

① Exam - SE chemical sem III CBGS

② Subject - process calculation -

③ Subject code

Exam Date - 13/12/17

④ O/P code - 24093

Q 1A) Batch - 200 kg NaCl, 600 kg KCl

$$\text{wt. of NaCl in mix} = 200 \text{ kg}$$

$$\text{wt. of KCl in mix} = 600 \text{ kg}$$

$$\text{wt. % of NaCl} = \frac{200}{800} \times 100 = 25$$

$$\text{wt. % of KCl} = \frac{600}{800} = 75$$

$$\text{Moles NaCl} = \frac{200}{58.5} = 3.419 \text{ kmol}$$

$$\text{moles KCl} = \frac{600}{74.5} = 8.05 \text{ kmol}$$

$$\begin{aligned} \text{Total moles mix} &= 3.419 \text{ kmol} + 8.05 \text{ kmol} \\ &\quad \overbrace{\qquad\qquad\qquad}^{\text{---}} \quad \overbrace{\qquad\qquad\qquad}^{= 11.469 \text{ kmol}} \\ &= 11.469 \text{ kmol} \end{aligned}$$

$$\text{Molar \% NaCl} = \frac{3.419}{11.469} \times 100$$

$$= 29.8$$

$$\text{Molar \% KCl} = 100 - 29.8$$

$$= 78.19 \text{ kmol}$$

Q1 B

formula of calculating weight percent to get the answer.

Solution : Basis : 100 kg urea sample.

The sample contains 45% N by weight.

$$\text{Amount of N in the sample} = 0.45 \times 100 = 45 \text{ kg}$$

$$\text{Atomic weight of N} = 14, \text{ Molecular weight of } \text{NH}_2\text{CONH}_2 = 60$$

The relationship between urea and N on the molar basis is

$$1 \text{ kmol } \text{NH}_2\text{CONH}_2 \equiv 2 \text{ kmol N}$$

On the weight basis, it becomes

$$60 \text{ kg } \text{NH}_2\text{CONH}_2 \equiv 28 \text{ kg N} \rightarrow 45 = \text{kg of N}$$

It means that when the sample contains 28 kg N, its urea content must be 60 kg

$$\therefore \text{Actual urea in the sample} = \frac{60}{28} \times 45 = 96.43 \text{ kg}$$

$$\begin{aligned} \text{Weight \% actual urea content of the sample} &= \frac{\text{kg urea}}{\text{kg sample}} \times 100 \\ &= \frac{96.43}{100} \times 100 = 96.43 \end{aligned}$$

... Ans.

2 (a)

$$x_{\text{C}_6\text{H}_6} = 0.5$$

$$x_{\text{C}_6\text{H}_5\text{Cl}_2} = 0.5$$

$$M_w = 85$$

$$\text{feed} = \frac{500}{85} = 5.882 \text{ kmol}$$

$$F = 5.882 = D + W$$

$$0.5 \times 5.882 = 0.950 + 0.1W$$

$$D = 2.768$$

$$\begin{aligned} W &= 3.114 \\ \text{Benzene in feed} &= 0.5 \times 5.882 = 2.94 \\ &= 22.93 \text{ kg} \end{aligned}$$

$$\text{Toluene in feed} = 0.5 \times 5.882 \times 92$$

$$\text{Benzene in distillate} = 0.95 \times 2.768$$

$$= 2.61 \text{ kg}$$

$$\text{Toluene in distillate} = 12.733 \text{ kg}$$

$$\text{Toluene in residue} = 257.81 \text{ kg}$$

$$\text{Toluene in tea}$$

$$\text{Benzene in residue} = 24.29 \text{ kg} \rightarrow$$

Q 2 B-

Stoichiometry

Example 3.37 : The feed water to a reverse osmosis plant contains 5000 ppm dissolved solids. The feed to product ratio is 4 : 3 (on weight basis). The treated water leaving the plant contains 600 ppm solids. Find the dissolved solids in the concentrated stream (rejected stream).

Solution : Basis : 4 kg feed water.

$$\text{Dissolved solids in the feed} = 5000 \text{ ppm}$$

$$1 \text{ ppm} = 1 \text{ mg/kg}$$

We know that :

$$\left[\begin{array}{l} \text{Amount of dissolved} \\ \text{solids in the feed water} \end{array} \right] = \frac{5000}{1} \times 4 = 20000 \text{ mg}$$

As the ratio of feed to product is 4 : 3, the quantity of the product stream is 3 kg for 4 kg feed.

$$\text{Feed} = \text{Product stream} + \text{Concentrated stream}$$

We have :

$$\text{Amount of concentrated stream} = 4 - 3 = 1 \text{ kg}$$

$$\left[\begin{array}{l} \text{Amount of dissolved} \\ \text{solids in the treated water} \end{array} \right] = \frac{600}{1} \times 3 = 1800 \text{ mg}$$

Let 'x' ppm be the dissolved solids content of the concentrated stream.

Material Balance of Dissolved Solids :

$$\left[\begin{array}{l} \text{Dissolved solids} \\ \text{in feed water} \end{array} \right] = \left[\begin{array}{l} \text{Dissolved solids} \\ \text{in product} \end{array} \right] + \left[\begin{array}{l} \text{Dissolved solids} \\ \text{in conc. stream} \end{array} \right]$$

$$20,000 = 1800 + \frac{x}{1} \times 1$$

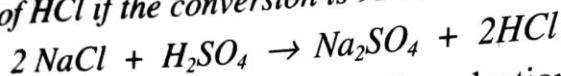
Solving, we get

$$x = 18200$$

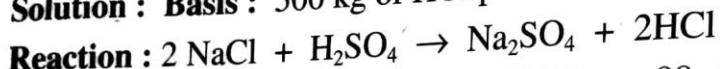
\therefore Dissolved solids content of the concentrated stream = 18200 ppm

Q 3 A

~~Consumption~~
Example 4.39 : Calculate the consumption of 90% NaCl and 93% H₂SO₄ to produce 500 kg of HCl if the conversion is 92%. The reaction taking place is :



Solution : Basis : 500 kg of HCl production.



Molecular weights : NaCl = 58.5, H₂SO₄ = 98, HCl = 36.5

From the reaction : 2 kmol NaCl \equiv 2 kmol HCl ... on mole basis

117 kg NaCl \equiv 73 kg HCl ... on weight basis

Conversion is 92%. As the purity of NaCl is 96%,

Actual amount of NaCl required / consumed

$$= \frac{117}{73} \left(\frac{500}{0.92 \times 0.96} \right) = 907.4 \text{ kg}$$

From the reaction : 1 kmol H₂SO₄ \equiv 2 kmol HCl

98 kg H₂SO₄ \equiv 73 kg HCl

As the conversion is 92% and purity of H₂SO₄ is 93%,

Actual amount of H₂SO₄ required / consumed

$$= \frac{98}{73} \times \left[\frac{500}{0.92 \times 0.93} \right] = 784.5 \text{ kg}$$

Q 3B

36 Example 4.60 : A furnace is burning fuel oil, assuming flue gases contain 10.6% CO_2 , 6% O_2 and the rest N_2 by volume. Find the C : H ratio in the fuel oil, assuming that the fuel oil does not contain nitrogen.

Solution : Basis : 100 kmol of dry flue gases.

It contains 10.6 kmol CO_2 , 6 kmol O_2 and 83.4 kmol N_2

We have :

$$1 \text{ mol } \text{CO}_2 = 1 \text{ mol } \text{O}_2$$

$$\therefore \text{O}_2 \text{ in } 10.6 \text{ kmol } \text{CO}_2 = \frac{1}{1} \times 10.6 = 10.6 \text{ kmol}$$

$$\begin{aligned}\text{O}_2 \text{ accounted} &= \text{O}_2 \text{ in } \text{CO}_2 + \text{O}_2 \text{ in flue gas} \\ &= 10.6 + 6 = 16.6 \text{ kmol}\end{aligned}$$

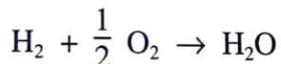
$$\text{N}_2 \text{ balance : } \text{N}_2 \text{ in air supplied} = \text{N}_2 \text{ in flue gas} = 83.4 \text{ kmol}$$

O_2 available from air (i.e., O_2 in the air supplied) based on 83.4 kmol N_2

$$= \frac{21}{79} \times 83.4 = 22.17 \text{ kmol}$$

$$\begin{aligned}\text{O}_2 \text{ unaccounted} &= \text{O}_2 \text{ in air} - \text{O}_2 \text{ accounted} \\ &= 22.17 - 16.6 = 5.57 \text{ kmol}\end{aligned}$$

5.57 kmol O_2 must have been utilised for the burning of hydrogen by the reaction:



$$\text{Hydrogen burnt} = \frac{1}{(1/2)} \times 5.57 = 11.14 \text{ kmol}$$

$$\text{Weight of carbon burnt} = 10.6 \times 12 = 127.2 \text{ kg}$$

(As 1 kmol C \equiv 1 kmol CO_2)

$$\text{Weight of hydrogen burnt} = 11.14 \times 2 = 22.28 \text{ kg}$$

$$\text{Carbon/hydrogen (w/w) ratio in the fuel} = \frac{127.2}{22.28} = 5.71 \text{ or } 5.71 : 1$$

Q4A

5.6

Stoichiometry

Recycle air

$$\text{Initial moisture (water) in the wet solids} = 0.2(100) = 20 \text{ kg}$$

$$\text{Solids (bone-dry) in the wet solids} = 100 - 20 = 80 \text{ kg}$$

Let the final moisture in the product solids be $y \text{ kg}$.

Solids (dried) contain 1% moisture.

$$\therefore \left(\frac{y}{80+y} \right) \times 100 = 1.0$$

$$y = 0.81 \text{ kg}$$

$$\text{Moisture removed from the solids} = 20 - 0.81 = 19.19 \text{ kg/h}$$

Let the moisture in the mixed air be $x \frac{\text{kg water}}{\text{kg dry air}}$

Moisture / Water Balance at inlet to the Dryer :

$$\text{Moisture in mixed air} = \text{Moisture in fresh air} + \text{Moisture in recycle air}$$

$$x \cdot M' = 0.02 F' + 0.1 R'$$

$$= 0.02 F' + 0.1 \times 3F' \quad \dots \dots \text{ (as } R' = 3F)$$

$$x \cdot M' = 0.32 F'$$

We have,

$$M' = 4F'$$

$$\therefore x(4F') = 0.32 F'$$

$$\therefore x = 0.08$$

Material Balance of Moisture over Dryer :

$$\text{Moisture gained by air} = \text{Moisture removed from solids}$$

$$0.1 M' - 0.08 M' = 19.19$$

$$\therefore M' = 959.5 \text{ kg/h}$$

$$M' = 4F'$$

$$\therefore F' = 959.5/4 = 239.8 \text{ kg/h}$$

$$\text{Water associated with dry air in the fresh air} = \frac{0.02}{1} \times 239.8 = 4.8 \text{ kg/h}$$

$$\therefore \text{Fresh air fed to the dryer} = 239.8 + 4.8 = 244.6 \text{ kg/h}$$

$$\text{Moles/h fresh air entering the dryer} = n'$$

$$\therefore n' = \frac{244.6}{28.8} = 8.5 \text{ kmol/h}$$

If V' is the volumetric flow rate of the fresh air, then

$$V' = \frac{n'RT}{P}$$

where, $n' = 8.5 \text{ kmol/h}$, $P = 101.325 \text{ kPa}$, $R = 8.31451 \text{ m}^3 \cdot \text{kPa}/(\text{kmol} \cdot \text{K})$, $T = 303 \text{ K}$

$$\therefore \text{Volumetric flow rate of the fresh air} = \frac{8.5 \times 8.31451 \times 303}{101.325} = 211.34 \text{ m}^3/\text{h}$$

Q 5 A,B

Q. 5 b) Limiting reactant -

defined as reactant that would disappear first if a reaction goes to completion.

Excess Reactant -

defined as reactant which is in excess of theoretical or stoichiometric requirement as determined by desired reactant.

Percent excess -

$$\text{Percent excess of A} = \left[\frac{\text{moles of A supplied} - \text{moles of A theoretically required}}{\text{moles of A theoretically required}} \right] \times 100$$

Conversion -

is the fraction of reactants that has been converted into reaction products.

$$\text{conversion} = \frac{\text{mols of A reacted}}{\text{mols of A charged}} \times 100$$

Yield - ratio of quantity of desired product actually produced to its maximally obtainable quantity.

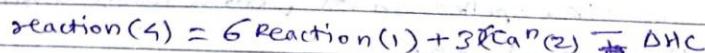
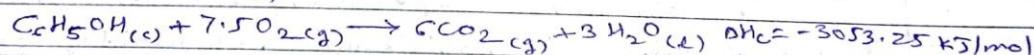
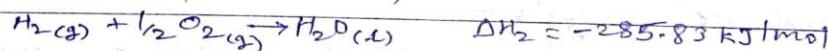
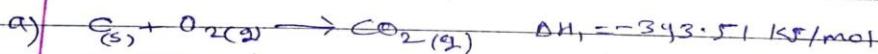
Selectivity - $\frac{\text{moles of desired product formed}}{\text{moles of undesired product formed}}$

$$Q = n \int_{T_1}^{T_2} C_p^\circ dT$$

$$n=1, T_1 = 303 \text{ K}, T_2 = 523 \text{ K}$$

$$Q = 9234.9 + 4735 + 459.9 + 187.8$$

$$Q = 9242 \text{ kJ}$$



$$= (-2361.0) + (857.49) - (-3053.25)$$

$$= -3218.58 + 3053.25 = -165.3 \text{ kJ/mol}$$