Chapter 3
Solutions to Selected Integrative and Advanced Exercises

83. (M)

molar mass = (1×6.941 g Li) + (1×26.9815 g Al) + (2×28.0855 g Si) + (6×15.9994 g O) = 186.09 g/mol

Conversion pathway approch:

$$\text{number of Li}-6\text{ atoms} = 518\text{ g spodumene} \times \frac{1\text{ mol spodumene}}{186.09\text{ g spodumene}} \times \frac{1\text{ mol Li}}{1\text{ mol spodumene}} \times \frac{7.40\text{ mol Li}-6}{100.00\text{ mol total Li}}$$

$$\times \frac{6.022\times10^{23}\text{ Li}-6\text{ atoms}}{1\text{ mol Li}-6} = 1.24\times10^{23}\text{ Li}-6\text{ atoms}$$

Stepwise approch:

$$518\text{ g spodumene} \times \frac{1\text{ mol spodumene}}{186.09\text{ g spodumene}} = 2.78\text{ mol spodumene}$$

$$2.78\text{ mol spodumene} \times \frac{1\text{ mol Li}}{1\text{ mol spodumene}} = 2.78\text{ mol lithium}$$

$$2.78\text{ mol lithium} \times \frac{7.40\text{ mol lithium}-6}{100.00\text{ mol total Li}} = 0.206\text{ mol lithium-6}$$

$$0.206\text{ mol lithium-6} \times \frac{6.022\times10^{23}\text{ lithium}-6\text{ atoms}}{1\text{ mol lithium}-6} = 1.24\times10^{23}\text{ Li}-6\text{ atoms}$$

84. (M) Determine the mass of each element in the sample.

$$\text{mass Sn} = 0.245\text{ g SnO}_2 \times \frac{1\text{ mol SnO}_2}{150.71\text{ g SnO}_2} \times \frac{1\text{ mol Sn}}{1\text{ mol SnO}_2} \times \frac{118.71\text{ g Sn}}{1\text{ mol Sn}} = 0.193\text{ g Sn}$$

$$\text{mass Pb} = 0.115\text{ g PbSO}_4 \times \frac{1\text{ mol PbSO}_4}{303.26\text{ g PbSO}_4} \times \frac{1\text{ mol Pb}}{1\text{ mol PbSO}_4} \times \frac{207.2\text{ g Pb}}{1\text{ mol Pb}} = 0.0786\text{ g Pb}$$

$$\text{mass Zn} = 0.246\text{ g Zn}_2\text{P}_2\text{O}_7 \times \frac{1\text{ mol Zn}_2\text{P}_2\text{O}_7}{304.72\text{ g Zn}_2\text{P}_2\text{O}_7} \times \frac{2\text{ mol Zn}}{1\text{ mol Zn}_2\text{P}_2\text{O}_7} \times \frac{65.39\text{ g Zn}}{1\text{ mol Zn}} = 0.106\text{ g Zn}$$

Then determine the % of each element in the sample.

$$\%\text{ Sn} = \frac{0.193\text{ g Sn}}{1.1713\text{ g brass}} \times 100\% = 16.5\%\text{ Sn} \qquad \%\text{ Pb} = \frac{0.0786\text{ g Pb}}{1.1713\text{ g brass}} \times 100\% = 6.71\%\text{ Pb}$$

$$\%\text{ Zn} = \frac{0.106\text{ g Zn}}{1.1713\text{ g brass}} \times 100\% = 9.05\%\text{ Zn}$$

The % Cu is found by difference. $\%\text{Cu} = 100\% - 16.5\%\text{ Sn} - 6.71\%\text{ Pb} - 9.05\%\text{ Zn} = 67.7\%\text{ Cu}$

88. (M) First, determine the formula of the compound. The compound is 26.58% K, 35.45% Cr and 37.97% O. Assuming 100 g of compound, 26.58 g are potassium, 35.45 g are chromium, and 37.97 g are oxygen.

$$26.58 \text{ g K} \times \frac{1 \text{ mol K}}{39.10 \text{ g K}} = 0.6798 \text{ mol K} \quad \div \quad 0.6798 \text{ mol} = 1 \text{ mol K}$$

$$35.45 \text{ g Cr} \times \frac{1 \text{ mol Cr}}{52.00 \text{ g Cr}} = 0.6818 \text{ mol Cr} \quad \div \quad 0.6798 \text{ mol} = 1 \text{ mol Cr}$$

$$37.97 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 2.373 \text{ mol O} \quad \div \quad 0.6798 \text{ mol} = 3.5 \text{ mol O}$$

$2 \times KCrO_{3.5} = K_2Cr_2O_7$ which is the formula of the compound

Cr = +6 and the compound $K_2Cr_2O_7$ is named potassium dichromate.

91. **(M)** We determine the masses of CO_2 and H_2O produced by burning the C_3H_8.

$$\text{mass}_{CO_2} = 6.00 \text{ g } C_3H_8 \times \frac{1 \text{ mol } C_3H_8}{44.0965 \text{ g } C_3H_8} \times \frac{3 \text{ mol C}}{1 \text{ mol } C_3H_8} \times \frac{1 \text{ mol } CO_2}{1 \text{ mol C}} \times \frac{44.01 \text{ g } CO_2}{1 \text{ mol } CO_2} = 17.9\underline{6} \text{ g } CO_2$$

$$\text{mass}_{H_2O} = 6.00 \text{ g } C_3H_8 \times \frac{1 \text{ mol } C_3H_8}{44.0965 \text{ g } C_3H_8} \times \frac{8 \text{ mol H}}{1 \text{ mol } C_3H_8} \times \frac{1 \text{ mol } H_2O}{2 \text{ mol H}} \times \frac{18.0153 \text{ g } H_2O}{1 \text{ mol } H_2O} = 9.80\underline{5} \text{ g } H_2O$$

Then, from the masses of CO_2 and H_2O in the unknown compound, we determine the amounts of C and H in that compound and finally its empirical formula.

$$\text{amount C} = (29.0 - 17.9\underline{6}) \text{ g } CO_2 \times \frac{1 \text{ mol } CO_2}{44.01 \text{ g } CO_2} \times \frac{1 \text{ mol C}}{1 \text{ mol } CO_2} = 0.251 \text{ mol C}$$

$$\text{amount H} = (18.8 - 9.80\underline{5}) \text{ g } H_2O \times \frac{1 \text{ mol } H_2O}{18.0153 \text{ g } H_2O} \times \frac{2 \text{ mol H}}{1 \text{ mol } H_2O} = 0.998\underline{6} \text{ mol H}$$

The empirical formula of the unknown compound is CH_4. The C:H ratio is 0.9986/0.251 = 3.98.

The molecular formula can be calculated by knowing that we have 0.251 moles, which accounts for the 4.00 g of hydrocarbon (40 % of 10.0 g). This gives a molar mass of 4.00÷0.251 = 15.9 g/mol. This is nearly the same as the molar mass of the empirical formula CH_4 (16.04 g/mol)

94. **(E)** $\% \text{ Ag} = \dfrac{\# \text{ grams Ag}}{\text{total mass in grams}} \times 100\%$

$$31.56 \text{ g AgCl} \times \frac{1 \text{ mol AgCl}}{143.32 \text{ g AgCl}} \times \frac{1 \text{ mol Ag}}{1 \text{ mol AgCl}} \times \frac{107.87 \text{ g Ag}}{1 \text{ mol Ag}} = 23.75 \text{ g Ag}$$

$$\% \text{ Ag} = \frac{23.75 \text{ g Ag}}{26.39 \text{ g sample}} \times 100\% = 90.00 \% \text{ Ag}$$

96. **(D)**

a) If we have one mole of entities, then we must have 0.7808 mol N_2, 0.2095 mol O_2, 0.0093 mol Ar, and 0.0004 mol CO_2.

$$0.7808 \text{ mol } N_2 \times \frac{28.02 \text{ g } N_2}{1 \text{ mol } N_2} = 21.88 \text{ g } N_2$$

$$0.2095 \text{ mol } O_2 \times \frac{32.00 \text{ g } O_2}{1 \text{ mol } O_2} = 6.704 \text{ g } O_2$$

$$0.0004 \text{ mol } CO_2 \times \frac{44.01 \text{ g } CO_2}{1 \text{ mol } CO_2} = 0.0176 \text{ g } CO_2$$

$$0.0093 \text{ mol Ar} \times \frac{39.948 \text{ g Ar}}{1 \text{ mol Ar}} = 0.3715 \text{ g Ar}$$

mass of air sample = 21.88g N_2 + 6.704 g O_2 + 0.0176 g CO_2 + 0.3715 g Ar = 28.97 g

$$1 \text{ m}^3 \times \frac{(100)^3 \text{ cm}^3}{1 \text{ m}^3} \times \frac{1 \text{ mL}}{1 \text{ cm}^3} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{1.2 \text{ g}}{1 \text{ L}} = 1200 \text{ g dry air}$$

b) $$1200 \text{ g} \times \frac{1 \text{ mol entities}}{28.97 \text{ g}} \times \frac{1.14\times10^{-4}}{100} = 4.72\times10^{-5} \text{ mol Kr}$$

$$4.72\times10^{-5} \text{ mol Kr} \times \frac{83.80 \text{ g}}{1 \text{ mol}} = 3.96\times10^{-3} \text{ g Kr} = 4.0 \text{ mg Kr}$$

98. **(M).** We can determine both the number of moles of M and the mass of M in 0.1131 g MSO_4. Their quotient is the atomic mass of M.

$$\text{mol } M^{2+} = 0.2193 \text{ g } BaSO_4 \times \frac{1 \text{ mol } BaSO_4}{233.39 \text{ g } BaSO_4} \times \frac{1 \text{ mol } SO_4^{2-}}{1 \text{ mol } BaSO_4} \times \frac{1 \text{ mol } M^{2+}}{1 \text{ mol } SO_4^{2-}} = 0.0009396 \text{ mol } M^{2+}$$

$$\text{mass } SO_4^{2-} = 0.0009396 \text{ mol } M^{2+} \times \frac{1 \text{ mol } SO_4^{2-}}{1 \text{ mol } M^{2+}} \times \frac{96.064 \text{ g } SO_4^{2-}}{1 \text{ mol } SO_4^{2-}} = 0.09026 \text{ g } SO_4^{2-}$$

$$\text{mass M} = \text{mass } MSO_4 - \text{mass } SO_4^{2-} = 0.1131 \text{ g } MSO_4 - 0.09026 \text{ g } SO_4^{2-} = 0.0228 \text{ g M}$$

$$\text{atomic mass M} = \frac{\text{mass M}}{\text{moles M}} = \frac{0.0228 \text{ g M}}{0.0009396 \text{ mol M}} = 24.3 \text{ g M/mol}$$

M is the element magnesium.

103. **(M)** If we determine the mass of anhydrous $ZnSO_4$ in the hydrate, we then can determine the mass of water, and the formula of the hydrate.

$$\text{mass } ZnSO_4 = 0.8223 \text{ g } BaSO_4 \times \frac{1 \text{ mol } BaSO_4}{233.391 \text{ g}} \times \frac{1 \text{ mol } ZnSO_4}{1 \text{ mol } BaSO_4} \times \frac{161.454 \text{ g } ZnSO_4}{1 \text{ mol } ZnSO_4} = 0.5688 \text{ g } ZnSO_4$$

The water present in the hydrate is obtained by difference.

mass H_2O = 1.013 g hydrate − 0.5688 g $ZnSO_4$ = 0.444 g H_2O

The hydrate's formula is determined by a method similar to that for obtaining an empirical formula.

$$\text{amt. } ZnSO_4 = 0.5688 \text{ g} \times \frac{1 \text{ mol } ZnSO_4}{161.454 \text{ mol } ZnSO_4} = 0.003523 \text{ mol } ZnSO_4 \div 0.003523 \longrightarrow 1.00 \text{ mol } ZnSO_4$$

$$\text{amt. } H_2O = 0.444 \text{ g} \times \frac{1 \text{ mol } H_2O}{18.0153 \text{ g } H_2O} = 0.0246\underline{5} \text{ mol } H_2O \div 0.003523 \longrightarrow 7.00 \text{ mol } H_2O$$

Thus, the formula of the hydrate is $ZnSO_4 \cdot 7H_2O$.

105.(M)

$$13 \text{ atoms} \times \frac{15.38 \text{ atoms E}}{100 \text{ atoms in formula unit}} = \frac{1.999 \text{ atom E}}{\text{formula unit}} \quad \therefore \ H_xE_2O_z \ \text{(Note: x + z = 11)}$$

34.80 % E by mass, hence, 65.20% H and O by mass

178 u × 0.3480 E = 61.944 u for 2 atoms of E, ∴ E = 30.972 u Probably P (30.9738 u)

H and O in formula unit = 178 u – 30.972 u = 116 u

x + z = 11 or x = 11 – z and x(1.00794 u) + z(15.9994 u) = 116 u

Substitute and solve for z: (11 – z)(1.00794 u) + z(15.9994 u) = 116 u

11.08734 u – 1.00794 u(z) + 15.9994 u(z) = 116 u   Divide through by u and collect terms

105 = 14.9915(z) or z = 7 and x = 11- z = 11- 7 = 4.

Therefore the formula is $H_4P_2O_7$ (ss a check, 13 atoms and 177.975 u ~ 178 u).

<u>106.</u> (M) First find the mass of carbon, hydrogen, chlorine, and oxygen. From the molar ratios, we determine the molecular formula.

$$2.094 \text{ g } CO_2 \times \frac{1 \text{mol } CO_2}{44.001 \text{g } CO_2} \times \frac{1 \text{mol C}}{1 \text{mol } CO_2} = 0.04759 \text{ mol C} \times \frac{12.011 \text{ g C}}{1 \text{mol C}} = 0.5716 \text{ g C}$$

$$0.286 \text{ g } H_2O \times \frac{1 \text{mol } H_2O}{18.0153 \text{g } H_2O} \times \frac{2 \text{mol H}}{1 \text{mol } H_2O} = 0.0317\underline{5} \text{mol H} \times \frac{1.00794 \text{ g H}}{1 \text{mol H}} = 0.0320 \text{ g H}$$

$$\text{moles of chlorine} = \frac{mol \text{ C}}{2} = \frac{0.04759}{2} = 0.02380 \text{ mol Cl}$$

$$\text{mass of Cl} = 0.02380 \text{ mol Cl} \times \frac{35.4527 \text{g Cl}}{1 \text{ mol Cl}} = 0.8436 \text{ g Cl}$$

mass of oxygen obtained by difference: 1.510 g - 0.8436 g – 0.5716 g – 0.0320 g = 0.063 g O

$$\text{moles of oxygen} = 0.063 \text{ g O} \times \frac{1 \text{ mol O}}{15.9994 \text{ g O}} = 0.0039\underline{4} \text{ mol O}$$

Divide the number of moles of each element by 0.0039<u>4</u> to give an empirical formula of $C_{12.\underline{1}}H_{8.0\underline{6}}Cl_{6.0\underline{4}}O_{1.00}$ owing to the fact that the oxygen mass is obtained by difference, and it has only two significant digits and thus a higher degree of uncertainty

The empirical formula is $C_{12}H_8Cl_6O$, which with a molecular mass of 381 u has the same molecular mass as the molecular formula. Hence, this empirical formula is also the molecular formula.