Mixed Stoichiometry Problems

1. Calculate the theoretical yield of hydrogen (in moles) when 200.0 g of aluminum metal is added to 4.31 L 6.00 M HCl(aq). $2\ Al(s) + 6\ HCl(aq) \rightarrow 2\ AlCl_3(aq) + 3\ H_2(g)$

2. A sealed room has 80.0 cubic feet of air with density 1.195 g/mL and containing 0.760 % $CO_2(g)$ by weight. How many grams of lithium hydroxide are needed to remove all the carbon dioxide gas from the room? $2\ LiOH(s) + CO_2(g) \rightarrow Li_2CO_3(s) + H_2O(l)$

3. Determine the molarity of the nitric acid solution prepared by reacting 168.0 g of $NO_2(g)$ with 800.0 mL of water. Assume the volume does not change. $3\ NO_2(g) + H_2O(l) \rightarrow 2\ HNO_3(aq) + NO(g)$

4. The reaction: $2\ KClO_3(s) \rightarrow 2\ KCl(s) + 3\ O_2(g)$ is used to supply emergency oxygen on airplanes.

   (a) How many moles of oxygen are required to fill 24.0 cubic meters of air at 745 torr and 72.0 °F so that it is 21.0 % $O_2(g)$ by volume? (b) How many kilograms of $KClO_3(s)$ are required to produce that much oxygen gas?

5. Nitroglycerine is explosive because it decomposes directly to gases according to:

   $$4\ C_3H_5(NO_3)_3(l) \rightarrow 12\ CO_2(g) + 10\ H_2O(g) + 6\ N_2(g) + O_2(g)$$

   a. What volume of gas at 100°C would be generated by the decomposition of 20.0 g of nitroglycerine at 1.00 atm?
   b. This reaction also generates enough heat to heat the gases to about 5000°C. Liquid nitroglycerine has a density of 1.594 g/mL. Determine the pressure exerted by the explosion of 20.0 g of trinitroglycerine in the space taken up by 20.0 g of liquid nitroglycerine.

6. Oxygen difluoride is produced by bubbling fluorine gas through aqueous sodium hydroxide:

   $$2\ F_2(g) + 2\ NaOH(aq) \rightarrow 2\ NaF(aq) + H_2O(l) + OF_2(g)$$

   How many grams of OF_2 can be produced by bubbling 40.0 liters of $F_2(g)$ at 2.30 atm and 32.0°C through 5.00 L of 2.10 M NaOH(aq)?

7. A 247.0-L tank of SF_6 contains 70.0 lb of gas. (a) What is the pressure in the tank at 22.0°C?

   (b) $SF_6(g)$ can be prepared according to : $S(s) + 3\ F_2(g) \rightarrow SF_6(g)$ How many tanks of $SF_6(g)$ can be made from **five** 26.2 L-tanks of $F_2(g)$ at 2.10 MPa at 22.0°C .

Answers: 1. Al is limiting, 11.12 mol H_2 **2.** 468. mol CO_2, so 22.4 kg LiOH

3. 2.43 mol HNO_3 per 800 mL is 3.04 M HNO_3 **4.** a. 203.4 mol O_2 b. 16.64 kg $KClO_3$

5. a. 2.55 mol gas = 78.2 L b. 8.76×10^4 atm = 1.29 million psi **6.** 99.2 g OF_2

7. a. 21.30 atm b. 1.67 tanks SF_6

Solutions:

1. ? mol rxn = 200.0 g Al $\times \frac{1 \text{ mol Al}}{26.98 \text{ g Al}} \times \frac{1 \text{ mol rxn}}{2 \text{ mol Al}}$ = 3.706 mol rxn so limiting

   ? mol rxn = 4.31 L soln $\times \frac{6 \text{ mol HCl}}{1 \text{ L soln}} \times \frac{1 \text{ mol rxn}}{6 \text{ mol HCl}}$ = 4.31 mol rxn

   ? mol H_2 = 3.706 mol rxn $\times \frac{3 \text{ mol } H_2}{1 \text{ mol rxn}}$ = 11.12 mol H_2

2. a. 80.0 $ft^3 \times \left(\frac{12 \text{ in}}{1 \text{ ft}}\right)^3 \times \left(\frac{2.54 \text{ cm}}{1 \text{ in}}\right)^3 \frac{1 \text{ mL}}{1 \text{ cm}^3} \times \frac{1.195 \text{ g}}{\text{mL}} \times \frac{0.760 \text{ g } CO_2}{100 \text{ g air}} \times \frac{1 \text{ mol } CO_2}{44.0 \text{ g } CO_2}$ = 468. mol CO_2

   b. ? kg LiOH = 468 mol $CO_2 \times \frac{2 \text{ mol LiOH}}{1 \text{ mol } CO_2} \times \frac{23.95 \text{ g LiOH}}{1 \text{ mol LiOH}} \times \frac{1 \text{ kg LiOH}}{1000 \text{ g LiOH}}$ = 22.4 kg LiOH

3. ? mol HNO_3 = 168 g $NO_2 \times \frac{1 \text{ mol } NO_2}{46.0 \text{ g } NO_2} \times \frac{2 \text{ mol } HNO_3}{3 \text{ mol } NO_2}$ = 2.43 mol HNO_3

   2.43 mol HNO_3 in 800 mL is $\frac{2.43 \text{ mol } HNO_3}{800 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}}$ = 3.04 M HNO_3

4. a. V = 24.0 $m^3 \times \left(\frac{100 \text{ cm}}{1\text{m}}\right)^3 \frac{1 \text{ L}}{1000 \text{ cm}^3} \times \frac{21.0 \text{ L } O_2}{100 \text{ L}}$ = 5040 L O_2

   n = $\frac{PV}{RT} = \frac{745 \text{ torr} \cdot 5040 \text{ L}}{0.08206 \frac{\text{L·atm}}{\text{mol·K}} 295.4 \text{ K}} \times \frac{1 \text{ atm}}{760 \text{ torr}}$ =203.8 mol

   b. ? kg $KClO_3$ = 203.8 mol $\times \frac{2 \text{ mol } KClO_3}{3 \text{ mol } O_2} \times \frac{122.5 \text{ g } KClO_3}{1 \text{ mol } KClO_3} \times \frac{1 \text{ kg}}{1000 \text{ g}}$ = 16.6 kg $KClO_3$

5. a. ? mol gas = 20.0 g nitroG $\times \frac{1 \text{ mol nitroG}}{227.1 \text{ g nitroG}} \times \frac{29 \text{ mol gas}}{4 \text{ mol nitroG}}$ = 0.6385 mol gas

   V = $\frac{nRT}{P} = \frac{0.6385 \text{ mol} \cdot 0.08206 \frac{\text{L·atm}}{\text{mol·K}} 373.15 \text{ K}}{1 \text{ atm}}$ = 19.6 L

   b. 20.0 g nitroG $\times \frac{1 \text{ mL}}{1.594 \text{ g}} \times \frac{1 \text{ L}}{1000 \text{ mL}}$ = 0.0126 L then use PV = nRT to calculate new pressure

   P = = $\frac{0.6385 \text{ mol} \times 0.08206 \frac{\text{L•atm}}{\text{mol•K}} \times 5273 \text{ K}}{0.0126 \text{ L}}$ = 2.19 x 10^4 atm $\times \frac{14.7 \text{ psi}}{1 \text{ atm}}$ = 322 thousand 1b/in^2 !

6. ? mol F_2 = n = $\frac{PV}{RT} = \frac{2.30\ \text{atm} \cdot 40.0\ \text{L}}{0.08206 \frac{\text{L·atm}}{\text{mol·K}} 305.15\ \text{K}} = 3.67\ \text{mol}\ F_2 \times \frac{1\ \text{mol rxn}}{2\ \text{mol}\ F_2} = 1.837\ \text{mol rxn (limiting)}$

? mol rxn = $5.00\ \text{L} \times \frac{2.10\ \text{mol NaOH}}{1\ \text{L}} \times \frac{1\ \text{mol rxn}}{2\ \text{mol NaOH}} = 5.25\ \text{mol rxn}$

$1.837\ \text{mol rxn} \times \frac{1\ \text{mol}\ OF_2}{1\ \text{mol rxn}} \times \frac{54.0\ \text{g}\ OF_2}{1\ \text{mol}\ OF_2} = 99.2\ \text{g}\ OF_2$

7. a. 1 tank SF_6 = $70.0\ \text{lb} \times \frac{453.6\ \text{g}}{1\ \text{lb}} \times \frac{1\ \text{mol}\ SF_6}{146.1\ \text{g}\ SF_6} = 217.3\ \text{mol}\ SF_6$

so P = $\frac{nRT}{V} = \frac{217.3\ \text{mol} \cdot 0.08206 \frac{\text{L·atm}}{\text{mol·K}} 295.15\ \text{K}}{247.0\ \text{L}} = 21.3\ \text{atm}$

b. 1 tank F_2 = ? mol F_2 = $\frac{PV}{RT} = \frac{2.10\ \text{MPa} \cdot 26.2\ \text{L}}{0.08206 \frac{\text{L·atm}}{\text{mol·K}} 295.15\ \text{K}} \times \frac{1\ \text{MPa}}{10^6\ \text{Pa}} \times \frac{10^3\ \text{Pa}}{1\ \text{kPa}} \times \frac{1\ \text{atm}}{101.3\ \text{kPa}} = 224.3\ \text{mol}\ F_2$

? tanks SF_6 = $5\ \text{tanks}\ F_2 \times \frac{224.3\ \text{mol}\ F_2}{1\ \text{tank}\ F_2} \times \frac{1\ \text{mol}\ SF_6}{3\ \text{mol}\ F_2} \times \frac{1\ \text{tank}\ SF_6}{217.3\ \text{mol}\ SF_6} = 1.72\ \text{tanks}\ SF_6$