AP CHEMISTRY

TOPIC 2: STOICHIOMETRY, PART B

Day 14:

Stoichiometry

- Limiting Reactants

Homework problems:

1) Consider the reaction: $Ca_{(l)} + Cl_{2\,(g)} \rightarrow CaCl_{2\,(s)}$

Identify the limiting reagent in each of the reaction mixtures below:

a) ***200 atoms of Ca*** and 300 molecules of Cl_2

$$\frac{200\ atoms\ Ca}{} \times \frac{1\ mol\ Ca}{6.02\times10^{23}\ atoms\ Ca} \times \frac{1\ mol\ Cl_2}{1\ mol\ Ca} \times \frac{6.02\times10^{23}\ molecules\ Cl_2}{1\ mol\ Cl_2} = 200\ molecules\ Cl_2$$

If 200 atoms of Ca react completely (NO atoms remain), one would need AT LEAST 200 molecules of Cl_2. Since one has MORE than 200 molecules of Cl_2 (100 molecules would remain after the reaction) – Calcium is the LIMITING REACT (L.R.) and extra (EXCESS) Cl_2.

b) ***0.16 mol Ca*** and 0.25 mol of Cl_2

$$\frac{0.16\ mol\ Ca}{} \times \frac{1\ mol\ Cl_2}{1\ mol\ Ca} = 0.16\ mol\ Cl_2$$

If 0.16 mol of Ca react completely (NO moles remain), one would need AT LEAST 0.16 moles of Cl_2. Since one has MORE than 0.16 moles of Cl_2 (0.09 moles would remain after the reaction) – Calcium is the LIMITING REACT (L.R.) and extra (EXCESS) Cl_2.

c) 50.0 grams of Ca and ***50.0 grams of Cl_2***

$$\frac{50.0\ g\ Ca}{} \times \frac{1\ mol\ Ca}{40.08\ g} \times \frac{1\ mol\ Cl_2}{1\ mol\ Ca} \times \frac{(2)35.45\ g}{1\ mol\ Cl_2} = 88.45\ g$$

Since there are ONLY 50.0 grams of Cl_2 – Ca **IS NOT** the limiting react.
There is not enough chlorine gas to completely react with the 50.0 grams of calcium.
Chlorine is the limiting reactant.

d) ***0.75 mol Ca*** and 60.0 grams of Cl_2

$$\frac{60.0\ g\ Cl_2}{} \times \frac{1\ mol\ Cl_2}{70.906\ g} \times \frac{1\ mol\ Ca}{1\ mol\ Cl_2} = 0.846\ mol\ Ca$$

Since there are ONLY 0.75 moles of Ca – Cl_2 **IS NOT** the limiting react.
There is not enough calcium to completely react with the 60.0 grams of chlorine gas.
Calcium is the limiting reactant.

2) Mercury and bromine gas, Br_2, will react with each other to produce mercury(I) bromide:

a) What is the mass of mercury(I) bromide can be produced from the reaction of 15.0 grams of Hg and 10.0 grams of Br_2?

$$\underline{\ 2\ }\ Hg_{(l)} + Br_{2\,(g)} \rightarrow \underline{\ 2\ }\ HgBr_{(s)}$$

$$\frac{15.0\ g\ Hg}{} \times \frac{1\ mol\ Hg}{200.59\ g} \times \frac{1\ mol\ Br_2}{2\ mol\ Hg} \times \frac{159.8\ g}{1\ mol\ Br_2} = 5.97\ g\ Br_2$$

Mercury is L.R. Think of it this way, If I used ALL 15.0 grams of Hg – I would have no Hg left over. Also, when I use all 15.0 grams of Hg, I will ONLY NEED 5.97 grams of Br_2.

- No Hg (remaining) and EXTRA Br_2 -

$$\frac{15.0\ g\ Hg}{} \times \frac{1\ mol\ Hg}{200.59\ g} \times \frac{2\ mol\ HgBr}{2\ mol\ Hg} \times \frac{280.5\ g}{1\ mol\ HgBr} = 21.0\ g\ HgBr$$

OR, and this is a "neat" trick if you have only ONE product…

15.0 g Hg + 5.97 g Br_2 = 21.0 g HgBr

b) What mass of which reactant is left un-reacted from above (part a)?

Br_2 10.0 g – 5.97 g = 4.03 g REMAIN

c) What is the mass of HgBr can be produced from the reaction of 5.00 mL of mercury (density 13.6 g/mL) and 5.00 mL of bromine (in the liquid state, Br_2) (density of 3.10 g / mL)?

$$\underline{\ 2\ }\ Hg_{(l)} + \underline{\quad}\ Br_{2\,(l)} \rightarrow \underline{\ 2\ }\ HgBr_{(s)}$$

$$\frac{5.00\ mL\ Hg}{} \times \frac{13.6\ g}{mL} \times \frac{1\ mol\ Hg}{200.59\ g} \times \frac{1\ mol\ Br_2}{2\ mol\ Hg} \times \frac{159.8\ g}{1\ mol\ Br} \times \frac{mL}{3.10\ g} = 8.74\ mL\ Br_2$$

Bromine is the Limiting Reactant. I would need AT LEAST 8.74 mL of Br_2 to react with ALL 5.00 mL of the Hg… Since I only have 5.00 mL of Br_2, the Br_2 will be totally consumed before the Hg.

$$\frac{5.00\ mL\ Br}{} \times \frac{3.10\ g}{mL} \times \frac{1\ mol\ Br_2}{159.8\ g} \times \frac{2\ mol\ HgBr}{1\ mol\ Br_2} \times \frac{280.5\ g}{1\ mol\ HgBr} = 54.4\ g\ HgBr$$

3) 75.0 grams of sucrose, $C_{12}H_{22}O_{11}$, reacts with 10.0 grams of oxygen gas in a combustion reaction. What is the mass of the water vapor produced when the reaction is complete?

$$\underline{\quad} \; C_{12}H_{22}O_{11\,(g)} + \underline{12}\; O_{2\,(g)} \rightarrow \underline{12}\; CO_{2\,(g)} + \underline{11}\; H_2O_{(g)}$$

$$\frac{10.0\ g\ O_2}{} \times \frac{1\ mol\ O_2}{32.00\ g} \times \frac{1\ mol\ C_{12}H_{22}O_{11}}{12\ mol\ O_2} \times \frac{342.31\ g}{1\ mol\ C_{12}H_{22}O_{11}} = 8.91\ g\ C_{12}H_{22}O_{11}$$

Oxygen is the Limiting Reactant, when all the oxygen is used, there will be 66 grams of sucrose remaining.

$$\frac{10.0\ g\ O_2}{} \times \frac{1\ mol\ O_2}{32.00\ g} \times \frac{11\ mol\ H_2O}{12\ mol\ O_2} \times \frac{18.016 g}{1\ mol\ H_2O} = 5.16\ g\ H_2O$$

Please Note: Since there are two products formed and the question is only asking about the mass of one of the products, one cannot added the reactant masses together to get the answer to the mass for water vapor…

Sorry…

4) Hydrogen cyanide gas, HCN, is produced industrially from the reaction of gaseous ammonia, oxygen, and methane:

$NH_{3\,(g)} + O_{2\,(g)} + CH_{4\,(g)} \rightarrow HCN_{(g)} + HOH_{(g)}$ (not balanced)

If 4.50 x 10^4 kg of each reagent is reacted, what mass of HCN will be produced?

$$\underline{2}\; NH_{3\,(g)} + \underline{3}\; O_{2\,(g)} + \underline{2}\; CH_{4\,(g)} \rightarrow \underline{2}\; HCN_{(g)} + \underline{6}\; H_2O_{(g)}$$

Determine the Limiting Reactant:

$$\frac{4.50\times10^4\ kg\ NH_3}{} \times \frac{1000\ g\ NH_3}{1\ kg} \times \frac{1\ mol\ NH_3}{17.03\ g} \times \frac{3\ mol\ O_2}{2\ mol\ NH_3} \times \frac{32.00\ g}{1\ mol\ O_2} \times \frac{1\ kg}{1000\ g} = 1.27\times10^5\ kg\ O_2$$

between these two: O_2 is L.R. and NH_3 is in Excess – NH_3 is out…

$$\frac{4.50\times10^4\ kg\ O_2}{} \times \frac{1000\ g\ O_2}{1\ kg} \times \frac{1\ mol\ O_2}{32.00\ g} \times \frac{2\ mol\ CH_4}{3\ mol\ O_2} \times \frac{16.0426\ g}{1\ mol\ CH_4} \times \frac{1\ kg}{1000\ g} = 1.50\times10^4\ kg\ CH_4$$

O_2 is the L.R. !!!

Because if we consumed ALL the oxygen gas, there would be CH_4 remaining…

How much HCN?

$$\frac{4.50\times10^4\ kg\ O_2}{} \times \frac{1000\ g\ O_2}{1\ kg} \times \frac{1\ mol\ O_2}{32.00\ g} \times \frac{2\ mol\ HCN}{3\ mol\ O_2} \times \frac{27.03\ g}{1\ mol\ HCN} = 2.53\times10^7\ g\ HCN$$