Stoichiometry Workshop - Solutions

1. $Fe_2O_{3\,(s)} + 2\,Al_{(s)} \rightarrow Al_2O_{3\,(s)} + 2\,Fe_{(\ell)}$

   $$150\text{ g Al}\times\frac{1\text{ mol Al}}{26.98\text{ g Al}}\times\frac{2\text{ mol Fe}}{2\text{ mol Al}}\times\frac{55.85\text{ g Fe}}{1\text{ mol Fe}}=311\text{ g Fe}$$

   $$250\text{ g Fe}_2\text{O}_3\times\frac{1\text{ mol Fe}_2\text{O}_3}{159.70\text{ g Fe}_2\text{O}_3}\times\frac{2\text{ mol Fe}}{1\text{ mol Fe}_2\text{O}_3}\times\frac{55.85\text{ g Fe}}{1\text{ mol Fe}}=175\text{ g Fe}$$

   Fe_2O_3 is the limiting reagent, and 175 g Fe is produced from this reaction.

2. Consider 100.0 g of vitamin A:

   $$100.00\text{ g vitamin A}\times\frac{1\text{ mol vitamin A}}{286.4\text{ g vitamin A}}=0.3492\text{ mol vitamin A}$$

   $$83.86\text{ g C}\times\frac{1\text{ mol C}}{12.011\text{ g C}}=6.982\text{ mol C}$$

   $$\frac{6.982\text{ mol C}}{0.3492\text{ mol vitamin A}}=\frac{19.99\text{ mol C}}{1\text{ mol vitamin A}}\approx\frac{20\text{ mol C}}{1\text{ mol vitamin A}}$$

   $$10.56\text{ g H}\times\frac{1\text{ mol H}}{1.0079\text{ g H}}=10.48\text{ mol H}$$

   $$\frac{10.48\text{ mol H}}{0.3492\text{ mol vitamin A}}=\frac{30.01\text{ mol H}}{1\text{ mol vitamin A}}\approx\frac{30\text{ mol H}}{1\text{ mol vitamin A}}$$

   $$\frac{(100-83.86-10.56)\text{ g E}}{0.3492\text{ mol vitamin A}}=\frac{15.98\text{ g E}}{1\text{ mol vitamin A}}\times\frac{1\text{ mol vitamin A}}{1\text{ mol E}}=\frac{15.98\text{ g E}}{1\text{ mol E}}$$

   The molecular weight of E is 15.98 g/mol, which suggests that E is oxygen (O) and the molecular formula of vitamin A is $C_{20}H_{30}O$.

3. a. By conservation of mass:

   $$(24.96\text{ g CO}_2+12.27\text{ g H}_2\text{O})-(10.00\text{ g C}_5\text{H}_{12}\text{O})=27.23\text{ g O}_2$$

   b. $$24.96\text{ g CO}_2\times\frac{1\text{ mol CO}_2}{44.01\text{ g CO}_2}\times\frac{1\text{ mol C}}{1\text{ mol CO}_2}=0.5671\text{ mol C}\times\frac{12.01\text{ g C}}{1\text{ mol C}}=6.811\text{ g C}$$

   $$12.27\text{ g H}_2\text{O}\times\frac{1\text{ mol H}_2\text{O}}{18.02\text{ g H}_2\text{O}}\times\frac{2\text{ mol H}}{1\text{ mol H}_2\text{O}}=1.362\text{ mol H}\times\frac{1.008\text{ g H}}{1\text{ mol H}}=1.373\text{ g H}$$

   mass of O = $(10.00\text{ g MTBE})-(6.811\text{ g C})-(1.373\text{ g H})=1.82\text{ g O}$

   $$1.82\text{ g O}\times\frac{1\text{ mol O}}{16.00\text{ g O}}=0.1135\text{ mol O}$$

Dividing each mole value by 0.1135 yields a mole ratio of 5 C : 12 H : 1 O.
The empirical formula is thus $(C_5H_{12}O)_n$, which has a formula weight of 88.15 amu.

c. The MTBE vapor has a mass about twice the mass of an equal volume of carbon dioxide gas at the same temperature and pressure. This implies that the molecular mass of MTBE is 2 times the molecular mass of carbon dioxide gas, which is 44.01 amu. Thus, the molecular mass of the sample must be ≈ 88 amu. The mass of the empirical formula unit $C_5H_{12}O$ is 88.15 amu. Thus, *n* = 1, and the molecular formula of MTBE must be $C_5H_{12}O$.

d. $2\ C_5H_{12}O_{(\ell)} + 15\ O_{2\,(g)} \rightarrow 10\ CO_{2\,(g)} + 12\ H_2O_{(g)}$

4. a. $CaCO_{3\,(s)} + 2\ HCl_{(aq)} \rightarrow CaCl_{2\,(aq)} + CO_{2\,(g)} + H_2O_{(g)}$

b. $MgCO_{3\,(s)} + 2\ HCl_{(aq)} \rightarrow MgCl_{2\,(aq)} + CO_{2\,(g)} + H_2O_{(g)}$

c. 1.000 g of lime contains 0.800 $CaCO_3$ and 0.200 $MgCO_3$.

$$0.800\text{ g CaCO}_3 \times \frac{1\text{ mol CaCO}_3}{100.05\text{ g CaCO}_3} \times \frac{1\text{ mol CO}_2}{1\text{ mol CaCO}_3} \times \frac{44.01\text{ g CO}_2}{1\text{ mol CO}_2} = 0.352\text{ g CO}_2$$

$$0.200\text{ g MgCO}_3 \times \frac{1\text{ mol MgCO}_3}{84.32\text{ g MgCO}_3} \times \frac{1\text{ mol CO}_2}{1\text{ mol MgCO}_3} \times \frac{44.01\text{ g CO}_2}{1\text{ mol CO}_2} = 0.104\text{ g CO}_2$$

total CO_2 = (0.352 g) + (0.104 g) = 0.456 g CO_2

d. 1.000 g of lime contains 0.800 $CaCO_3$ and 0.200 $MgCO_3$.

$$0.800\text{ g CaCO}_3 \times \frac{1\text{ mol CaCO}_3}{100.05\text{ g CaCO}_3} \times \frac{2\text{ mol HCl}}{1\text{ mol CaCO}_3} \times \frac{36.46\text{ g HCl}}{1\text{ mol HCl}} = 0.583\text{ g HCl}$$

$$0.200\text{ g MgCO}_3 \times \frac{1\text{ mol MgCO}_3}{84.32\text{ g MgCO}_3} \times \frac{2\text{ mol HCl}}{1\text{ mol CaCO}_3} \times \frac{36.46\text{ g HCl}}{1\text{ mol HCl}} = 0.173\text{ g HCl}$$

total HCl = (0.583 g) + (0.173 g) = 0.756 g HCl

e. 1.000 g mixture = (x g $CaCO_3$) + (y g $MgCO_3$)

$$\text{x g CaCO}_3 \times \frac{1\text{ mol CaCO}_3}{100.05\text{ g CaCO}_3} \times \frac{1\text{ mol CO}_2}{1\text{ mol CaCO}_3} \times \frac{44.01\text{ g CO}_2}{1\text{ mol CO}_2} = 0.440\text{x g CO}_2 \text{ from CaCO}_3$$

$$\text{y g MgCO}_3 \times \frac{1\text{ mol MgCO}_3}{84.32\text{ g MgCO}_3} \times \frac{1\text{ mol CO}_2}{1\text{ mol MgCO}_3} \times \frac{44.01\text{ g CO}_2}{1\text{ mol CO}_2} = 0.522\text{y g CO}_2 \text{ from MgCO}_3$$

0.500 g CO_2 = (0.440x g CO_2 from $CaCO_3$) + (0.522y g CO_2 from $MgCO_3$)

0.500 g CO_2 = (0.440x g CO_2) + (0.522 × (1.000–x) g CO_2)

0.500 g CO_2 = 0.522 g CO_2 – 0.082x g CO_2

$$\text{x} = \frac{(0.522 - 0.500)\text{ g CO}_2}{0.082\text{ g CO}_2} = 0.268$$

The mixture contains 0.268 g $CaCO_3$ and 0.732 g $MgCO_3$.