oxalate; (d) vanadyl sulfide; (e) potassium dichromate; (f) lithium thiocyanate

D.26 (a) alcohol; (b) carboxylic acid; (c) fluorocarbon

E.2 (a) moles of sand $= \left(\frac{1000 \text{ tons}}{10^{12} \text{ grains}} \right) (6.022 \times 10^{23} \text{ grains} \cdot \text{mol}^{-1}) (1 \text{ mol})$
 $= 6 \times 10^{14} \text{ tons}$

$$\begin{aligned}
 \text{(b) depth of sand} &= \left(\frac{\text{volume of 1 mol of sand}}{\text{area of United States}} \right) \\
 &= (1 \text{ mm}^3 \cdot \text{grain}^{-1}) \frac{(6.02 \times 10^{23} \text{ grain} \cdot \text{mol}^{-1})}{(3.6 \times 10^6 \text{ mi}^2) \left(\frac{1 \times 10^6 \text{ mm}}{0.6214 \text{ mi}} \right)} (1 \text{ mol}) \left(\frac{1 \text{ m}}{1000 \text{ mm}} \right) \\
 &= 65 \text{ m}
 \end{aligned}$$

E.4 molar mass of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O} = 249.68 \text{ g} \cdot \text{mol}^{-1}$

$$\begin{aligned}
 &29.50 \text{ g CuSO}_4 \cdot 5\text{H}_2\text{O} \left(\frac{1 \text{ mol CuSO}_4 \cdot 5\text{H}_2\text{O}}{249.68 \text{ g CuSO}_4 \cdot 5\text{H}_2\text{O}} \right) \left(\frac{1 \text{ mol Cu}}{1 \text{ mol CuSO}_4 \cdot 5\text{H}_2\text{O}} \right) \\
 &\times \left(\frac{63.54 \text{ g Cu}}{1 \text{ mol Cu}} \right) \\
 &= 7.507 \text{ g Cu}
 \end{aligned}$$

E.6 molar mass of sulfur

$$\begin{aligned}
 &= \left(\frac{95.0}{100} \right) (31.97 \text{ g} \cdot \text{mol}^{-1}) + \left(\frac{0.8}{100} \right) (32.97 \text{ g} \cdot \text{mol}^{-1}) \\
 &\quad + \left(\frac{4.2}{100} \right) (33.97 \text{ g} \cdot \text{mol}^{-1}) \\
 &= 32.06 \text{ g} \cdot \text{mol}^{-1} \quad (30 \text{ g} \cdot \text{mol}^{-1} \text{ to 1 SF})
 \end{aligned}$$

E.8 molar mass of krypton

$$\begin{aligned}
 &= \left(\frac{0.3}{100} \right) (77.92 \text{ g} \cdot \text{mol}^{-1}) + \left(\frac{2.3}{100} \right) (79.91 \text{ g} \cdot \text{mol}^{-1}) \\
 &\quad + \left(\frac{11.6}{100} \right) (81.91 \text{ g} \cdot \text{mol}^{-1}) + \left(\frac{11.5}{100} \right) (82.92 \text{ g} \cdot \text{mol}^{-1}) \\
 &\quad + \left(\frac{56.9}{100} \right) (83.91 \text{ g} \cdot \text{mol}^{-1}) + \left(\frac{17.4}{100} \right) (85.91 \text{ g} \cdot \text{mol}^{-1}) \\
 &= 83.8 \text{ g} \cdot \text{mol}^{-1} \quad (80 \text{ g} \cdot \text{mol}^{-1} \text{ to 1 SF})
 \end{aligned}$$

$$\text{E.10 (a) mass} = \left(\frac{5.68 \times 10^{15} \text{ atoms}}{6.022 \times 10^{23} \text{ atoms} \cdot \text{mol}^{-1}} \right) (200.59 \text{ g} \cdot \text{mol}^{-1}) \left(\frac{1 \times 10^6 \mu\text{g}}{1 \text{ g}} \right) \\ = 1.89 \mu\text{g}$$

$$\text{(b) mass} = (7.924 \times 10^{-9} \text{ mol}) (178.49 \text{ g} \cdot \text{mol}^{-1}) \left(\frac{1 \times 10^6 \mu\text{g}}{1 \text{ g}} \right) = 1.41 \mu\text{g}$$

$$\text{(c) mass} = (3.49 \mu\text{mol}) \left(\frac{1 \text{ mol}}{1 \times 10^6 \mu\text{mol}} \right) (157.25 \text{ g} \cdot \text{mol}^{-1}) \left(\frac{1 \times 10^6 \mu\text{g}}{1 \text{ g}} \right) \\ = 549 \mu\text{g}$$

$$\text{(d) mass} = \left(\frac{6.29 \times 10^{24} \text{ atoms}}{6.022 \times 10^{23} \text{ atoms} \cdot \text{mol}^{-1}} \right) (121.75 \text{ g} \cdot \text{mol}^{-1}) \left(\frac{1 \times 10^6 \mu\text{g}}{1 \text{ g}} \right) \\ = 1.27 \times 10^9 \mu\text{g}$$

$$\text{E.12 (a) } m_{\text{Cu}} = \left(\frac{0.00735 \text{ g K}}{39.10 \text{ g} \cdot \text{mol}^{-1} \text{ K}} \right) (63.54 \text{ g} \cdot \text{mol}^{-1} \text{ Cu}) \\ = 0.0119 \text{ g Cu or } 11.9 \text{ mg Cu}$$

$$\text{(b) } m_{\text{Cu}} = \left(\frac{0.00735 \text{ g Au}}{196.97 \text{ g} \cdot \text{mol}^{-1} \text{ Au}} \right) (63.54 \text{ g} \cdot \text{mol}^{-1} \text{ Cu}) \\ = 0.00237 \text{ g Cu or } 2.37 \text{ mg Cu}$$

$$\text{E.14 (a) molar mass of H}_2\text{O} = 18.02 \text{ g} \cdot \text{mol}^{-1}$$

$$n_{\text{H}_2\text{O}} = \left(\frac{1.80 \text{ kg}}{18.02 \text{ g} \cdot \text{mol}^{-1}} \right) \left(\frac{1000 \text{ g}}{1 \text{ kg}} \right) = 1.00 \times 10^2 \text{ mol}$$

$$N_{\text{H}_2\text{O}} = (1.00 \times 10^2 \text{ mol}) (6.022 \times 10^{23} \text{ atoms} \cdot \text{mol}^{-1}) = 6.02 \times 10^{25} \text{ molecules}$$

$$\text{(b) molar mass of benzene} = 78.11 \text{ g} \cdot \text{mol}^{-1}$$

$$n_{\text{benzene}} = \left(\frac{49 \text{ kg}}{78.11 \text{ g} \cdot \text{mol}^{-1}} \right) \left(\frac{1000 \text{ g}}{1 \text{ kg}} \right) = 6.3 \times 10^2 \text{ mol}$$

$$N_{\text{benzene}} = (6.3 \times 10^2 \text{ mol}) (6.022 \times 10^{23} \text{ atoms} \cdot \text{mol}^{-1}) = 3.8 \times 10^{26} \text{ molecules}$$

$$\text{(c) molar mass of P atom} = 30.97 \text{ g} \cdot \text{mol}^{-1}$$

$$n_{\text{P}} = \left(\frac{100.0 \text{ g}}{30.97 \text{ g} \cdot \text{mol}^{-1}} \right) = 3.229 \text{ mol P atoms}$$

$$N_{\text{P}} = (3.229 \text{ mol})(6.022 \times 10^{23} \text{ atoms} \cdot \text{mol}^{-1}) = 1.944 \times 10^{24} \text{ P atoms}$$

$$\text{molar mass of P}_4 \text{ molecule} = 123.88 \text{ g} \cdot \text{mol}^{-1}$$

$$n_{\text{P}_4} = \left(\frac{100.0 \text{ g}}{123.88 \text{ g} \cdot \text{mol}^{-1}} \right) = 0.8072 \text{ mol P}_4 \text{ molecules}$$

$$N_{\text{P}_4} = (0.8072 \text{ mol})(6.022 \times 10^{23} \text{ atoms} \cdot \text{mol}^{-1}) = 4.861 \times 10^{23} \text{ P}_4 \text{ molecules}$$

$$\text{(d) molar mass of CO}_2 = 44.01 \text{ g} \cdot \text{mol}^{-1}$$

$$n_{\text{CO}_2} = \left(\frac{5.0 \text{ g}}{44.01 \text{ g} \cdot \text{mol}^{-1}} \right) = 0.11 \text{ mol}$$

$$N_{\text{CO}_2} = (0.11 \text{ mol})(6.022 \times 10^{23} \text{ atoms} \cdot \text{mol}^{-1}) = 6.6 \times 10^{22} \text{ molecules}$$

$$\text{(e) molar mass of NO}_2 = 46.01 \text{ g} \cdot \text{mol}^{-1}$$

$$n_{\text{NO}_2} = \left(\frac{5.0 \text{ g}}{46.01 \text{ g} \cdot \text{mol}^{-1}} \right) = 0.11 \text{ mol}$$

$$N_{\text{NO}_2} = (0.11 \text{ mol})(6.022 \times 10^{23} \text{ atoms} \cdot \text{mol}^{-1}) = 6.6 \times 10^{22} \text{ molecules}$$

$$\text{E.16 (a) molar mass of KCN} = 65.12 \text{ g} \cdot \text{mol}^{-1}$$

$$n_{\text{CN}^-} = \left(\frac{1.00 \text{ g KCN}}{65.12 \text{ g} \cdot \text{mol}^{-1} \text{ KCN}} \right) \left(\frac{1 \text{ mol CN}^-}{1 \text{ mol KCN}} \right) = 1.54 \times 10^{-2} \text{ mol}$$

$$\text{(b) molar mass of H}_2\text{O} = 18.02 \text{ g} \cdot \text{mol}^{-1}$$

$$n_{\text{H}} = \left(\frac{2.00 \times 10^{-1} \text{ g H}_2\text{O}}{18.02 \text{ g} \cdot \text{mol}^{-1} \text{ H}_2\text{O}} \right) \left(\frac{2 \text{ mol H}}{1 \text{ mol H}_2\text{O}} \right) = 2.2 \times 10^{-2} \text{ mol}$$

$$\text{(c) molar mass of CaCO}_3 = 100.09 \text{ g} \cdot \text{mol}^{-1}$$

$$n_{\text{CaCO}_3} = \left(\frac{5.00 \times 10^3 \text{ g CaCO}_3}{100.09 \text{ g} \cdot \text{mol}^{-1} \text{ CaCO}_3} \right) = 5.00 \text{ mol}$$

$$\text{(d) molar mass of La}_2(\text{SO}_4)_3 \cdot 9 \text{ H}_2\text{O} = 728.14 \text{ g} \cdot \text{mol}^{-1}$$

$$\begin{aligned} n_{\text{CN}^-} &= \left(\frac{5.00 \text{ g La}_2(\text{SO}_4)_3 \cdot 9 \text{ H}_2\text{O}}{728.14 \text{ g} \cdot \text{mol}^{-1} \text{ La}_2(\text{SO}_4)_3 \cdot 9 \text{ H}_2\text{O}} \right) \left(\frac{9 \text{ mol H}_2\text{O}}{1 \text{ mol La}_2(\text{SO}_4)_3 \cdot 9 \text{ H}_2\text{O}} \right) \\ &= 6.18 \times 10^{-2} \text{ mol} \end{aligned}$$

E.18 (a) molar mass of $\text{CaH}_2 = 42.10 \text{ g} \cdot \text{mol}^{-1}$

$$\begin{aligned}\text{number of formula units} &= \left(\frac{5.294 \text{ g}}{42.10 \text{ g} \cdot \text{mol}^{-1}} \right) (6.022 \times 10^{23} \text{ formula units} \cdot \text{mol}^{-1}) \\ &= 7.572 \times 10^{22} \text{ formula units}\end{aligned}$$

(b) molar mass of $\text{NaBF}_4 = 109.80 \text{ g} \cdot \text{mol}^{-1}$

$$\text{mass} = \left(\frac{6.25 \times 10^{24} \text{ formula units}}{6.022 \times 10^{23} \text{ formula units} \cdot \text{mol}^{-1}} \right) (109.80 \text{ g} \cdot \text{mol}^{-1}) = 1.14 \times 10^3 \text{ g}$$

$$\text{(c) moles of } \text{CeI}_3 = \left(\frac{9.54 \times 10^{21} \text{ g formula units}}{6.022 \times 10^{23} \text{ formula units} \cdot \text{mol}^{-1}} \right) = 1.58 \times 10^{-2} \text{ mol}$$

E.20 (a) molar mass of $\text{C}_8\text{H}_{18} = 114.22 \text{ g} \cdot \text{mol}^{-1}$

$$\begin{aligned}\text{mass of one octane molecule} &= \frac{114.22 \text{ g} \cdot \text{mol}^{-1}}{6.022 \times 10^{23} \text{ molecules} \cdot \text{mol}^{-1}} \\ &= 1.897 \times 10^{-22} \text{ g} \cdot \text{molecule}^{-1}\end{aligned}$$

$$\begin{aligned}\text{(b) } N_{\text{C}_8\text{H}_{18}} &= \frac{0.82 \text{ g}}{1.897 \times 10^{-22} \text{ g} \cdot \text{molecule}^{-1}} \\ &= 4.3 \times 10^{21} \text{ molecules}\end{aligned}$$

$$\begin{aligned}\text{E.22 } ? \text{ g CuSO}_4 &= 100. \text{ g CuSO}_4 \cdot 5 \text{ H}_2\text{O} \left(\frac{1 \text{ mol CuSO}_4 \cdot 5 \text{ H}_2\text{O}}{249.70 \text{ g CuSO}_4 \cdot 5 \text{ H}_2\text{O}} \right) \\ &\quad \times \left(\frac{1 \text{ mol CuSO}_4}{1 \text{ mol CuSO}_4 \cdot 5 \text{ H}_2\text{O}} \right) \left(\frac{159.62 \text{ g CuSO}_4}{1 \text{ mol CuSO}_4} \right) \\ &= 63.9 \text{ g CuSO}_4\end{aligned}$$

E.24 molar mass $\text{AuCl}_3 \cdot 2 \text{ H}_2\text{O} = 339.35 \text{ g} \cdot \text{mol}^{-1}$

$$\begin{aligned}\text{mass Au} &= 35.35 \text{ g AuCl}_3 \cdot 2 \text{ H}_2\text{O} \left(\frac{1 \text{ mol AuCl}_3 \cdot 2 \text{ H}_2\text{O}}{339.35 \text{ g AuCl}_3 \cdot 2 \text{ H}_2\text{O}} \right) \\ &\times \left(\frac{1 \text{ mol Au}}{1 \text{ mol AuCl}_3 \cdot 2 \text{ H}_2\text{O}} \right) \left(\frac{196.67 \text{ g Au}}{1 \text{ mol Au}} \right) \\ &= 20.46 \text{ g}\end{aligned}$$

$$\begin{aligned}\text{E.26} \quad ? \text{ atoms} &= 25.5 \text{ g chloroform} \left(\frac{1.000 \text{ cm}^3}{1.492 \text{ g}} \right) \left(\frac{0.250 \text{ mol}}{20.0 \text{ mL}} \right) \\ &\times \left(\frac{6.022 \times 10^{23} \text{ molecules}}{1 \text{ mol}} \right) \left(\frac{5 \text{ atoms}}{\text{molecule}} \right) \\ &= 6.43 \times 10^{23} \text{ atoms}\end{aligned}$$

$$\begin{aligned}? \text{ g C}_2\text{H}_4\text{Cl}_2 &= 6.43 \times 10^{23} \text{ atoms} \left(\frac{1 \text{ molecule}}{8 \text{ atoms}} \right) \\ &\times \left(\frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ molecules}} \right) \left(\frac{98.95 \text{ g}}{1 \text{ mol}} \right) \\ &= 13.2 \text{ g C}_2\text{H}_4\text{Cl}_2\end{aligned}$$

$$\begin{aligned}\text{E.28} \quad ? \text{ Si atoms} &= (28.0000... \text{ g } ^{28}\text{Si}) \left(\frac{1 \text{ atom}}{4.64567 \times 10^{-23} \text{ g}} \right) \\ &= 6.027118 \times 10^{23} \text{ atoms} = 1 \text{ mole}\end{aligned}$$

Since there are more atoms per mole, each mole will weigh more and all of the molar masses will be proportionately higher

$$\text{by } \frac{6.02712 \times 10^{23} - 6.02214 \times 10^{23}}{6.02214 \times 10^{23}} \times 100 = 0.0827\% .$$

$$(a) \text{ } ^{12}\text{C} \rightarrow 12.0000... \text{ g} \cdot \text{mol}^{-1} \times 1.000827 = 12.0099 \text{ g} \cdot \text{mol}^{-1}$$

$$(b) \text{ Cl} \rightarrow 35.45 \text{ g} \cdot \text{mol}^{-1} \times 1.000827 = 35.48 \text{ g} \cdot \text{mol}^{-1}$$

E.30 If x_1 , x_2 , and x_3 represent percentage composition of each of three isotopes having m_1 , m_2 , and m_3 respectively, then $x_1 + x_2 + x_3 = L = 100$

and $m_{\text{mean}} = \frac{x_1 m_1 + x_2 m_2 + x_3 m_3}{100}$. The composition triangle given in the

problem can be mapped onto a corresponding mass triangle such that each apex represents a composition of 100% of one of the isotopes and 0% of the other two. The central point inside the equilateral triangle represents a composition consisting of equal parts of each isotope, or $33.\overline{33}\%$ each. Since the composition can vary over “the whole range of possibilities,” a plot marking all of these composition, or mass, points would cover the whole triangle.

F.2 molar mass of $\text{C}_{14}\text{H}_{18}\text{N}_2\text{O}_5 = 294.30 \text{ g} \cdot \text{mol}^{-1}$

$$\%C = \frac{14 \times 12.01 \text{ g} \cdot \text{mol}^{-1}}{294.30 \text{ g} \cdot \text{mol}^{-1}} \times 100 = 57.13\%$$

$$\%H = \frac{18 \times 1.0079 \text{ g} \cdot \text{mol}^{-1}}{294.30 \text{ g} \cdot \text{mol}^{-1}} \times 100 = 6.1645\%$$

$$\%N = \frac{2 \times 14.01 \text{ g} \cdot \text{mol}^{-1}}{294.30 \text{ g} \cdot \text{mol}^{-1}} \times 100 = 9.520\%$$

$$\%O = \frac{5 \times 16.00 \text{ g} \cdot \text{mol}^{-1}}{294.30 \text{ g} \cdot \text{mol}^{-1}} \times 100 = 27.18\%$$

F.4 (a) M_2O_3 69.9% M For 100 g of compound, 69.9 g is M, 30.1 g is O.

$$\begin{aligned} \frac{? \text{ g } \text{M}_2\text{O}_3}{\text{mole } \text{M}_2\text{O}_3} &= \left(\frac{100 \text{ g } \text{M}_2\text{O}_3}{30.1 \text{ g O}} \right) \left(\frac{16.00 \text{ g O}}{1 \text{ mol O}} \right) \left(\frac{3 \text{ mol O}}{1 \text{ mol } \text{M}_2\text{O}_3} \right) \\ &= 159 \text{ g} \cdot \text{mol}^{-1} \text{M}_2\text{O}_3 \end{aligned}$$

Therefore, $159 - 48 = 111 \text{ g/mol}$ are due to M. Since there are 2 moles of M per mole of M_2O_3 , the molar mass of M = 55.5 g/mol. That molar mass matches Fe. (b) iron (III) oxide

F.6 (a) For 100 g of talc,

$$\text{moles of Mg} = \frac{19.2 \text{ g}}{24.31 \text{ g} \cdot \text{mol}^{-1}} = 0.790 \text{ mol}$$

$$\text{moles of Si} = \frac{29.6 \text{ g}}{28.09 \text{ g} \cdot \text{mol}^{-1}} = 1.05 \text{ mol}$$

$$\text{moles of O} = \frac{42.2 \text{ g}}{16.00 \text{ g} \cdot \text{mol}^{-1}} = 2.64 \text{ mol}$$

$$\text{moles of H} = \frac{9.0 \text{ g}}{1.0079 \text{ g} \cdot \text{mol}^{-1}} = 8.9 \text{ mol}$$

Dividing each number by 0.790 mol gives a ratio of 1 Mg : 1.33 Si : 3.34 O : 11.3 H. Multiplying by 3 in order to get appropriate whole numbers gives the formula $\text{Mg}_3\text{Si}_4\text{O}_{10}\text{H}_{34}$.

(b) For 100 g of saccharin,

$$\text{moles of C} = \frac{45.89 \text{ g}}{12.01 \text{ g} \cdot \text{mol}^{-1}} = 3.821 \text{ mol}$$

$$\text{moles of H} = \frac{2.75 \text{ g}}{1.0079 \text{ g} \cdot \text{mol}^{-1}} = 2.73 \text{ mol}$$

$$\text{moles of N} = \frac{7.65 \text{ g}}{14.01 \text{ g} \cdot \text{mol}^{-1}} = 0.546 \text{ mol}$$

$$\text{moles of O} = \frac{26.20 \text{ g}}{16.00 \text{ g} \cdot \text{mol}^{-1}} = 1.638 \text{ mol}$$

$$\text{moles of S} = \frac{17.50 \text{ g}}{32.06 \text{ g} \cdot \text{mol}^{-1}} = 0.546 \text{ mol}$$

Dividing by 0.546 mol gives a ratio of 7.00 C : 5.00 H : 1.00 N : 3.00 O : 1.00 S. The empirical formula is $\text{C}_7\text{H}_5\text{NO}_3\text{S}$.

(c) For 100 g of salicylic acid,

$$\text{moles of C} = \frac{60.87 \text{ g}}{12.01 \text{ g} \cdot \text{mol}^{-1}} = 5.068 \text{ mol}$$

$$\text{moles of H} = \frac{4.38 \text{ g}}{1.0079 \text{ g} \cdot \text{mol}^{-1}} = 4.35 \text{ mol}$$

$$\text{moles of O} = \frac{34.75 \text{ g}}{16.00 \text{ g} \cdot \text{mol}^{-1}} = 2.172 \text{ mol}$$

Dividing by 2.172 mole gives a ratio of 2.333 C : 2.00 H : 1.00 O.

Multiplying by 3 gives the empirical formula $\text{C}_7\text{H}_6\text{O}_3$.

F.8 moles of S = $\frac{4.69 \text{ g}}{32.06 \text{ g} \cdot \text{mol}^{-1}} = 0.146 \text{ mol}$

moles of F = $\frac{15.81 \text{ g} - 4.69 \text{ g}}{19.00 \text{ g} \cdot \text{mol}^{-1}} = 0.585 \text{ mol}$

Dividing by 0.146 mol gives a ratio of 4 F : 1 S. The formula is SF₄.

F.10 For 100 g of compound,

moles of C = $\frac{64.56 \text{ g}}{12.01 \text{ g} \cdot \text{mol}^{-1}} = 5.376 \text{ mol}$

moles of H = $\frac{5.42 \text{ g}}{1.0079 \text{ g} \cdot \text{mol}^{-1}} = 5.38 \text{ mol}$

moles of Fe = $\frac{30.02 \text{ g}}{55.85 \text{ g} \cdot \text{mol}^{-1}} = 0.5375 \text{ mol}$

Dividing by 0.5375 mol gives 10.00 C : 10.00 H : 1.00 Fe. The empirical formula is FeC₁₀H₁₀ with a molar mass of 186.03 g · mol⁻¹.

F.12 For 100 g of Paclitaxel,

moles of C = $\frac{66.11 \text{ g}}{12.01 \text{ g} \cdot \text{mol}^{-1}} = 5.504 \text{ mol}$

moles of H = $\frac{6.02 \text{ g}}{1.0079 \text{ g} \cdot \text{mol}^{-1}} = 5.97 \text{ mol}$

moles of N = $\frac{1.64 \text{ g}}{14.01 \text{ g} \cdot \text{mol}^{-1}} = 0.117 \text{ mol}$

mass of O = 100 – 66.11 – 6.02 – 1.64 = 26.23 g

moles of O = $\frac{26.23 \text{ g}}{16.00 \text{ g} \cdot \text{mol}^{-1}} = 1.639 \text{ mol}$

Dividing by 0.117 mol gives a ratio of 47.0 C : 51.0 H : 1.00 N : 14.0 O.

The empirical formula of Paclitaxel is C₄₇H₅₁NO₁₄.

F.14 For 1 mol of cacodyl,

$$\text{moles of C} = \frac{(0.2288)(209.96 \text{ g})}{12.01 \text{ g} \cdot \text{mol}^{-1}} = 4.00 \text{ mol}$$

$$\text{moles of H} = \frac{(0.0576)(209.96 \text{ g})}{1.0079 \text{ g} \cdot \text{mol}^{-1}} = 12.00 \text{ mol}$$

$$\text{moles of As} = \frac{(0.7136)(209.96 \text{ g})}{74.92 \text{ g} \cdot \text{mol}^{-1}} = 2.00 \text{ mol}$$

The molecular formula is $\text{C}_4\text{H}_{12}\text{As}_2$.

F.16 For the 1.78 mg sample of didemninn-A,

$$\text{mmoles of C} = \frac{1.11 \text{ mg}}{12.01 \text{ g} \cdot \text{mol}^{-1}} = 0.0924 \text{ mmol}$$

$$\text{mmoles of H} = \frac{0.148 \text{ mg}}{1.0079 \text{ g} \cdot \text{mol}^{-1}} = 0.147 \text{ mmol}$$

$$\text{mmoles of N} = \frac{0.159 \text{ mg}}{14.01 \text{ g} \cdot \text{mol}^{-1}} = 0.0113 \text{ mmol}$$

$$\text{mmoles of O} = \frac{0.363 \text{ mg}}{16.00 \text{ g} \cdot \text{mol}^{-1}} = 0.0227 \text{ mmol}$$

Dividing by 0.0113 mmol gives 8.18 C : 13.0 H : 1.00 N : 2.00 O.

Multiplying by 7 gives the formula $\text{C}_{49}\text{H}_{78}\text{N}_6\text{O}_{12}$ with a molar mass of $942 \text{ g} \cdot \text{mol}^{-1}$.

F.18 We can write the formula for dolomite as $(\text{Mg}_x\text{Ca}_y)\text{CO}_3$. Then



$$\text{mass of carbon dioxide lost} = 9.66 \text{ g} - 4.84 \text{ g} = 4.82 \text{ g}$$

$$\text{moles } \text{CO}_2(\text{g}) \text{ lost} = 4.82 \text{ g} \left(\frac{1 \text{ mol}}{44.01 \text{ g}} \right) = 0.110 \text{ mol}, \text{ so } x + y = 0.110.$$

It must also be true that the sum of the masses of the oxides add up to 4.84 g.

$$x \text{ mol MgO} \left(\frac{40.30 \text{ g MgO}}{1 \text{ mol MgO}} \right) + y \text{ mol CaO} \left(\frac{56.08 \text{ g CaO}}{1 \text{ mol CaO}} \right) \\ = 4.84 \text{ g mixed oxides}$$

Rearranging $x + y = 0.110$ gives $x = 0.110 - y$. Substituting for x ,

$$(0.110 - y) (40.30) + y (56.08) = 4.84$$

$$15.78y = 0.41$$

$$y = 0.026$$

and

$$x = 0.110 - 0.026 = 0.084$$

Then the original sample contained

$$\% \text{ mass MgCO}_3 = \left(\frac{0.084 \text{ mol MgCO}_3}{9.66 \text{ g sample}} \right) \left(\frac{84.31 \text{ g MgCO}_3}{1 \text{ mol MgCO}_3} \right) \times 100 \\ = 73\%$$

G.2 Distillation could be used to separate water from dissolved salts.

G.4 (a) heterogeneous, decanting; (b) homogeneous, distillation;
(c) heterogeneous, dissolving followed by filtration and distillation

G.6 (a) molarity of $\text{NaNO}_3 = \frac{2.345 \text{ g}}{(85.00 \text{ g} \cdot \text{mol}^{-1})(0.200 \text{ L})} = 0.1379 \text{ M NaNO}_3$

(b) molarity of $\text{NaNO}_3 = \frac{2.345 \text{ g}}{(85.00 \text{ g} \cdot \text{mol}^{-1})(0.250 \text{ L})} = 0.1104 \text{ M NaNO}_3$

G.8 molarity of $\text{Na}_2\text{CO}_3 = \frac{7.112 \text{ g}}{(105.99 \text{ g} \cdot \text{mol}^{-1})(0.2500 \text{ L})} = 0.2684 \text{ M Na}_2\text{CO}_3$

(a) $V = \frac{5.112 \times 10^{-3} \text{ mol Na}_2\text{CO}_3}{0.2684 \text{ mol Na}_2\text{CO}_3 \cdot \text{L}^{-1}} = 1.905 \times 10^{-2} \text{ L} = 19.05 \text{ mL}$

(b) $V = \frac{3.451 \times 10^{-3} \text{ mol CO}_3^{2-}}{0.2684 \text{ mol CO}_3^{2-} \cdot \text{L}^{-1}} = 1.286 \times 10^{-2} \text{ L} = 12.86 \text{ mL}$

$$\text{G.10 (a) molarity} = \frac{(1.345 \text{ mol} \cdot \text{L}^{-1})(0.01256 \text{ L})}{(0.2500 \text{ L})} = 0.06757 \text{ mol} \cdot \text{L}^{-1}$$

$$\text{(b) molarity} = \frac{(0.366 \text{ mol} \cdot \text{L}^{-1})(0.02500 \text{ L})}{(0.12500 \text{ L})} = 0.0732 \text{ mol} \cdot \text{L}^{-1}$$

$$\begin{aligned} \text{G.12 (a) moles transferred to the second flask} &= \frac{(0.094 \text{ g})(2.00 \text{ mL})}{(249.68 \text{ g} \cdot \text{mol}^{-1})(500 \text{ mL})} \\ &= 1.5 \times 10^{-6} \text{ mol} \end{aligned}$$

$$\text{new concentration} = \frac{1.5 \times 10^{-6} \text{ mol}}{0.5000 \text{ L}} = 3.0 \times 10^{-6} \text{ mol} \cdot \text{L}^{-1}$$

$$\begin{aligned} \text{(b) mass} &= (249.68 \text{ g} \cdot \text{mol}^{-1})(1.5 \times 10^{-6} \text{ mol}) \\ &= 3.7 \times 10^{-4} \text{ g or } 0.37 \text{ mg} \end{aligned}$$

$$\begin{aligned} \text{G.14 (a) volume of } 15.0 \text{ M NH}_3 \text{ that must be diluted} &= \frac{(1.25 \text{ mol} \cdot \text{L}^{-1})(500 \text{ mL})}{(15.0 \text{ mol} \cdot \text{L}^{-1})} \\ &= 41.7 \text{ mL} \end{aligned}$$

$$\begin{aligned} \text{(b) volume of } 15.0 \text{ M NH}_3 \text{ needed} &= \frac{(0.32 \text{ mol} \cdot \text{L}^{-1})(15.0 \text{ L})}{(15.0 \text{ mol} \cdot \text{L}^{-1})} \\ &= 0.32 \text{ L or } 3.2 \times 10^2 \text{ mL} \end{aligned}$$

$$\begin{aligned} \text{G.16 (a) molarity of the first solution} &= \frac{(0.661 \text{ g})}{(294.20 \text{ g} \cdot \text{mol}^{-1})(0.2500 \text{ L})} \\ &= 8.99 \times 10^{-3} \text{ mol} \cdot \text{L}^{-1} \text{ K}_2\text{Cr}_2\text{O}_7(\text{aq}) \end{aligned}$$

$$\begin{aligned} \text{molarity of the second solution} &= \frac{(8.99 \times 10^{-3} \text{ mol} \cdot \text{L}^{-1})(1 \times 10^{-3} \text{ L})}{(0.500 \text{ L})} \\ &= 1.80 \times 10^{-5} \text{ mol} \cdot \text{L}^{-1} \text{ K}_2\text{Cr}_2\text{O}_7(\text{aq}) \end{aligned}$$

$$\begin{aligned} \text{molarity of the final solution} &= \frac{(1.80 \times 10^{-5} \text{ mol} \cdot \text{L}^{-1})(0.010 \text{ L})}{(0.250 \text{ L})} \\ &= 7.20 \times 10^{-7} \text{ mol} \cdot \text{L}^{-1} \text{ K}_2\text{Cr}_2\text{O}_7(\text{aq}) \end{aligned}$$

$$\text{(b) mass} = (7.20 \times 10^{-7} \text{ mol} \cdot \text{L}^{-1})(0.250 \text{ L})(294.2 \text{ g} \cdot \text{mol}^{-1}) = 5.3 \times 10^{-5} \text{ g}$$

G.18 (a) mass of NaOH = $(5.0 \text{ mol} \cdot \text{L}^{-1})(0.0750 \text{ L})(40.00 \text{ g} \cdot \text{mol}^{-1}) = 15 \text{ g}$

Add 15 g of NaOH to a 75.0-mL volumetric flask and dilute to the line.

(b) mass of BaCl₂ = $(0.21 \text{ mol} \cdot \text{L}^{-1})(5.0 \text{ L})(208.24 \text{ g} \cdot \text{mol}^{-1}) = 2.2 \times 10^2 \text{ g}$

Add 220 g of BaCl₂ to a 5.0-L flask and fill with water to the line.

(c) mass of AgNO₃ = $(0.0340 \text{ mol} \cdot \text{L}^{-1})(0.300 \text{ L})(169.88 \text{ g} \cdot \text{mol}^{-1})$
 $= 1.73 \text{ g}$

Add 1.73 g of AgNO₃ to a 300-mL volumetric flask and fill with water to the line.

G.20 $10 \text{ mL} \times \frac{0.10 \text{ mol}}{1000 \text{ mL}} \times \frac{6.02214 \times 10^{23} \text{ molecules}}{1 \text{ mol}} = 6.0 \times 10^{20} \text{ molecules}$ are

in the first 10 mL aliquot of the solution. The number of successive ten-fold dilutions, n , required to get down to just one molecule can be found from this relationship:

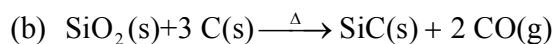
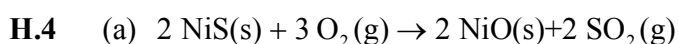
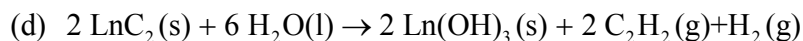
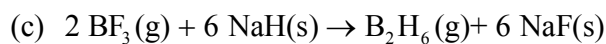
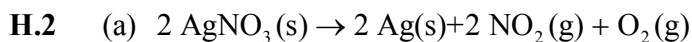
$$6.0 \times 10^{20} \text{ molecules} \times (0.1)^n = 1 \text{ molecule}$$

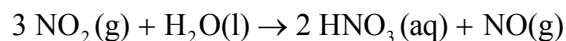
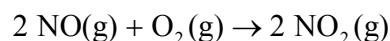
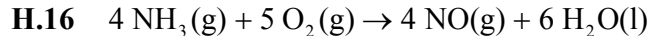
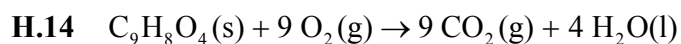
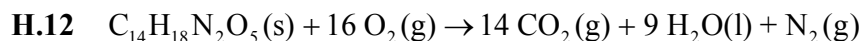
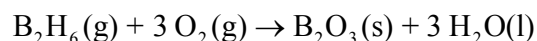
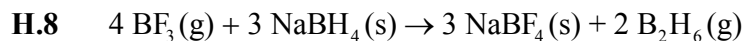
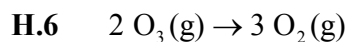
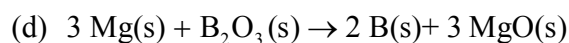
$$\log(6.0 \times 10^{20}) + n \log(0.1) = \log(1)$$

$$20.78 + n(-1) = 0$$

$$n = 20.78$$

So after 20 such dilutions, less than 10 molecules are left. The last dilution should be by a factor of $(0.1)^{0.78} = 0.17 > 0.1$ in order to try to ensure that one molecule will still remain.





H.18 (a), (b), and (d) are conserved overall in any chemical reaction.

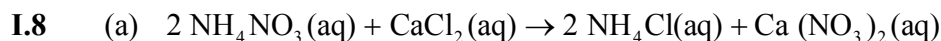
I.2 (a) strong electrolyte; (b) strong electrolyte; (c) weak electrolyte

I.4 (a) soluble; (b) insoluble; (c) insoluble; (d) soluble

I.6 (a) $\text{PbSO}_4(\text{s})$ is insoluble but to the extent that it does dissolve the species

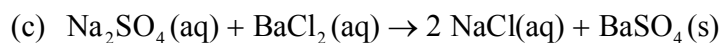
are $\text{Pb}^{2+}(\text{aq})$ and $\text{SO}_4^{2-}(\text{aq})$; (b) K^+ , CO_3^{2-} ; (c) K^+ , CrO_4^{2-} ;

(d) $\text{Hg}_2\text{Cl}_2(\text{s})$ is insoluble but to the extent that it does dissolve the species are $\text{Hg}_2^{2+}(\text{aq})$ and $\text{Cl}^-(\text{aq})$.

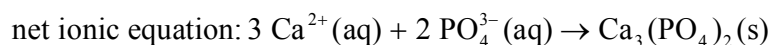
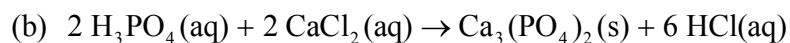


No precipitate is expected.

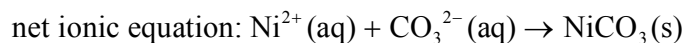
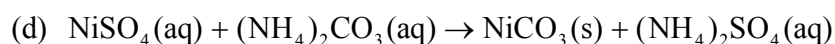
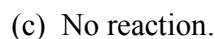
(b) $\text{MgCO}_3(\text{s})$ is insoluble. It will remain undissolved and the NaNO_3 will dissolve.



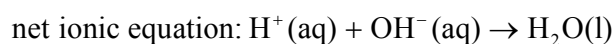
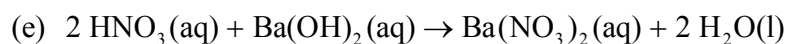
Barium sulfate, BaSO_4 , will precipitate.



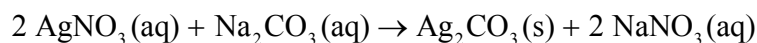
spectator ions: H^+ , Cl^-



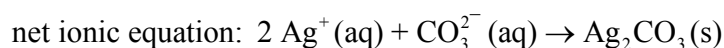
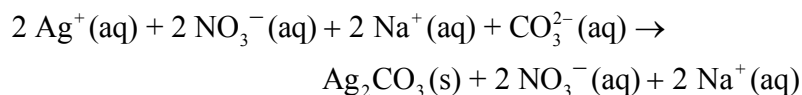
spectator ions: NH_4^+ , SO_4^{2-}



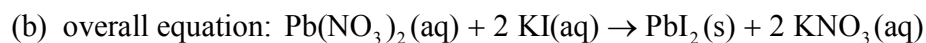
spectator ions: Ba^{2+} , NO_3^-



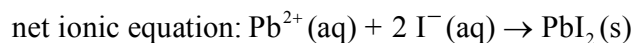
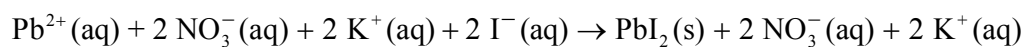
complete ionic equation:



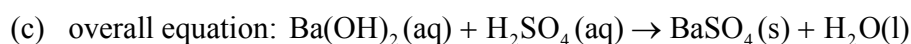
spectator ions: Na^+ , NO_3^-



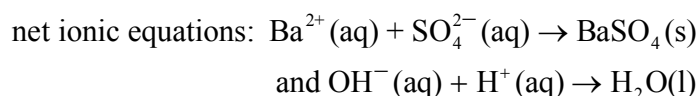
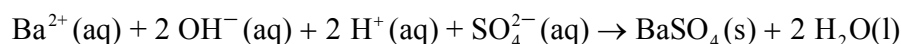
complete ionic equation:



spectator ions: K^{+} , NO_3^{-}

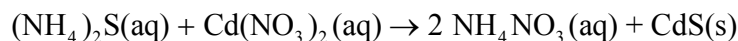


complete ionic equation:

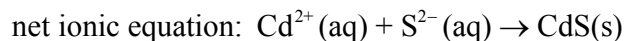
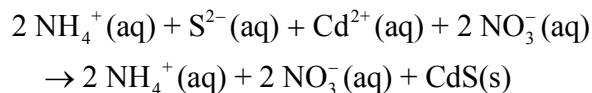


no spectator ions

(d) overall equation:

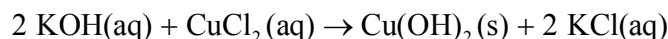


complete ionic equation:

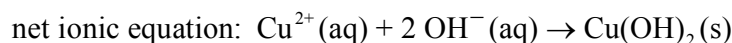
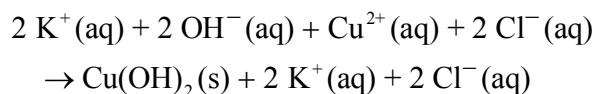


spectator ions: NH_4^{+} , NO_3^{-}

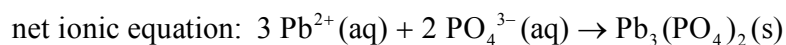
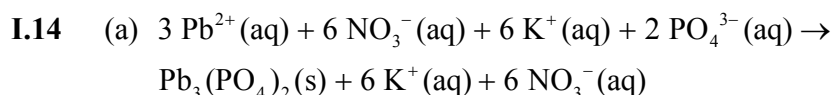
(e) overall equation:

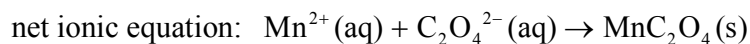
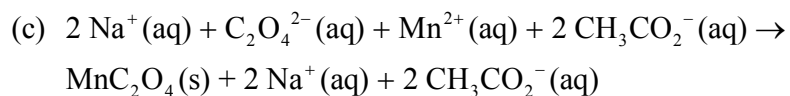
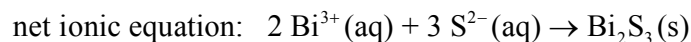
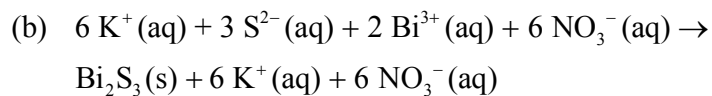


complete ionic equation:

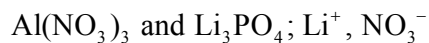
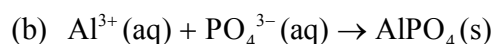


spectator ions: K^{+} , Cl^{-}

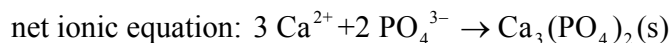
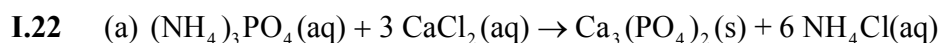




- I.16** (a) $AgNO_3(aq)$ and $Na_2SO_4(aq)$; (b) $MgSO_4(aq)$ and $KOH(aq)$; (c) $Ca(NO_3)_2(aq)$ and $(NH_4)_2PO_4(aq)$



- I.20** No precipitate with Cl^- indicates no Ag^+ . The white precipitate with SO_4^{2-} is $CaSO_4$, so Ca^{2+} is present. The black precipitate with the supernatant is HgS , indicating the presence of Hg^{2+} . Therefore we would report Ca^{2+} and Hg^{2+} as being present in the solution.



$$\begin{aligned}
 \text{(b)} \quad \frac{? \text{ mol NH}_4^+}{1 \text{ L solution}} &= \left(\frac{25.0 \text{ g (NH}_4)_3\text{PO}_4}{70.0 \text{ mL solution}} \right) \left(\frac{1 \text{ mol (NH}_4)_3\text{PO}_4}{149.095 \text{ g (NH}_4)_3\text{PO}_4} \right) \\
 &\quad \times \left(\frac{3 \text{ mol NH}_4^+}{1 \text{ mol (NH}_4)_3\text{PO}_4} \right) \left(\frac{1000 \text{ mL}}{1 \text{ L}} \right) \\
 &= 7.19 \text{ M NH}_4^+
 \end{aligned}$$

$$\begin{aligned}
 \frac{? \text{ mol Cl}^-}{1 \text{ L solution}} &= \left(\frac{50.0 \text{ mL CaCl}_2(\text{aq})}{70.0 \text{ mL solution}} \right) \left(\frac{0.125 \text{ mol CaCl}_2}{1000 \text{ mL CaCl}_2(\text{aq})} \right) \\
 &\quad \times \left(\frac{2 \text{ mol Cl}^-}{1 \text{ mol CaCl}_2} \right) \left(\frac{1000 \text{ mL solution}}{1 \text{ L solution}} \right) \\
 &= 0.179 \text{ M Cl}^-
 \end{aligned}$$

$$\text{I.24} \quad ? \text{ mol CuI} = 15.75 \text{ g CuI} \left(\frac{1 \text{ mol CuI}}{190.45 \text{ g CuI}} \right) = 0.08270 \text{ mol CuI}$$

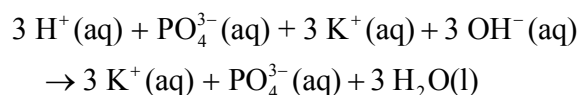
Since the reaction was limited by the CuNO_3 and the stoichiometry is 1:1, there was an equivalent number of moles of CuNO_3 in the original reactant solution, or

$$\left(\frac{0.08270 \text{ mol CuNO}_3}{50.0 \text{ mL CuNO}_3(\text{aq})} \right) \left(\frac{1000 \text{ mL}}{1 \text{ L}} \right) = 1.654 \text{ M CuNO}_3(\text{aq})$$

J.2 (a) acid; (b) base; (c) acid; (d) base; (e) acid

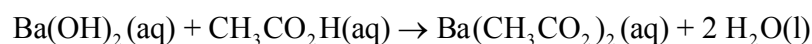
J.4 (a) overall equation: $\text{H}_3\text{PO}_4(\text{aq}) + 3 \text{ KOH}(\text{aq}) \rightarrow \text{K}_3\text{PO}_4(\text{aq}) + 3 \text{ H}_2\text{O}(\text{l})$

total ionic equation:

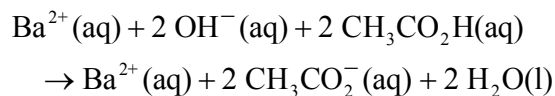


net ionic equation: $3 \text{ H}^+(\text{aq}) + 3 \text{ OH}^-(\text{aq}) \rightarrow 3 \text{ H}_2\text{O}(\text{l})$

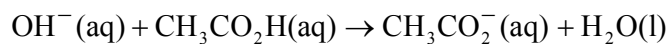
(b) overall equation:



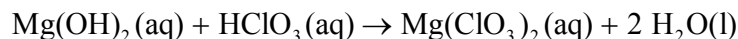
total ionic equation:



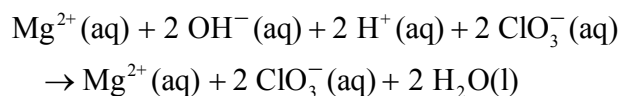
net ionic equation:



(c) overall equation:

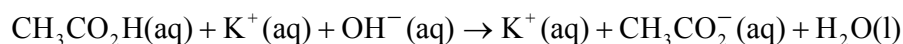


total ionic equation:

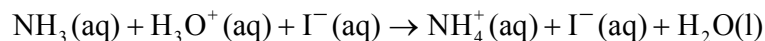


net ionic equation: $\text{OH}^{-}(\text{aq}) + \text{H}^{+}(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l})$

J.6 (a) $\text{CH}_3\text{CO}_2\text{K}$, potassium acetate;



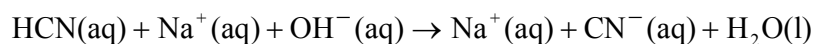
(b) NH_4I , ammonium iodide;



(c) BaSO_4 , barium sulfate;



(d) NaCN , sodium cyanide;



J.8 (a) acid: $\text{CH}_3\text{CO}_2\text{H}(\text{aq})$, base: $\text{NH}_3(\text{aq})$; (b) acid: $\text{HCl}(\text{aq})$,

base: $(\text{CH}_3)_3\text{N}(\text{aq})$; (c) acid: $\text{H}_2\text{O}(\text{l})$, base: $\text{O}^{2-}(\text{aq})$

J.10 (a) $43.64 \text{ g P} \times \left(\frac{1 \text{ mol P}}{30.97 \text{ g P}} \right) = 1.409 \text{ mol P}$

$$56.36 \text{ g O} \times \left(\frac{1 \text{ mol O}}{16.00 \text{ g O}} \right) = 3.523 \text{ mol O}$$

$$\frac{3.523}{1.409} = 2.5 = \text{mole ratio of O:P in compound A}$$

P_4O_{10} is the molecular formula with this stoichiometry that has the correct molar mass since $(4 \times 30.97) + (10 \times 16.00) = 283.88 \text{ g} \cdot \text{mol}^{-1}$.

(b) There is a mistake in the information given in the problem. Hydrogen composes 3.087% of compound B (not 1.029%).

$$3.087 \text{ g H} \times \left(\frac{1 \text{ mol H}}{1.0079 \text{ g H}} \right) = 3.063 \text{ mol H}$$

$$31.60 \text{ g P} \times \left(\frac{1 \text{ mol P}}{30.97 \text{ g P}} \right) = 1.020 \text{ mol P}$$

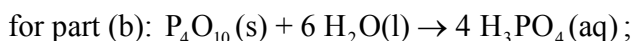
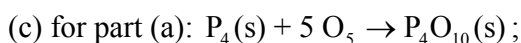
$$65.31 \text{ g O} \times \left(\frac{1 \text{ mol O}}{16.00 \text{ g O}} \right) = 4.082 \text{ mol O}$$

$$\frac{4.082}{1.020} = 4.00 = \text{mole ratio of O:P in compound B}$$

$$\frac{3.063}{1.020} = 3.00 = \text{mole ratio of H:P in compound B}$$

The molecular formula H_3PO_4 has the correct stoichiometry as well as the appropriate molar mass since

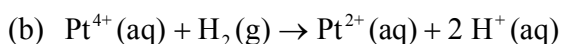
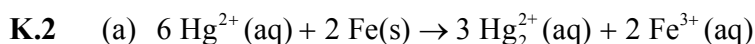
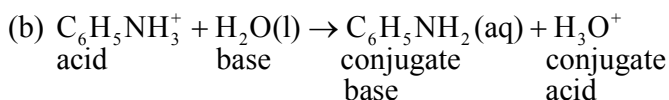
$$(3 \times 1.0079) + (1 \times 30.97) + (4 \times 16.00) = 97.99 \text{ g} \cdot \text{mol}^{-1}.$$

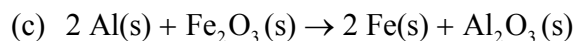


J.12 (a) ? M

$$C_6H_5NH_3^+ = \left(\frac{50.0 \text{ g } C_6H_5NH_3Cl}{150.0 \text{ mL}} \right) \left(\frac{1000 \text{ mL}}{L} \right) \left(\frac{1 \text{ mol } C_6H_5NH_3Cl}{129.45 \text{ g } C_6H_5NH_3Cl} \right)$$

$$= 2.57 \text{ M } C_6H_5NH_3Cl = 2.57 \text{ M } C_6H_5NH_3^+$$





K.4 (a) +4; (b) +6; (c) +5; (d) +4; (e) +5; (f) +2

K.6 (a) +3; (b) +3; (c) +4; (d) +2; (e) +4

K.8 (a) $-\frac{1}{2}$; (b) -1; (c) -1; (d) -1; (e) $-\frac{1}{3}$

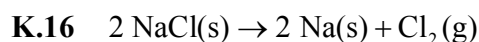
K.10 (a) $\text{Cl}_2\text{(g)}$ is reduced to $\text{Cl}^-\text{(aq)}$ so the oxidation number on Cl changes from 0 to 1-. $\text{I}^-\text{(aq)}$ is oxidized to $\text{I}_2\text{(aq)}$ with the oxidation number on I changing from 1- to 0. (b) $\text{Cl}_2\text{(g)}$ is both oxidized to OCl^- (oxidation number changes from 0 to 1+) and reduced to Cl^- (oxidation number changes from 0 to 1-). A reaction in which a single substance is both oxidized and reduced is known as a *disproportionation reaction*. (c) The N atom in NO, which has a 2+ oxidation state, is oxidized up to 4+ in NO_2 while one O atom is reduced from 0 in O_3 to 2- in NO_2 .

K.12 (a) KBrO_3 will be the stronger oxidizing agent. Br^{5+} will more readily accept electrons than Br^+ . (b) MnO_4^- will be the better oxidizing agent because Mn^{7+} will more readily accept electrons than Mn^{2+} .

K.14 (a) Oxidizing agent: $\text{Cr}_2\text{O}_3\text{(s)}$; reducing agent: Al(s)

(b) Oxidizing agent: $\text{N}_2\text{(g)}$; reducing agent: Li(s)

(c) Oxidizing agent: $\text{Ca}_3(\text{PO}_4)_2\text{(s)}$; reducing agent: C(s)



Na(s) is produced by reduction while $\text{Cl}_2\text{(g)}$ is produced by oxidation.

- K.18** (a) redox reaction: oxidizing agent: $\text{I}_2\text{O}_5(\text{s})$; reducing agent: $\text{CO}(\text{g})$
 (b) redox reaction: oxidizing agent: $\text{I}_2(\text{aq})$; reducing agent: $\text{S}_2\text{O}_3^{2-}(\text{aq})$
 (c) precipitation reaction: $\text{Ag}^+(\text{aq}) + \text{Br}^-(\text{aq}) \rightarrow \text{AgBr}(\text{s})$
 (d) redox reaction: oxidizing agent: $\text{Mg}(\text{s})$; reducing agent: $\text{UF}_4(\text{g})$

K.20

Group	IA	IIA	IIIA	IVA	VA	VIA	VIIA
	H +1,-1						
	Li +1	Be +2	B +3	C +4,-4	N +5,-3	O +2,-2	F -1
	Na +1	Mg +2	Al +3	Si +4,-4	P +5,-3	S +6,-2	Cl +7,-1
	K +1	Ca +2	Ga +3	Ge +4,-4	As +5,-3	Se +6,-2	Br +5,-1
	Rb +1	Sr +2	In +3	Sn +4,+2	Sb +5,-3	Te +6,-2	I +7,-1

Metals only exhibit positive maximum oxidation states while non-metals have both positive maximum states and negative minimum states. For the most part, the maximum oxidation number corresponds to the Group number, or the number of valence electrons. The minimum oxidation number for the non-metals corresponds to the number of electrons needed to complete the outermost electron shell.

- K.22** (a) Silver goes from 0 as Ag to 1+ as Ag_2S , so it is oxidized when it is tarnished.

$$\begin{aligned} \text{(b) } ? \text{ moles Ag} &= 5.0 \text{ g Ag}_2\text{S} \left(\frac{1 \text{ mol Ag}_2\text{S}}{247.81 \text{ g Ag}_2\text{S}} \right) \left(\frac{2 \text{ mol Ag}}{1 \text{ mol Ag}_2\text{S}} \right) \\ &= 0.040 \text{ mol Ag was oxidized} \end{aligned}$$

- (c) Since one mole of electrons is transferred for every Ag^+ formed, 0.040 moles of electrons were lost from the 0.040 moles of Ag atoms that were oxidized.

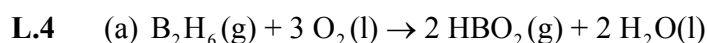
- L.2** (a) $\text{Ca}_3(\text{PO}_4)_2(\text{aq}) + 3 \text{H}_2\text{SO}_4(\text{aq}) \rightarrow 3 \text{CaSO}_4(\text{s}) + 2 \text{H}_3\text{PO}_4(\text{aq})$

$$(200 \text{ kg H}_2\text{SO}_4) \left(\frac{1000 \text{ g}}{1 \text{ kg}} \right) \left(\frac{1 \text{ mol H}_2\text{SO}_4}{98.08 \text{ g H}_2\text{SO}_4} \right) \left(\frac{2 \text{ mol H}_3\text{PO}_4}{3 \text{ mol H}_2\text{SO}_4} \right)$$

$$= 1.36 \times 10^3 \text{ mol H}_3\text{PO}_4$$

$$(b) \quad (200 \text{ mol Ca}_3(\text{PO}_4)_2) \left(\frac{3 \text{ mol CaSO}_4}{1 \text{ mol Ca}_3(\text{PO}_4)_2} \right) \left(\frac{136.14 \text{ g CaSO}_4}{1 \text{ mol CaSO}_4} \right)$$

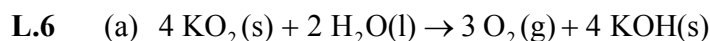
$$= 8.17 \times 10^4 \text{ g CaSO}_4$$



$$(257 \text{ g B}_2\text{H}_6) \left(\frac{1 \text{ mol B}_2\text{H}_6}{27.67 \text{ g B}_2\text{H}_6} \right) \left(\frac{3 \text{ mol O}_2}{1 \text{ mol B}_2\text{H}_6} \right) \left(\frac{32.00 \text{ g O}_2}{1 \text{ mol O}_2} \right) = 892 \text{ g O}_2(\text{l})$$

$$(b) \quad (106 \text{ g B}_2\text{H}_6) \left(\frac{1 \text{ mol B}_2\text{H}_6}{27.67 \text{ g B}_2\text{H}_6} \right) \left(\frac{2 \text{ mol HBO}_2}{1 \text{ mol B}_2\text{H}_6} \right) \left(\frac{43.82 \text{ g HBO}_2}{1 \text{ mol HBO}_2} \right)$$

$$= 336 \text{ g HBO}_2(\text{g})$$

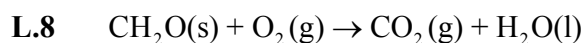


$$(115 \text{ g O}_2) \left(\frac{1 \text{ mol O}_2}{32.00 \text{ g O}_2} \right) \left(\frac{4 \text{ mol KO}_2}{3 \text{ mol O}_2} \right) \left(\frac{71.10 \text{ g KO}_2}{1 \text{ mol KO}_2} \right) = 341 \text{ g KO}_2$$

$$(b) \quad (75.0 \text{ g KO}_2) \left(\frac{1 \text{ mol KO}_2}{71.10 \text{ g KO}_2} \right) \left(\frac{4 \text{ mol KOH}}{4 \text{ mol KO}_2} \right)$$

$$\times \left(\frac{1 \text{ mol CO}_2}{1 \text{ mol KOH}} \right) \left(\frac{44.01 \text{ g CO}_2}{1 \text{ mol CO}_2} \right)$$

$$= 46.4 \text{ g CO}_2$$



$$\text{volume of wood} = 12 \times 14 \times 25 \text{ cm}^3 = 4.2 \times 10^3 \text{ cm}^3$$

$$\text{mass of wood} = (4.2 \times 10^3 \text{ cm}^3) \left(\frac{0.72 \text{ g}}{1 \text{ cm}^3} \right) = 3.0 \times 10^3 \text{ g oak}$$

$$\text{moles of wood} = (3.0 \times 10^3 \text{ g oak}) \left(\frac{1 \text{ mol oak}}{30.03 \text{ g oak}} \right) = 1.0 \times 10^2 \text{ mol oak}$$

$$(1.0 \times 10^2 \text{ mol oak}) \left(\frac{1 \text{ mol H}_2\text{O}}{1 \text{ mol CH}_2\text{O}} \right) \left(\frac{18.02 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} \right) = 1.8 \times 10^3 \text{ g H}_2\text{O}$$



$$(25.67 \text{ mL NaOH}(\text{aq})) \left(\frac{0.327 \text{ mol NaOH}}{1000 \text{ mL NaOH}(\text{aq})} \right)$$

$$= 8.39 \times 10^{-3} \text{ mol NaOH used}$$

$$(8.39 \times 10^{-3} \text{ mol NaOH}) \left(\frac{1 \text{ mol H}_2\text{C}_2\text{O}_4}{2 \text{ mol NaOH}} \right)$$

$$= 4.20 \times 10^{-3} \text{ mol H}_2\text{C}_2\text{O}_4 \text{ neutralized}$$

$$\left(\frac{4.20 \times 10^{-3} \text{ mol H}_2\text{C}_2\text{O}_4}{0.03525 \text{ L}} \right) = 0.119 \text{ mol} \cdot \text{L}^{-1} \text{ H}_2\text{C}_2\text{O}_4$$

$$(b) (0.03525 \text{ L}) \left(\frac{0.119 \text{ mol}}{1 \text{ L}} \right) \left(\frac{90.04 \text{ g H}_2\text{C}_2\text{O}_4}{1 \text{ mol H}_2\text{C}_2\text{O}_4} \right) = 0.328 \text{ g H}_2\text{C}_2\text{O}_4$$



$$\text{moles of KOH} = (0.100 \text{ L})(3.0 \text{ mol} \cdot \text{L}^{-1}) = 0.030 \text{ mol}$$

$$\text{concentration of diluted KOH} = \frac{0.030 \text{ mole}}{0.250 \text{ L}} = 0.12 \text{ mol} \cdot \text{L}^{-1}$$

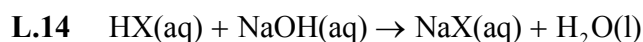
$$\text{moles of OH}^- \text{ required} = (0.0385 \text{ L})(0.12 \text{ mol} \cdot \text{L}^{-1}) = 4.6 \times 10^{-3} \text{ mol}$$

$$(0.0046 \text{ mol KOH}) \left(\frac{1 \text{ mol H}_3\text{PO}_4}{3 \text{ mol KOH}} \right) = 0.0015 \text{ mol H}_3\text{PO}_4 \text{ neutralized}$$

$$\text{molarity of H}_3\text{PO}_4 = \frac{0.0015 \text{ mol}}{0.010 \text{ L}} = 0.15 \text{ mol} \cdot \text{L}^{-1}$$

(b) mass of

$$\text{H}_3\text{PO}_4 = (0.0015 \text{ mol H}_3\text{PO}_4)(97.99 \text{ g} \cdot \text{mol}^{-1}) = 0.15 \text{ g H}_3\text{PO}_4$$



$$(0.014\ 56\ \text{L})(0.115\ \text{mol} \cdot \text{L}^{-1}) = 0.001\ 67\ \text{mol NaOH and HX}$$

$$\frac{0.2037\ \text{g}}{0.001\ 67\ \text{mol}} = 122\ \text{g} \cdot \text{mol}^{-1}$$

L.16 $\text{mol I}_3^- = (0.0101\ \text{L})(0.0521\ \text{mol} \cdot \text{L}^{-1}) = 5.26 \times 10^{-4}\ \text{mol}$

$$\left(\frac{5.26 \times 10^{-4}\ \text{mol I}_3^-}{10.0\ \text{mL solution}} \right) \left(\frac{1\ \text{mol vitamin C}}{1\ \text{mol I}_3^-} \right) \left(\frac{176\ \text{g vitamin C}}{1\ \text{mol vitamin C}} \right) \times \left(\frac{100.00\ \text{mL solution}}{1\ \text{tablet}} \right) = 0.926\ \text{g vitamin C per tablet}$$

No, the manufacturer was not truthful.

L.18 Let x = number of moles of $\text{CaCl}_2 \cdot 2\ \text{H}_2\text{O}$ in the mixture. Then $2x$ moles of water lost upon heating = $2.543\ \text{g} - 2.312\ \text{g} = 0.231\ \text{g}$, or

$$2x = (0.231\ \text{g H}_2\text{O}) \left(\frac{1\ \text{mol H}_2\text{O}}{18.02\ \text{g H}_2\text{O}} \right)$$

$$x = 6.41 \times 10^{-3}\ \text{mols}$$

number of grams of CaCl_2 in the dry

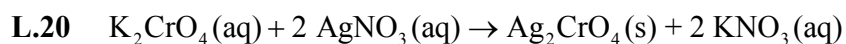
$$\text{mixture} = (6.41 \times 10^{-3}\ \text{mols}) \left(\frac{110.98\ \text{g CaCl}_2}{1\ \text{mol CaCl}_2} \right) = 0.711\ \text{g CaCl}_2$$

Therefore, the original sample consisted of $(0.711 + 0.231)\ \text{g} = 0.942\ \text{g}$ $\text{CaCl}_2 \cdot 2\ \text{H}_2\text{O}$ and

$$(2.543 - 0.942)\ \text{g} = 1.601\ \text{g KCl}.$$

$$\left(\frac{0.942\ \text{g CaCl}_2 \cdot 2\ \text{H}_2\text{O}}{2.543\ \text{g original mixture}} \right) \times 100 = 37.1\% \text{ CaCl}_2 \cdot 2\ \text{H}_2\text{O}$$

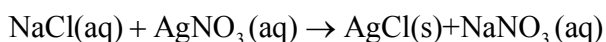
$$\left(\frac{1.601\ \text{g KCl}}{2.543\ \text{g original mixture}} \right) \times 100 = 62.9\% \text{ KCl}$$



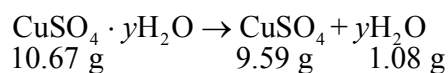
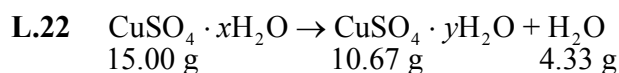
$$25.0\ \text{mL} \left(\frac{0.5\ \text{mol K}_2\text{CrO}_4}{1000\ \text{mL solution}} \right) = 0.0125\ \text{mol K}_2\text{CrO}_4$$

Since the reaction requires 2 moles of AgNO_3 for every one mole of K_2CrO_4 , the concentration of the AgNO_3 solution is

$$\frac{(0.0125 \text{ mol K}_2\text{CrO}_4) \left(\frac{2 \text{ mol AgNO}_3}{1 \text{ mol K}_2\text{CrO}_4} \right)}{15.0 \text{ mL AgNO}_3(\text{aq})} \left(\frac{1000 \text{ mL}}{1 \text{ L}} \right) = 1.67 \text{ M}$$



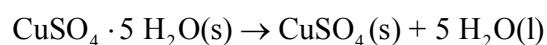
$$\begin{aligned} ? \text{ g NaCl} &= 35.0 \text{ mL AgNO}_3(\text{aq}) \left(\frac{1.67 \text{ mol AgNO}_3}{1000 \text{ mL AgNO}_3(\text{aq})} \right) \\ &\quad \times \left(\frac{1 \text{ mol NaCl}}{1 \text{ mol AgNO}_3} \right) \left(\frac{58.44 \text{ g NaCl}}{1 \text{ mol NaCl}} \right) \\ &= 3.42 \text{ g NaCl} \end{aligned}$$



$$\text{total moles of water} = \frac{5.41 \text{ g}}{18.02 \text{ g} \cdot \text{mol}^{-1}} = 0.300 \text{ mols}$$

$$\text{total moles of CuSO}_4 = \frac{9.59 \text{ g}}{159.62 \text{ g} \cdot \text{mol}^{-1}} = 0.0601 \text{ mols}$$

$$\frac{\text{mols H}_2\text{O}}{\text{mols CuSO}_4} = \frac{0.300}{0.0601} = \frac{5}{1}, \text{ so } x = 5 \text{ and } y = 4$$

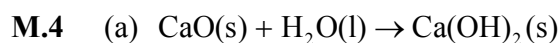


theoretical yield:

$$(77.25 \text{ g P}_4) \left(\frac{1 \text{ mol P}_4}{123.88 \text{ g P}_4} \right) \left(\frac{4 \text{ mol PCl}_3}{1 \text{ mol P}_4} \right) \left(\frac{137.32 \text{ g PCl}_3}{1 \text{ mol PCl}_3} \right) = 342.5 \text{ g PCl}_3$$

actual yield:

$$\frac{300.5 \text{ g PCl}_3}{342.5 \text{ g PCl}_3} \times 100\% = 87.73\% \text{ yield}$$



$$(30.0 \text{ g CaO}) \left(\frac{1 \text{ mol CaO}}{56.08 \text{ g CaO}} \right) \left(\frac{1 \text{ mol H}_2\text{O}}{1 \text{ mol CaO}} \right) \left(\frac{18.02 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} \right) = 9.64 \text{ g H}_2\text{O}$$

Because 10.0 g H_2O are present, the limiting reagent is CaO .

$$(30.0 \text{ g CaO}) \left(\frac{1 \text{ mol CaO}}{56.08 \text{ g CaO}} \right) \left(\frac{1 \text{ mol Ca(OH)}_2}{1 \text{ mol CaO}} \right) \left(\frac{74.10 \text{ g Ca(OH)}_2}{1 \text{ mol Ca(OH)}_2} \right) \\ = 39.6 \text{ g Ca(OH)}_2$$



$$n_{\text{FeO}} = \frac{10.325 \text{ g FeO}}{71.85 \text{ g} \cdot \text{mol}^{-1} \text{ FeO}} = 0.1437 \text{ mol FeO}$$

$$n_{\text{Al}} = \frac{5.734 \text{ g Al}}{26.98 \text{ g} \cdot \text{mol}^{-1} \text{ Al}} = 0.2125 \text{ mol Al}$$

The reaction stoichiometry requires 2 moles of Al for 3 moles of FeO.

For complete reduction of FeO

$$n_{\text{Al required to reduce all FeO}} = 0.1437 \text{ mol FeO} \left(\frac{2 \text{ mol Al}}{3 \text{ mol FeO}} \right) = 0.0958 \text{ mol Al}$$

Because there is more than 0.0958 mol Al, there is more than sufficient Al to reduce all of the FeO. FeO is, therefore, the limiting reagent.

(b) Because 1 mol Fe is produced per mol FeO, the amount of Fe produced will be 0.1437 mol.

(c) Al is present in excess. $0.2125 - 0.0958 \text{ mol} = 0.1167 \text{ mol}$ of Al will remain, or $0.1167 \text{ mol} \times 26.98 \text{ g} \cdot \text{mol}^{-1} \text{ Al} = 3.148 \text{ g Al}$.

M.8 The molar mass of ephedrine is $165.23 \text{ g} \cdot \text{mol}^{-1}$.

$$n_{\text{ephedrine}} = \frac{0.05732 \text{ g}}{165.23 \text{ g} \cdot \text{mol}^{-1}} = 3.469 \times 10^{-4} \text{ mol}$$

1 mole of ephedrine will produce 10 moles of CO_2 and 7.5 moles of H_2O .

$$\begin{aligned}
 m_{\text{CO}_2} &= (3.469 \times 10^{-4} \text{ mol ephedrine}) \left(\frac{10 \text{ mol CO}_2}{1 \text{ mol ephedrine}} \right) \\
 &\quad \times (44.01 \text{ g} \cdot \text{mol}^{-1} \text{ CO}_2) \\
 &= 0.1527 \text{ g CO}_2
 \end{aligned}$$

$$\begin{aligned}
 m_{\text{H}_2\text{O}} &= (3.469 \times 10^{-4} \text{ mol ephedrine}) \left(\frac{7.5 \text{ mol H}_2\text{O}}{1 \text{ mol ephedrine}} \right) \\
 &\quad \times (18.02 \text{ g} \cdot \text{mol}^{-1} \text{ H}_2\text{O}) \\
 &= 0.04688 \text{ g H}_2\text{O}
 \end{aligned}$$

$$\begin{aligned}
 \text{M.10} \quad (1.072 \text{ g CO}_2) &\left(\frac{1 \text{ mol CO}_2}{44.01 \text{ g CO}_2} \right) \left(\frac{1 \text{ mol C}}{1 \text{ mol CO}_2} \right) = 0.02436 \text{ mol C} \\
 (0.02436 \text{ mol C}) &\left(\frac{12.01 \text{ g C}}{1 \text{ mol C}} \right) = 0.2926 \text{ g C}
 \end{aligned}$$

$$(0.307 \text{ g H}_2\text{O}) \left(\frac{1 \text{ mol H}_2\text{O}}{18.02 \text{ g H}_2\text{O}} \right) \left(\frac{2 \text{ mol H}}{1 \text{ mol H}_2\text{O}} \right) = 0.0341 \text{ mol H}$$

$$(0.0341 \text{ mol H})(1.0079 \text{ g} \cdot \text{mol}^{-1} \text{ H}) = 0.0343 \text{ g H}$$

$$(0.068 \text{ g N}_2) \left(\frac{1 \text{ mol N}_2}{28.02 \text{ g N}_2} \right) \left(\frac{2 \text{ mol N}}{1 \text{ mol N}_2} \right) = 0.0049 \text{ mol N}$$

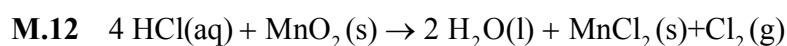
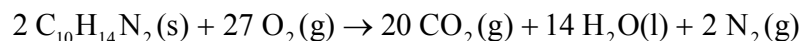
$$(0.0049 \text{ mol N})(14.01 \text{ g} \cdot \text{mol}^{-1} \text{ N}) = 0.068 \text{ g N}$$

Dividing each amount by 0.0049 gives C : H : N ratios = 5.0 : 7.0 : 1.0.

The empirical formula is $\text{C}_5\text{H}_7\text{N}$. The molecular mass is $162 \text{ g} \cdot \text{mol}^{-1}$.

Its empirical formula mass is $81 \text{ g} \cdot \text{mol}^{-1}$.

molecular formula = $2 \times$ empirical formula = $\text{C}_{10}\text{H}_{14}\text{N}_2$



$$\begin{aligned}
 \text{(a)} \quad (42.7 \text{ g MnO}_2) &\left(\frac{1 \text{ mol MnO}_2}{86.94 \text{ g MnO}_2} \right) \left(\frac{1 \text{ mol Cl}_2}{1 \text{ mol MnO}_2} \right) \left(\frac{70.90 \text{ g Cl}_2}{1 \text{ mol Cl}_2} \right) \\
 &= 34.8 \text{ g Cl}_2
 \end{aligned}$$

$$(b) \quad (0.300 \text{ L}) \left(\frac{0.100 \text{ mol HCl}}{1.00 \text{ L}} \right) \left(\frac{1 \text{ mol Cl}_2}{4 \text{ mol HCl}} \right) \left(\frac{70.90 \text{ g Cl}_2}{1 \text{ mol Cl}_2} \right) \left(\frac{1 \text{ L}}{3.17 \text{ g Cl}_2} \right)$$

$$= 0.168 \text{ L Cl}_2$$

$$(c) \quad \frac{0.150 \text{ L}}{0.168 \text{ L}} \times 100 = 89.3\%$$

M.14 First calculate the theoretical percentages of C and H for $\text{C}_{14}\text{H}_{20}\text{O}_2\text{N}$ and $\text{C}_2\text{H}_2\text{Cl}_4$.

For $\text{C}_{14}\text{H}_{20}\text{O}_2\text{N}$:

$$\%C = \frac{14(12.01 \text{ g} \cdot \text{mol}^{-1})}{(234.31 \text{ g} \cdot \text{mol}^{-1})} \times 100\% = 71.76\% \text{ C}$$

$$\%H = \frac{20(1.0079 \text{ g} \cdot \text{mol}^{-1})}{(234.31 \text{ g} \cdot \text{mol}^{-1})} \times 100\% = 8.60\% \text{ H}$$

For $\text{C}_2\text{H}_2\text{Cl}_4$:

$$\%C = \frac{2(12.01 \text{ g} \cdot \text{mol}^{-1})}{(167.84 \text{ g} \cdot \text{mol}^{-1})} \times 100\% = 14.31\% \text{ C}$$

$$\%H = \frac{2(1.0079 \text{ g} \cdot \text{mol}^{-1})}{(167.84 \text{ g} \cdot \text{mol}^{-1})} \times 100\% = 1.20\% \text{ H}$$

If x = mass of $\text{C}_{14}\text{H}_{20}\text{O}_2\text{N}$ and y = mass of $\text{C}_2\text{H}_2\text{Cl}_4$ in the sample, the total masses of C and H can be expressed as

$$m_{\text{C}} = 0.7176x + 0.1431y$$

$$m_{\text{H}} = 0.0860x + 0.0120y$$

The analysis results give these relationships for a 100 g sample:

$$68.50 \text{ g C} = 0.7176x + 0.1431y$$

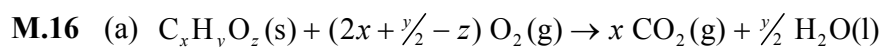
$$8.18 \text{ g H} = 0.0860x + 0.0120y$$

Solving these two equations in two unknowns by rearranging and substitution gives

$$x = 94.32$$

$$y = 5.69$$

Therefore, the percentage purity by mass of the $\text{C}_{14}\text{H}_{20}\text{O}_2\text{N}$ is 94.32%.



$$\frac{1.811 \text{ g } CO_2}{44.01 \text{ g} \cdot \text{mol}^{-1}} = 0.04115 \text{ mol } CO_2 \left(\frac{12.01 \text{ g C}}{1 \text{ mol } CO_2} \right) = 0.4942 \text{ g C}$$

$$\frac{0.3172 \text{ g } H_2O}{18.02 \text{ g} \cdot \text{mol}^{-1}} = 0.01762 \text{ mol } H_2O \left(\frac{2.0158 \text{ g H}}{1 \text{ mol } H_2O} \right) = 0.03552 \text{ g H}$$

$$1.000 \text{ g} - (0.4942 + 0.03552) \text{ g} = 0.4703 \text{ g O}$$

$$\frac{0.4703 \text{ g O}}{16.00 \text{ g} \cdot \text{mol}^{-1}} = 0.02939 \text{ mol O}$$

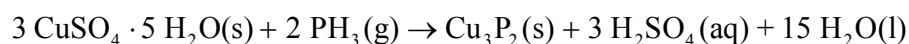
Dividing each amount of moles by 0.02939 gives a ratio of C:H:O of 1.4:1.2:1.

Multiplying through by 5 gives whole numbers as required for an empirical formula of



(b) Since the molar mass of this empirical formula matches the given value of about 170 g/mol, the molecular formula is the same as the empirical formula.

M.18 (a)



(b) $CuSO_4 \cdot 5 H_2O$ copper(II) sulfate pentahydrate; PH_3 phosphine;

Cu_3P_2 copper(II) phosphide; H_2SO_4 sulfuric acid; H_2O water

(c) $\frac{4.94 \text{ g}(0.85)}{33.994 \text{ g} \cdot \text{mol}^{-1}} = 0.1235 \text{ mol } PH_3 \text{ present, therefore}$

$$0.1235 \text{ mol } PH_3 \left(\frac{3 \text{ mol } CuSO_4 \cdot 5 H_2O}{2 \text{ mol } PH_3} \right) \\ = 0.1853 \text{ mol } CuSO_4 \cdot 5 H_2O \text{ needed}$$

$$\frac{0.110 \times 10^3 \text{ g}}{249.68 \text{ g} \cdot \text{mol}^{-1}} = 0.4406 \text{ mol } CuSO_4 \cdot 5 H_2O \text{ present}$$

>0.1853 mol needed

PH_3 is the limiting reagent while $\text{CuSO}_4 \cdot 5 \text{H}_2\text{O}$ is present in excess.

(d)

$$\begin{aligned} ? \text{ g Cu}_3\text{P}_2 &= 0.1235 \text{ mol PH}_3 \left(\frac{1 \text{ mol Cu}_3\text{P}_2}{2 \text{ mol PH}_3} \right) \left(\frac{252.56 \text{ g Cu}_3\text{P}_2}{1 \text{ mol Cu}_3\text{P}_2} \right) (0.0631) \\ &= 0.984 \text{ g Cu}_3\text{P}_2 \end{aligned}$$