SE Chem. Sem- III
Process Calculations
Model Answersheet Q.P. Code = 24089

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Q.1 A) Basis : 100 kg of compound

Amount of carbon = $\frac{81.5}{100} \times 100 = 81.5$ kg

kg atoms of carbon = $\frac{81.5}{12} = 6.795 \simeq 7.0$

Amount of hydrogen = $\frac{4.9}{100} \times 100 = 4.9$ kg

kg atoms of hydrogen = $\frac{4.9}{1} = 4.9 \simeq 5.0$

Amount of nitrogen = $\frac{13.6}{100} \times 100 = 13.6$

kg atoms of nitrogen = $\frac{13.6}{14} \simeq 1.0$

Hence, formula of the compound is C_7H_5N

B) Basis - 1 kg Calcium carbide

Reaction is, $CaC_2 + 2H_2O \longrightarrow C_2H_2 + Ca(OH)_2$

Molecular wt. of $CaC_2 = 64$

moles of $CaC_2 = \frac{1}{64} = 0.01562$ kmol

From eqn,

1 kmol $CaC_2 \equiv$ 1 kmol C_2H_2

i.e. 1 kmol C_2H_2 is produced from 1 kmol CaC_2

$\therefore$ moles of C_2H_2 produced from $CaC_2 = \frac{1}{1} \times 0.01562$

$= 0.01562$ kmol

we have, $PV = nRT$

$V = \frac{nRT}{P}$

$\therefore$ volume of C_2H_2, $V = \frac{0.01562 \times 8.3145 \times 293}{98.6586}$

$\because$ 740 mm Hg = 98.6586 kPa

$V = 0.3857\ m^3 = 385.7$ lit

Burning rate of acetylene gas = 60 lit/hr

$\therefore$ No. of hours of service = $\frac{\text{volume of acetylene gas}}{\text{Burning rate of acetylene}}$

$= \frac{385.7}{60} = 6.4283$ hrs

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Q.2 A) Basis :- 100 kg of sodium carbonate 25% solution

Let,

C = crystals formed

E = water evaporated

M = mother liquor

Water present in solution = 75 kg

water evaporated = $75 \times 0.15 = 11.25$ kg

$$F = C + E + M = C + 11.25 + M$$

or $100 - 11.25 = C + M$

$$\therefore M = 88.75 - C$$

Mol. wt. of $Na_2CO_3 \cdot 10H_2O = 286$

$$x_C = \frac{106}{286} = 0.371$$

$$x_M = \frac{21.5}{121.5} = 0.177$$

Na_2CO_3 balance is,

$$F \cdot x_F = M \cdot x_M + C \cdot x_C$$

$$100 \times 0.25 = (88.75 - C) \times 0.177 + 0.371\,C$$

solving, we get,

$$C = 47.94 \text{ kg}$$

Crystals formed = 47.94 kg

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Q.2 B) Basis – 2 litres of NH_3

$PV = nRT$

n = No. of moles of $NH_3 = \frac{PV}{RT}$

Given,

$P = 20.265\ kPa$, $T = 303\ K$, $V = 2\ l$

$R = 8.31451\ m^3.kPa/(kmol.K) = 8.31451\ l.kPa/(mol.K)$

$\therefore n = \frac{20.265 \times 2}{8.31451 \times 303} = 0.01609\ mol$

The neutralisation reaction is,

$2NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4$

from reaⁿ, for neutralisation of 2 moles of NH_3,

1 mole of H_2SO_4 is required.

$\therefore$ moles of H_2SO_4 required $= \frac{1}{2} \times 0.01609$

$= 8.045 \times 10^{-3}\ mol$

Amount of H_2SO_4 required $= 8.045 \times 10^{-3} \times 98 = 0.788\ gm$

Gram equivalents of H_2SO_4 required $= \frac{0.788}{49} = 0.01609$

Volume of H_2SO_4 solution $= 135\ ml = 0.135\ l$

Normality of acid $= \frac{0.01609}{0.135} = 0.12\ N$

Q.2 C) Basis – 100 kg of the sample.

The nitrogen content of the sample is 34.5 % by wt.

$\therefore$ Amount of nitrogen in sample $= 0.345 \times 100 = 34.5\ kg$

Mol. wt. of $NH_4NO_3 = 80$, Atomic wt. of Nitrogen $= 14$

Now,

1 kmol $NH_4NO_3 \equiv$ 2 katom N

on weight basis,

80 kg $NH_4NO_3 \equiv$ 28 kg N

$\therefore$ Amount of NH_4NO_3 in sample $= \frac{80}{28} \times 34.5 = 98.57$

$\therefore$ % NH_4NO_3 content of sample $= \frac{98.57}{100} \times 100 = 98.57$

$\therefore$ Actual ammonium nitrate content of sample is 98.57 %

Q.3 A) Given,

$V = 1000\ m^3$,

Partial pressure ratio, $P_{H_2} : P_{N_2} : P_{CO_2} = 1:4:3$

total pressure = 2 atm, $T = 150°C = 423\ K$,

$R = 0.08206\ m^3.atm/(kmol.K)$

$$n = \frac{PV}{RT} = \frac{2 \times 1000}{0.08206 \times 423} = 57.6180$$

Total no. of moles = 57.6180

moles of $H_2 = \frac{1}{8} \times 57.6180 = 7.2022$

moles of $N_2 = \frac{4}{8} \times 57.6180 = 28.809$

moles of $CO_2 = \frac{3}{8} \times 57.6180 = 21.6068$

mole fraction of $H_2 = \frac{7.2022}{57.6180} = 0.125$

mole fraction of $N_2 = \frac{28.809}{57.6180} = 0.5$

mole fraction of $CO_2 = \frac{21.6068}{57.6180} = 0.375$

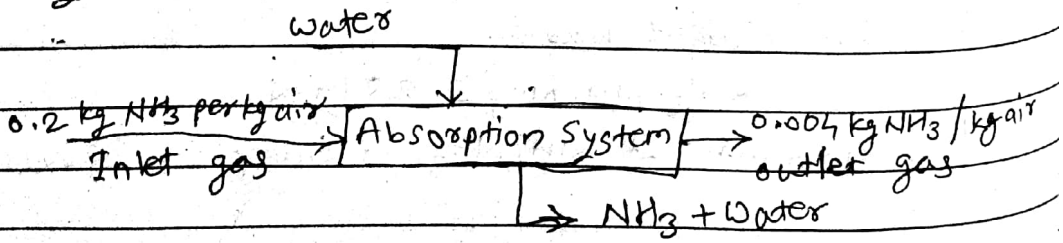
Avg. molecular wt. of mixture $= [M_{H_2} \times x_{H_2} + M_{N_2} \times x_{N_2} + M_{CO_2} \times x_{CO_2}]$

$\therefore M_{avg} = [(2 \times 0.125) + (28 \times 0.5) + (44 \times 0.375)]$

$= 0.25 + 14 + 16.5$

$M_{avg} = 30.75$

Q.3 B) Basis :- 1 kg of air in the gas inlet to the absorption system.



Ammonia in the inlet gas to the absorption system $= \frac{0.2}{1} \times 1 = 0.2\ kg$

In this operation, air is inert component.

∴ Air in the gas leaving the system = Air in inlet gas = 1 kg

NH_3 in the gas leaving the system = $\frac{0.004}{1} \times 1 = 0.004$ kg

Material balance of NH_3

NH_3 in gas entering = NH_3 in gas leaving + NH_3 absorbed

$0.2 = 0.004 + NH_3$ absorbed

∴ NH_3 absorbed = $0.2 - 0.004 = 0.196$ kg

∴ % recovery of NH_3 = $\frac{NH_3 \text{ absorbed}}{NH_3 \text{ in gas inlet}} \times 100$

$= \frac{0.196}{0.2} \times 100 = 98$

Q.4A) Basis :- 100 kg of cake formed.

Reaction -

$$CaCO_3 + H_2SO_4 \longrightarrow CaSO_4 + CO_2 + H_2O$$

Amount of $CaSO_4$ formed = 86.54 kg

$CaCO_3$ consumed = $\frac{100}{136} \times 86.54 = 63.63$ kg

$CaCO_3$ unconverted = 3.11

a) Degree of completion of reaction

$= \frac{63.63}{63.63 + 3.11} \times$

$= 95.34$

b) Acid used = $\frac{98}{136} \times 86.54 = 62.36$ kg

acid in cake = 1.35 kg

acid supplied = $62.36 + 1.35 = 63.71$ kg

Lime stone used = $63.63 + 3.11 + 2.77 = 69.51$ kg

69.51 kg limestone require 63.71 kg H_2SO_4

∴ 1000 kg limestone require

$= \frac{63.71}{69.51} \times 1000 = 916.56$ kg H_2SO_4

∴ Acid solution fed = $\frac{916.56}{0.7} = 1309.37$ kg

c) Water in acid = 1309.37 − 916.56 = 392.81 kg

water formed = $\frac{18}{100} \times 68.63$

= 11.45 kg (per 69.51 kg limestone)

∴ Total water formed by reaⁿ.

= $\frac{11.45}{69.51} \times 1000$ = 164.72 kg

Amount of water (acid solution and reaction)

= 392.81 + 164.72 = 557.53 kg

water left in cake per 1000 kg of limestone

= $\frac{6.23}{69.51} \times 1000$ = 89.63 kg

∴ water evaporated = 557.53 − 89.63 = 467.9 kg

CO_2 formed = $\frac{44}{100} \times 63.63$ = 28.00 kg

For 1000 kg limestone,

CO_2 formed = $\frac{44}{100} \times \frac{28}{69.51} \times 1000$ = 402.82 kg

Mass of gas driven off = 467.90 (H_2O) + 402.82 (CO_2)

= 870.72 kg

d) Composition of gases driven off:

Constituent	Weight (kg)	kg mol	Mol %
CO_2	402.82	9.155	26.06
H_2O	467.90	25.994	73.95
	Total	35.149	100

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Q.5A) Basis :- 1 mol of gaseous n-heptane

1) $C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$, $\Delta H_1 = -393.51$ kJ/mol

2) $H_{2(g)} + \frac{1}{2} O_{2(g)} \rightarrow H_2O_{(l)}$, $\Delta H_2 = -285.83$ kJ/mol

3) $C_7H_{16(g)} + 11 O_{2(g)} \rightarrow 7 CO_{2(g)} + 8 H_2O_{(l)}$

$\Delta H_c^\circ = -4853.43$ kJ/mol

4) $7 C_{(s)} + 8 H_{2(g)} \rightarrow C_7H_{16(g)}$, $\Delta H^\circ_{f_{C_7H_{16}}} = ?$

$\Delta H^\circ_{f_{C_7H_{16}}}$ = Standard heat of formation of $C_7H_{16(g)}$

Reaction(4) = 7 Reaction(1) + 8 Reaction(2) − Reaction(3)

$\Delta H^\circ_{f_{C_7H_{16(g)}}} = 7\Delta H_1 + 8\Delta H_2 - \Delta H_c^\circ$

$= 7(-393.51) + 8(-285.83) - (-4853.43)$

$= -5041.21 + 4853.43$

$\Delta H_f^\circ = -187.78$ kJ/mol

Q.5B) Basis – 100 kmol/min of CO_2

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

$$= n \int_{T_1}^{T_2} (21.3655 + 64.2841 \times 10^{-3} T - 41.0506 \times 10^{-6} T^2 + 9.7999 \times 10^{-9} T^3) \, dT$$

$$= n \left[21.3655 (T_2 - T_1) + \frac{64.2841 \times 10^{-3}}{2} (T_2^2 - T_1^2) - \frac{41.0506 \times 10^{-6}}{3} (T_2^3 - T_1^3) + \frac{9.7999 \times 10^{-9}}{4} (T_2^4 - T_1^4) \right]$$

$n = 100$ kmol/min, $T_2 = 383$ K, $T_1 = 298$ K

$$\therefore \Phi = 100 \left[21.3655 (383 - 298) + \frac{64.2841 \times 10^{-3}}{2} (383^2 - 298^2) - \frac{41.0506 \times 10^{-6}}{3} (383^3 - 298^3) + \frac{9.7999 \times 10^{-9}}{4} (383^4 - 298^4) \right]$$

$\Phi = 330335.5$ kJ/min

$= 5505.6$ kJ/s

$\Phi = 5505.6$ kW