INTRODUCTION TO NATURAL SCIENCE

CHEMISTRY HOMEWORK – FALL 2006 – WEEK 5

Chapter 4

6 (a) $SF_4(g) + 2H_2O(l) \longrightarrow SO_2(g) + 4HF(l)$

sulfur tetrafluoride | water | sulfur dioxide | hydrofluoric acid

(b) $2NH_3(aq) + \frac{5}{2}O_2(aq) \longrightarrow 2NO(g) + 3H_2O(l)$

ammonia | oxygen | nitrogen monoxide | water

(c) $BF_3(g) + 3H_2O(l) \longrightarrow 3HF(aq) + H_3BO_3(aq)$

boron trifluoride | water | hydrofluoric acid | boric acid

7 $4Al(s) + 3O_2(g) \longrightarrow 2Al_2O_3(s)$

6.0 mol

Moles of O_2 needed = $6.0\,\text{mol Al} \times \boxed{\dfrac{3\,\text{mol } O_2}{4\,\text{mol Al}}} = \underline{\underline{4.5\,\text{mol}}}$

moles of Al_2O_3 produced = $6.0\,\text{mol Al} \times \boxed{\dfrac{2\,\text{mol } Al_2O_3}{4\,\text{mol Al}}} = \underline{\underline{3.0\,\text{mol}}}$

$3.0\,\text{mol } Al_2O_3 \times \boxed{\dfrac{102\,g}{1\,\text{mol } Al_2O_3}} = 306\,g = \underline{\underline{310\,g}}$

(10) $Fe_2O_3(s) + 3CO(g) \longrightarrow 2Fe(s) + 3CO_2(g)$

(a) $454\,g\ Fe_2O_3 \times \boxed{\dfrac{1\,mol}{160\,g\ Fe_2O_3}} = 2.8375\ mol$

moles of Fe produced $= 2.8375\ mol\ Fe_2O_3 \times \boxed{\dfrac{2\,mol\ Fe}{1\,mol\ Fe_2O_3}}$

$= 5.675\ mol\ Fe$

$= 5.675\ mol\ Fe \times \boxed{\dfrac{55.85\,g}{1\,mol\ Fe}}$

$= 316.95\,g$

$= \underline{\underline{317\,g}}$

(b) moles of CO required $= 2.8375\ mol\ Fe_2O_3 \times \boxed{\dfrac{3\,mol\ CO}{1\,mol\ Fe_2O_3}}$

$= 8.5125\ mol$

$8.5125\ mol\ CO \times \boxed{\dfrac{28\,g}{1\,mol\ CO}} = 238.35\,g\ CO$

$= \underline{\underline{238\,g\ CO}}$

(13) $2SO_2(g) + 2CaCO_3(s) + O_2(g) \rightarrow 2CaSO_4(s) + 2CO_2(g)$

(a) $155\,g\ SO_2 \times \boxed{\dfrac{1\,mol}{64\,g}} = \cancel{1.7969}\ mol\ SO_2$

2.4219

Moles of $CaCO_3$ required for the reaction $\Big\} = \overset{2.4219}{\cancel{1.7959}}$ mol SO_2 $\times \boxed{\dfrac{2\,mol\ CaCO_3}{2\,mol\ SO_2}}$

$= 2.4219$ mol $CaCO_3$

$= 2.4219$ mol $CaCO_3$ $\times \boxed{\dfrac{100\,g}{1\,mol\ CaCO_3}}$

$= \overset{242.19}{\cancel{179.69}}$ g $CaCO_3$

$= \cancel{179\,g}$ $\underline{\underline{242\,g}}$

(b) Moles of $CaSO_4$ formed $= 2.4219$ mol SO_2 $\times \boxed{\dfrac{2\,mol\ CaSO_4}{2\,mol\ SO_2}}$

$= 2.4219$ mol $CaSO_4$

$= 2.4219$ mol $\times \boxed{\dfrac{136\,g\ CaSO_4}{1\,mol}}$

$= 329.38\,g = \underline{\underline{329\,g}}$

17 (a) $4\,Cr(s) + 3\,O_2(g) \longrightarrow 2\,Cr_2O_3(s)$

(b) $0.175\,g\ Cr \times \boxed{\dfrac{1\,mol\ Cr}{51.996\,g}} = 3.366 \times 10^{-3}$ mol Cr

moles of Cr_2O_3 produced $\Big\} = 3.366 \times 10^{-3}$ mol Cr $\times \boxed{\dfrac{2\,mol\ Cr_2O_3}{4\,mol\ Cr}}$

$= 1.683 \times 10^{-3}$ mol Cr_2O_3

$= 1.683 \times 10^{-3}$ mol Cr_2O_3 $\times \boxed{\dfrac{151.992\,g}{1\,mol\ Cr_2O_3}}$

$$= 2.1558\ g \times 10^{-1}\ Cr_2O_3$$

$$= \cancel{2.56\ g}\ \ 0.256\ g$$

(c) moles of O_2 required $= 3.366 \times 10^{-3}\ mol\ Cr \times \boxed{\dfrac{3\ moles\ O_2}{4\ mol\ Cr}}$

$$= 2.5245 \times 10^{-3}\ mol\ O_2$$

$$= 2.5245 \times 10^{-3}\ mol\ O_2 \times \boxed{\dfrac{32\ g}{1\ mol\ O_2}}$$

$$= 8.078 \times 10^{-2}\ g\ O_2$$

$$= 8.08 \times 10^{-2}\ g\ O_2$$

18 (a & b)

$$C_2H_6\ (g) + \frac{7}{2} O_2(g) \longrightarrow \underbrace{2CO_2(g) + 3H_2O(g)}_{\text{products}}$$

(c)

$$13.6\ g\ C_2H_6 \times \boxed{\dfrac{1\ mol}{30\ g}} = 0.4533\ mol\ C_2H_6$$

Moles of O_2 required $= 0.4533\ mol\ C_2H_6 \times \boxed{\dfrac{7/2\ mol\ O_2}{1\ mol\ C_2H_6}}$

$$= 1.5867\ mol\ O_2$$

$$= 1.5867\ mol\ O_2 \times \boxed{\dfrac{32\ g}{1\ mol\ O_2}}$$

(d) Total mass of reactants = mass of C_2H_6 + mass of O_2

$= 13.6g + 50.8g$

$= 64.4g$

Due to law of conservation of mass

total mass of products = total mass of reactants

$= \underline{\underline{64.4\,g}}$

(19)

$$Na_2SO_4(s) + 4C(s) \rightarrow Na_2S(s) + 4CO(g)$$

15 g   7.5 g

moles of Na_2SO_4 = $15g \times \boxed{\frac{mol}{142g}} = 0.1056\,mol$

moles of C = $7.5g \times \boxed{\frac{mol}{12g}} = 0.625\,mol$

# of moles of C needed to react with 0.1261 mol of Na_2SO_4 $\Big\}$ = $\overset{0.1056}{\cancel{0.1261}}$ mol Na_2SO_4 $\times \boxed{\frac{4\,mol\ C}{1\,mol\ Na_2SO_4}}$

$= \overset{0.4225}{\cancel{0.5044}}$ mol C

We have excess C. Na_2SO_4 is the limiting reactant.

Mol. of Na_2S produced = $\overset{0.1056}{\cancel{0.1261}}$ mol Na_2SO_4 $\times \boxed{\frac{1\,mol\ Na_2S}{1\,mol\ Na_2SO_4}}$

$= \overset{0.1056}{\cancel{0.1261}}$ mol Na_2S

molar mass of Na_2S = $(2 \times 23 + 32)$ g/mol = 78 g/mol

$\cancel{0.1261}$ 0.1056 mol $Na_2S \times \boxed{\dfrac{78\,g}{1\,mol}}$ = $\cancel{9.8358}$ 8.236 g Na_2S

= $\cancel{9.8}$ 8.2 g Na_2S

(25) (a) $C_6H_{14}(l) + \frac{19}{2}O_2(g) \longrightarrow 6CO_2(g) + 7H_2O(g)$

$$\begin{array}{r} 12 \\ 7 \\ \hline 19 \end{array}$$

(b) 215 g 215 g

moles of C_6H_{14} = $215\,g \times \boxed{\dfrac{mol}{86\,g}}$ = 2.50 mol

moles of O_2 = $215\,g \times \boxed{\dfrac{mol}{32\,g}}$ = 6.719 mol

mol of O_2 needed to react with 2.50 mol of C_6H_{14} $\Big\}$ = 2.50 mol C_6H_4 $\times \boxed{\dfrac{\left(\frac{19}{2}\right) mol\ O_2}{1\,mol\ C_6H_{14}}}$

= 23.75 mol O_2

since we only have 6.719 mol O_2, O_2 is the limiting reactant.

moles of CO_2 produced = 6.719 mol $O_2 \times \boxed{\dfrac{6\,mol\ CO_2}{\frac{19}{2}\,mol\ O_2}}$

= 4.2436 mol CO_2

$= 186.718 \text{ g } CO_2$

$= \underline{\underline{187 \text{ g } CO_2}}$

Mass of H_2O produced $= 6.719 \text{ mol } O_2 \times \boxed{\dfrac{7 \text{ mol } H_2O}{\frac{19}{2} \text{ mol } O_2}}$

$= 4.9508 \text{ mol } H_2O$

$= 4.9508 \text{ mol } H_2O \times \boxed{\dfrac{18 \text{ g}}{1 \text{ mol } H_2O}}$

$= 89.115 \text{ g } H_2O = \underline{\underline{89.1 \text{ g } H_2O}}$

(c) hexane is the excess agent.

moles of hexane that reacts $= 6.719 \text{ mol } O_2 \times \boxed{\dfrac{1 \text{ mol } C_6H_{14}}{\frac{19}{2} \text{ mol } O_2}}$

$= 0.70726 \text{ mol } C_6H_4$

$= 0.70726 \text{ mol } C_6H_4 \times \boxed{\dfrac{86 \text{ g}}{1 \text{ mol } C_6H_{14}}}$

$= 60.824 \text{ g}$

Mass of hexane in excess $= 215 \text{ g} - 60.824 \text{ g}$

$= 154.176 \text{ g}$

$= \underline{\underline{154 \text{ g}}}$

(26) $C_6H_4(OH)COOH(s) + (CH_3CO)_2O(l) \longrightarrow C_6H_4(OCOCH_3)COOH(s) + CH_3COOH(l)$

salicylic acid 100. g

acetic anhydride 100. g

aspirin

molar mass of salicylic acid = 138.095 g/mol

molar mass of acetic anhydride = 102.062 g/mol

moles of salicylic acid = $100.\,g \times \boxed{\frac{mol}{138.095\,g}} = 0.7241\,mol$

moles of acetic anhydride = $100.\,g \times \boxed{\frac{mol}{102.062\,g}} = 0.9798\,mol$

moles of acetic anhydride needed to react with 0.7241 mol salicylic acid } = 0.7241 mol salicylic acid $\times \boxed{\frac{1\,mol\ acetic\ anhydride}{1\,mol\ salicylic\ acid}}$

= 0.7241 mol acetic anhydride

∴ We have excess of acetic anhydride. Salicylic acid is the limiting reagent.

moles of aspirin produced = 0.7241 mol salicylic acid $\times \boxed{\frac{1\,mol\ aspirin}{1\,mol\ salicylic\ acid}}$

= 0.7241 mol aspirin

molar mass of aspirin = 180.123 g/mol

$0.7241\,mol\ aspirin \times \boxed{\frac{180.123\,g}{1\,mol\ aspirin}} = 130.427\,g$

= $\underline{\underline{130.\,g}}$

(28) Theoretical yield = 68.0 g

actual yield = 16.3 g

Percent yield $= \dfrac{\text{actual yield}}{\text{theoretical yield}} \times 100\%$

$= \dfrac{16.3\,g}{68.0\,g} \times 100\% = 23.97\%$

$= \underline{\underline{24.0\%}}$

(30) (a) $2\,CH_3SH\,(l) + CO(g) \longrightarrow CH_3COSCH_3\,(l) + H_2S(g)$

10.0 g

molar mass of CH_3SH = 48.109 g/mol

$10.0\,g\ CH_3SH \times \boxed{\dfrac{mol}{48.109\,g}} = 0.2079\ mol\ CH_3SH$

moles of CH_3COSCH_3 produced $= 0.2079\,mol\ CH_3SH \times \boxed{\dfrac{1\,mol\ CH_3COSCH_3}{2\,mol\ CH_3SH}}$

$= 0.10393\ mol\ CH_3COSCH_3$

molar mass of CH_3COSCH_3 = 90.137 g/mol

$0.10393\,mol\ CH_3COSCH_3 \times \boxed{\dfrac{90.137\,g}{1\,mol\ CH_3COSCH_3}} = 9.3679\,g\ CH_3COSCH_3$

theoretical yield $= \underline{\underline{9.37\,g\ CH_3COSCH_3}}$

(b) actual yield = 8.65 g

$$\text{Percentage yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100\%$$

$$= \frac{8.659}{9.3679\,g} \times 100\% = 92.336\%$$

$$= \underline{\underline{92.3\%}}$$

33 $$CaCO_3(s) \longrightarrow CaO(s) + CO_2(g)$$

$0.558\,g$

molar mass of CO_2 = $43.991\ g/mol$

moles of CO_2 recovered $= 0.558\,g \times \boxed{\frac{mol}{43.991\,g}}$

$= 1.268 \times 10^{-2}\ mol\ CO_2$

moles of $CaCO_3$ reacted $= 1.268 \times 10^{-2}\ mol\,CO_2 \times \boxed{\frac{1\,mol\ CaCO_3}{1\,mol\ CO_2}}$

$= 1.268 \times 10^{-2}\ mol\ CaCO_3$

Molar mass of $CaCO_3$ = $100.059\ g/mol$

$1.268 \times 10^{-2}\ mol\ CaCO_3 \times \boxed{\frac{100.059\,g}{1\,mol\ CaCO_3}} = 1.2687\,g\ CaCO_3$

Mass percent of $CaCO_3$ in the limestone sample $\Big\} = \frac{1.2687\,g}{1.506\,g} \times 100\%$

$= 84.246\%$

$= \underline{\underline{84.2\%}}$