

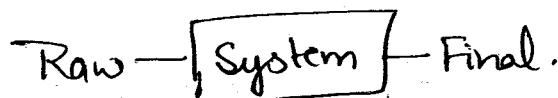
PC PROCESS CALCULATION

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- After mailing within 2 minute you will get all subject note's
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- Very soon we will update you with well organized printed material & practice papers :

Thanks to all of You :

↳ Unit operation - physical

↳ Unit process - chem



Units & Dimensions :-

Dimensions :-

eg:- length, mass, temp, volume, velocity.

Physical variables required to define the nature & characteristic of the ~~nature~~ system or object.

↳ Primary - (fundamental) \rightarrow Independent dimension & measurable. time, length, mass, temp, etc.

↳ Secondary - (Derived) \rightarrow Combination of fundamental dimension. volume, speed, density.

Units :-

To characterize (define) the dimensions.

time \rightarrow sec, hrs, min, yrs, days

Mass \rightarrow kg, g, lb

temp \rightarrow K, R, °C, F

Unique units are associated with unique dimensions.

System of Units	mass	time	temp.	length
↳ MKS System (metric System)	kg	sec	°C	m
↳ FPS System	lb	sec	°F	ft
↳ CJS System	g	sec	°C	cm
↳ SI System (System International)	kg	sec	K	m
Dimension	M	T	or θ K	L

Derived Units

force

$$F = ma$$

$$F = kg \text{ m/s}^2 = [MLT^{-2}]$$

1N

Force required to displace the 1 kg of mass with
acc. of $1 \text{ m}^2/\text{sec}^2$

$$\underbrace{1 \text{ N}}_{\text{SI}} = \underbrace{1 \text{ kg} \cdot 1 \text{ m/s}^2}_{\text{MKS}}$$

C·g·s

$$1 \text{ kg m/s}^2 = 1 \text{ kg} \cdot \frac{\text{m}}{\text{s}^2} \left(\frac{10^3 \text{ g}}{1 \text{ kg}} \right) \times \left(\frac{100 \text{ cm}}{1 \text{ m}} \right)$$

$$1 \text{ N} = 1 \text{ kg} \cdot \text{m/s}^2 = 10^8 \text{ g} \cdot \text{cm/s}^2$$

In G.R.S System,

$$1 \text{ dyne} = 1 \text{ g} \cdot \text{cm/g}^2$$

$$1 \text{ N} = 10^5 \text{ dyne}$$

$$1 \text{ lb} = 0.4536 \text{ kg}$$

$$1 \text{ ft} = 0.3048 \text{ m}$$

$$1 \text{ ft} = 12 \text{ inch}$$

1 inch = 2.54 cm

$$1 \text{ kg}\cdot\text{m/s}^2 = 1 \text{ lb}\cdot\text{ft/s}^2$$

Mars \rightarrow Kg. lbm

$$\underline{\text{Weight}} \rightarrow \text{mass} \times g = \text{kg} \times \frac{m}{s^2} = N = \text{lb}_f$$

$$H = 80\text{kg}$$

$$W_{earth} = 80 \times 9.81 \text{ m/s}^2$$

$$W_{\text{moon}} = 80 \text{ kg} \times \frac{1}{6} \times 9.81 \text{ m/s}^2$$

* Pressure

$$P = \frac{F_N}{A} = \frac{N}{m^2}$$

4

$$1 Pa = 1 N/m^2$$

$$P = \rho h g$$

$$P = \frac{kg}{m^3} \times \rho \times \frac{m}{s^2} = \frac{kg \cdot m}{m^2 \cdot s^2} = 1 N/m^2 =$$

$$1 atm = 101325 Pa \text{ or } (N/m^2) = 1.01325 bar$$

$$1 bar = 10^5 Pa \text{ascal}$$

$$1 atm = 760 \text{ mm Hg} = 760 \text{ torr}$$

$$1 \text{ mm Hg} = (1 \text{ torr})$$

$$1 atm = 101.325 \text{ kPa} = 101.325 \text{ KN/m}^2$$

$$= 101.325$$

$$= 101325 \text{ kPa} = 101325 \text{ N/m}^2$$

$$= 101325 \text{ } (kg \cdot m/s^2)/m^2$$

$$= 101325 \text{ } \left(\frac{lbm \cdot ft/s^2}{ft^2} \right)$$

$$g = 9.81 \text{ m/sec}^2 = ft/s^2$$

$$\frac{lbf}{ft^2} = \frac{lbf}{in^2}$$

$$= 101325 \text{ lbf/in}^2$$

$$1 atm = 14.7 \text{ psi}$$

pound per sq. ineh.

* Work

$$W = F \times d$$

$$1 J = 1 N \times m = \frac{kg \cdot m}{s^2} \times m$$

$$1 J = kg \cdot m^2/s^2 \quad [ML^2T^{-2}]$$

$$1 J = 1 \cdot Nm = 1 \text{ kgm}^2/s^2 = \frac{10^3 g \times (10^2 \text{ cm})^2}{s^2}$$

$$= 10^7 \text{ g cm}^2/\text{s}^2$$

(3)

$$1 \text{ erg} = 1 \text{ g cm}^2/\text{s}^2$$

$$1 \text{ J} = 10^7 \text{ erg}$$

* Power

$$P = W/t$$

$$1 \text{ hp} = 745.7 \text{ W}$$

$$1 \text{ W} = 1 \text{ J/sec} = 1 \cdot \text{Nm/sec}$$

$$\frac{\left(\frac{\text{kg m}}{\text{s}^2}\right) \text{m}}{\text{s}} = \frac{\text{kg m}^2}{\text{s}^3} = [\text{ML}^2\text{T}^{-3}]$$

* Energy

Heat, PE, KE

$$PE = mgh = \text{kg} \cdot \frac{\text{m}}{\text{s}^2} \cdot \text{m} = \text{kg m}^2/\text{s}^2 = \text{N/m} = \text{Joule.}$$

$$KE = \frac{1}{2}mv^2 = \text{kg}(\text{m/s})^2 = \text{kg m}^2/\text{s}^2 = \text{N m} = \text{Joule.}$$

Heat \rightarrow Joule (mech. unit)
 \rightarrow Cal (actual)

$$1 \text{ Cal} = 4.1858 \text{ J}$$

$10^{-1} \rightarrow$ deca (da)

$10^{-1} \rightarrow$ deci (d)

$10^{-2} \rightarrow$ Centi (c)

$10^{-3} \rightarrow$ mili (m)

$10^2 \rightarrow$ hecto (h)

$10^3 \rightarrow$ kilo (k)

$10^{-6} \rightarrow$ micro (μ)

$10^{-9} \rightarrow$ nano (n)

$10^{-12} \rightarrow$ Pico (p)

$10^6 \rightarrow$ mega (M)

$10^9 \rightarrow$ giga (G)

$10^{12} \rightarrow$ tera (T)

Q7 T1

1:

1

Q7 J

F

k

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2>

Q7 The flow rate of water through a pipe is reported as 15 ft³/min. The density of water is 1 g/cm³. Calculate the mass flow rate kg/s?

$$m^o = 15 \frac{\text{ft}^3}{\text{min}} \times 1 \text{ g/cm}^3$$

$$= 15 \frac{\text{ft}^3}{\text{min}} \times \frac{1}{\text{cm}^3} \times \frac{1 \text{ min}}{60 \text{ sec}} \times \frac{1 \text{ kg}}{1000 \text{ g}} \times \frac{0.3048 \text{ m}}{1 \text{ ft}^3} \times \frac{1 \text{ cm}}{10^2 \text{ m}}$$

$$= 7.079 \text{ kg/sec.}$$

Q7 In SI system, thermal conductivity has the unit of W/mK.

For a solid material thermal conductivity is given by

$$K = \frac{\pi \cdot Q}{A \cdot \Delta T} \text{ where } Q = \text{rate of heat transfer}, \pi = \text{thickness of material}, A = \text{cross-sectional area}, \Delta T = \text{temp diff.}$$

For an experiment the values are found to be $Q = 10000 \text{ KJ/h}$, $A = 1 \text{ m}^2$, $\pi = 100 \text{ mm}$, $\Delta T = 800 \text{ K}$. Calculate

i) K in W/mK

ii) K in $\text{Kcal/mhr}^{\circ}\text{C}$

i)

$$K = \frac{100 \text{ mm} \times 10000 \text{ KJ/h}}{1 \text{ m}^2 \times 800 \text{ K}}$$

$$g = 9.80658 \text{ m/sec}^2$$

$$= \frac{10^6}{800} \frac{\text{mm} \times \text{KJ}}{\text{h} \times \text{m}^2 \times \text{K}} \times \frac{10^{-3} \text{ m}}{1 \text{ mm}} \times \frac{1 \text{ hr}}{3600 \text{ sec}} \times \frac{1000}{11 \text{ C}}$$

$$= 0.347 \text{ W/mK.}$$

2) $0.347 \frac{\text{J}}{\text{mSK}} \times \left(\frac{1 \text{ Cal}}{4.1868 \text{ J}} \right) \times \left(\frac{3600 \text{ sec}}{1 \text{ hr}} \right) \left(\frac{1 \text{ K}}{1^{\circ}\text{C}} \right)$

$$298.628 \text{ Cal/mhr}^{\circ}\text{C}$$

$$0.29862 \text{ Kcal/mhr}^{\circ}\text{C}$$

$\Delta T = \text{K}$
 $\Delta T = ^{\circ}\text{C}$

Q.) The potential energy of a body at a height of 15m 7

⇒ 2KJ. If the body is moving with the velocity of 50 m/sec. What is the KE. $g = 9.8067 \text{ m/sec}^2$

$$PE = mgh$$

$$2 \text{ KJ} = m \times 9.8067 \frac{\text{m}}{\text{s}^2} \times 15 \text{ m}$$
$$2 \times 10^3 \text{ J} \quad \text{kg}$$

$$\frac{2 \text{ KJ} \times \text{s}^2 \times 10^3}{9.8067 \times \text{m} \times 15 \text{ m}} = m$$

$$0.0135 \times 10^3 \frac{\text{KJ s}^2}{\text{m}^2} = m$$

$$KE = \frac{1}{2} m v^2$$

$$= \frac{1}{2} \times 0.0135 \times 10^3 \frac{\text{KJ s}^2}{\text{m}^2} \times 50 \times 50 \frac{\text{m}^2}{\text{sec}^2}$$
$$= 16.99 \text{ J/s}$$
$$\times 10^3$$
$$= 16.99 \text{ KJ},$$

↳ Dimensional Consistency : —

$$f(n=0)$$

In any algebraic relation or eqn, the units of L.H.S=R.H.S

→ Addition of two quantity is possible only when then have same dimension & same unit.

Q.) $E = mc^2$

$$J = \text{Kg} \cdot (\text{m/s})^2$$

N.m

$$\left(\frac{\text{Kgm}}{\text{s}^2} \right) \text{m} = \text{Kgm}^2/\text{s}^2$$

$$[\text{ML}^2\text{T}^{-2}] = [\text{ML}^2\text{T}^{-2}]$$

Q.)

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Bunc

15m
y of

Q. 7

$$\frac{d}{dx} \left[\frac{x}{\sqrt{1+ax^2}} \right] = \frac{2ax}{(\sqrt{1+ax^2})^2}$$
$$m \neq m^2$$

(8)

$$\begin{aligned} \text{Unit} &= a_m \text{ Unit} \\ 1 &= a_m \\ a &\rightarrow m \end{aligned}$$

Dimensionally not consistent.

* Dimensional Analysis:-

→ To relate the dependent & independent variable for any system.

↳ Rayleigh Method

↳ Businger Π theorem.

Rayleigh Method:-

Used only when total no. of variable $n = (3-s)$

* $Q = f(g, M, V)$

\downarrow density \uparrow velocity
viscosity

$$Q \propto g^a M^b V^c$$

$$Q = C g^a M^b V^c$$

$$[M^0 L^3 T^{-1}] = C [M L^{-3} T^0]^a [M L^{-1} T^{-1}]^b [L T^{-1}]^c$$

$$M: a+b=0$$

$$L: -3a-b+c=3$$

$$T: -b-c=1$$

$$a=2$$

$$b=2$$

$$c=-1$$

$$Q = C g^2 M^2 V^{-1}$$

$$Q = \frac{C M^2}{g^2 V}$$

Businger Π -theorem:-

first convert them to dimensionless variables (Π)

no. of Π terms $= n-m$

$n \rightarrow$ total no. of variables

$m \rightarrow$ total no. of repeating fundamental dimension

$\begin{matrix} M \\ L \\ T \\ O \end{matrix}$

$$\Pi_1 = f(\Pi_2, \Pi_3, \dots, \Pi_{n-m})$$

Π_1 = f (dependent variable)

$$Q_\alpha = f(\beta, d, u, v, g)$$

$$n=6 \quad m=3 \quad \frac{(\beta, d, u)}{m=3}$$

$$D=6-3=3$$

q=3

$$\Pi_1 = f(\Pi_2, \Pi_3)$$

$$\Pi_1 = g^{a_1} d^{b_1} v^{c_1} \theta$$

$$\Pi_2 = g^{a_2} d^{b_2} v^{c_2} \mu$$

$$\Pi_3 = g^{a_3} d^{b_3} v^{c_3} \cdot g$$

$$\Pi_1 = g^{a_1} d^{b_1} v^{c_1} \theta$$

$$[M^0 L^0 T^0] = [ML^3]^{a_1} [L]^{b_1} [LT^{-1}]^{c_1} [L^3 T^{-1}]$$

Q>1

$$M: a_1 = 0$$

$$L: 3a_1 + b_1 + c_1 + 3 = 0$$

$$T: -c_1 - 1 = 0$$

$$\boxed{\Pi_1 = \frac{Q}{d^2 v}}$$

$$\Pi_2 = g^{a_2} d^{b_2} v^{c_2} \mu$$

$$M^0 L^0 T^0 = (ML^3)^{a_2} (L)^{b_2} [LT^{-1}]^{c_2} (ML^{-1} T^{-1})$$

$$M: a_2 + 1 = 0$$

$$L: 3a_2 + b_2 + c_2 = 0$$

$$T: -c_2 - 1 = 0$$

$$\Pi_2 = \frac{u}{g v d} = \frac{1}{Re}$$

Q>1

$$\Pi_1 = f(\Pi_2, \Pi_3)$$

$$\boxed{\frac{Q}{d^2 v} = f\left(\frac{1}{Re}, \Pi_3\right)}$$

(10)

for σ_{xn} we use mol terms.

g-atom

$$= \frac{\text{mass in g}}{\text{Atomic wt.}}$$

$$\text{k-atom} = \frac{\text{mass in kg}}{\text{Atomic wt.}}$$

$$\text{No. of g-molecules} = \frac{\text{mass in (g)}}{\text{Molecular wt.}}$$

Q: 1000 lb/min of a gas (M.W = 30.24) is being send to an absorption column. What will be the molar flow rate in kmol/hr.

$$\text{flow rate} = 1000 \frac{\text{lb.}}{\text{min}} \times \frac{0.4536 \text{ kg}}{1 \text{ lb}} \times \frac{60 \text{ min}}{1 \text{ hr}}$$

$$\text{mass flow rate} = 27216 \text{ kg/hr}$$

$$\text{molar flow rate} = \frac{\text{mass}}{\text{mol. wt.}} = \frac{27216 \text{ kg/hr}}{30.24 \text{ kg/kmol}}$$

$$= 900 \text{ kmol/hr}$$

Q: How many molecules are present in 691 kg of K_2CO_3
 K-39, C-12, O-16

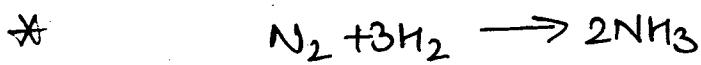
$$\text{M.W of } \text{K}_2\text{CO}_3 = 138$$

$$\text{moles} = \frac{691}{138} = 5.0072 \text{ moles of } \text{K}_2\text{CO}_3$$

$$= 5.0072 \times 6.023 \times 10^{23}$$

$$= 3.015 \times 10^{24} \text{ molecules} \text{ (is not standard form)}$$

$$= 3.01536 \times 10^{23} \text{ molecules}$$



(11)

Na

How much N_2 & H_2 are required to produce 100 kg of NH_3

Moles basis

(Molar Calculation)

Basis 100 kg of NH_3

2 kmol of NH_3 produces by = 1 kmol of N_2

$$\text{No. of moles of } NH_3 = \frac{100 \text{ kg}}{17} = 5.88 \text{ kmol.}$$

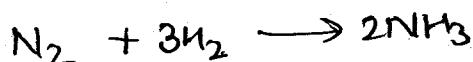
$$1 \text{ kmol of } NH_3 = \frac{1}{2} \text{ kmol } N_2$$

$$5.88 \text{ kmol of } NH_3 = \frac{1}{2} \times 5.88 \text{ kmol } N_2 \\ = 2.94 \text{ kmol } N_2$$

$$N_2 \text{ in kg} = 2.94 \text{ kmol} \times (28 \text{ kg/kmol}) \\ = 82.35 \text{ kg of } N_2.$$

(Molar Calculation)

Basis: 100 kg of NH_3



mol.wt.	28	6	$\frac{14 \times 2}{28} = 2$
	$28x_1$	$3x_2$	

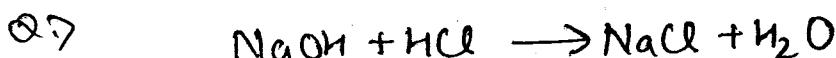
34 kg of NH_3 producing by = 28 kg of N_2

$$100 \text{ kg of } NH_3 = \left(\frac{28}{34} \right) \times 100 \text{ kg of } N_2$$

$$\frac{28 \text{ kg of } N_2}{34 \text{ kg of } NH_3} \times 100 \text{ kg of } NH_3 = 82.35 \text{ kg of } N_2$$

↳

Cost



Na-23, O-16, H-1, Cl-35.5

Calculate the amt of $NaOH$ & HCl required to produce 108 kg of H_2O .

H₃

NaOH

(12)

Basis: 108 kg of H₂O

$$\text{No. of moles of H}_2\text{O} = \frac{108}{18} = 6 \text{ kmol}$$

$$1 \text{ kmol of NaOH} = 1 \text{ kmol H}_2\text{O}$$

$$\text{So } " " " = 6 \text{ kmol of H}_2\text{O}$$

$$= 6 \times 40$$

$$= 240 \text{ kg of NaOH}$$

$$\text{HCl} = 6 \times 36.5 = 219 \text{ kg HCl}$$

1 kmol of H₂O is producing = 1 kmol of NaCl

$$6 \text{ kmol of H}_2\text{O} = 6 \text{ kmol of NaCl}$$

$$\text{Mass of NaCl produced} = 6 \text{ kmol} \times 58.5 \text{ kg/kmol}$$

$$= 351 \text{ kg.}$$

OR

Acc. to mass conservation

Mass of react = Mass of prod

$$M_{\text{NaOH}} + M_{\text{HCl}} = M_{\text{NaCl}} + M_{\text{H}_2\text{O}}$$

$$M_{\text{NaCl}} = M_{\text{NaOH}} + M_{\text{HCl}} - M_{\text{H}_2\text{O}}$$

$$= 240 + 219 - 108$$

$$= 351 \text{ kg.}$$

↳ Concentration ↳ Normality (N) ↳ Molarity (cm) ↳ Molality (m)

Concentration

$$C = \frac{\text{mass of solute in (g)}}{\text{Volume of solution (l)}}$$

$$\text{↳ mass concn} = \frac{\text{mass in g}}{\text{Vol. of soln (in l)}}$$

$$\text{↳ Molar concn} = \frac{\text{g moles of solute}}{\text{Vol. of soln (in l)}}$$

Molarity (M)

(13)

$$= \frac{\text{No. of g moles of solute}}{\text{Vol. of soln (in l)}}$$

Q3
1

Molarity (M)

$$= \frac{\text{no. of g moles of solute}}{\text{kg of solvent}}$$

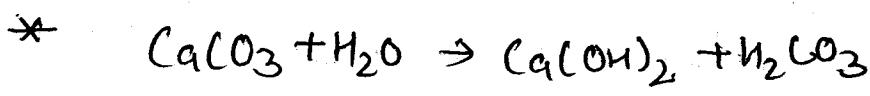
Normality (N)

$$= \frac{\text{no. of g equivalents}}{\text{Volume of soln (l)}}$$

$$\text{No. of g. equivalent} = \frac{\text{mass in (g)}}{\text{equivalent wt.}}$$

$$\text{Equivalent wt} = \frac{\text{Molecular wt.}}{\text{Valency.}}$$

Valance \equiv No. of hydrogen ions accepted or OH^- ions donated
or
No. of electron transfer.



$$\text{CaCO}_3 \text{ eq. wt} = \text{M.W.} / \text{Valance}$$

$$= \frac{100}{2} = 50 \text{ eq. wt.}$$

Q3) 98 g of H_2SO_4 has to be dissolved in water to prepare 1 l of solution. Find out the normality, molarity of soln

$$M = \frac{98}{98 \times 1} = 1M$$

$$N = M \times 2 = 2N/1$$

Q) 500 ml of H_2SO_4 soln. has the density 1.075 g/cm³. Then calculate the H_2SO_4 required for 1 N of soln, 1M of soln & 1m of soln.

15

$$1M = \frac{2 \times 1000}{500 \times 98}$$

$$x = 49 \text{ g.}$$

$$1N = \frac{2 \times 1000}{500 \times 98} \times 2$$

$$x = 24.5 \text{ g.}$$

$$1m = \frac{\text{g mol of } H_2SO_4}{\text{kg of solvent}}$$

Soln = Solute + Solvent.

kg solvent = kg soln - kg solute.

kg of soln = Vol. \times

$$= 0.5 \text{ l} \times 1.075 \frac{\text{g}}{\text{cm}^3} \times \frac{1 \text{ kg}}{10^3 \text{ g}} \times \frac{10^3 \text{ cm}^3}{1 \text{ l}}$$

$$\text{kg of soln} = 0.5375 \text{ kg of soln.}$$

Let x kg of solute required.

$$\text{kg of solvent} = 0.5375 - x$$

$$m = \frac{\text{g mol of solute}}{\text{kg of solvent}}$$

$$\text{g mol of solute} = \frac{\text{measured g}}{\text{m.wt.}}$$

$$= \frac{x \text{ kg} (10^3 \text{ g/kg})}{98}$$

$$= \frac{1600}{98} \text{ g}$$

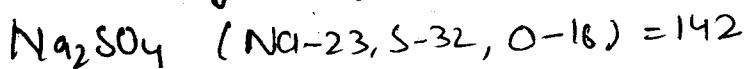
$$1 = \frac{1600 \times x}{98 \times 1.075 \text{ l}}$$

$$x = 47.979 \text{ g}$$

clonated

repose
of

Q> How many kg of S will be reqd to form 100 kg of (15) mole



Basis: 100 kg of Na_2SO_4

$$\text{moles of } \text{Na}_2\text{SO}_4 = \frac{100}{142} = 0.704 \text{ kmol}$$

$$\begin{aligned} \text{Kg of S required} &= 0.704 \text{ kmol} \times 32 \text{ kg/kmol} \\ &= 22.03 \text{ kg} \end{aligned}$$

Q> for same quest, how many g-atom of S will be then PF

$$= 22.03 \text{ kg} \times \left(\frac{10^3 \text{ g}}{1 \text{ kg}} \right)$$

$$= 704.22 \text{ g atom of S,}$$

Q>

$$\begin{aligned} 1 \text{ kmol of } \text{Na}_2\text{SO}_4 &= 1 \text{ k-atom of S} = 2 \text{ k atom of Na} \\ &= 4 \text{ k atom of O} \end{aligned}$$

$$\begin{aligned} 0.704 \text{ kmol} &= 0.704 \text{ k atom of S} \\ &= 704 \text{ g atom of S,} \end{aligned}$$

w

Nov 22, 14

wt

mass fraction

$$\frac{m_i}{\sum m_i} = \frac{\text{mass of 'i'}}{\text{total mass}}$$

me

Volume fraction

$$= \frac{\text{Volume of } i}{\text{total volume}} = \frac{V_i}{\sum V_i} = \frac{V_i}{V_{\text{total}}}$$

Soln

Amagat's law

of

mole fraction

$$\frac{\text{moles of 'i'} \rightarrow}{\text{total mass}} = \frac{n_i}{\sum n_i}$$

(16)

ppm

$$1 \text{ ppm} = \frac{\text{mg. of Solute}}{10^6 \text{ g of soln}} \quad | \text{ parts per million.}$$

or

$$1 \text{ ppm} = \frac{1 \text{ g of Solute}}{10^6 \text{ ml of soln}} = \frac{1 \text{ g of Solute}}{10^3 \text{ l of soln}}$$

then

$$1 \text{ l} = 10^3 \text{ ml}$$

$$= \frac{\text{mg. of Solute}}{1 \text{ l of soln}}$$

Q) 99% aq. soln of NaCl is prepared by dissolving 25 kg of NaCl in 100 kg of H_2O . Find out wt %, mole %.

wt fractⁿ

$$= \frac{w_i}{\sum w_i}$$



wt %

$$= \text{wt. fract}^n \times 100$$

Volume %

$$= \text{vol. fract}^n \times 100$$

mol %

$$= \text{mol fract}^n \times 100$$

Soln

$$\text{wt fraction NaCl} = \frac{25}{125} = \frac{1}{5} = 0.2$$

$$\text{wt \%} = 20\%$$

$$\text{wt. fract} H_2O = \frac{100}{125} = \frac{4}{5} = 0.8$$

$$= 80\%$$

part's law

⇒ mol %.

$$\text{NaCl} = \frac{\frac{23}{58.5}}{\frac{23}{58.5} + \frac{18}{18}}$$

17

$$\approx 0.0714 \\ \approx 7.14\%$$

Q

Ans

$$\text{H}_2\text{O} = 0.928$$

$$\approx 92.8\%$$

wt. fractⁿ \leftrightarrow mol fractⁿ

$$\text{wt. fract}^n \text{ NaCl} = \frac{0.2}{0.2 + 0.8} \\ = \frac{(0.2/58.5)}{(0.2/58.5) + (0.8/18)} \\ = 0.0714 \\ \approx 7.14\%$$

Pc

E

$$\text{mol} = \text{mass/M.W}$$

$$\text{mol} \% \times \text{M.W} = \text{mass}$$

Q) A solⁿ contain 50% NaOH & 50% H₂O (by mol). Find out their wt%.

$$w = 0.5 \times 40 \\ \text{Neon} \\ = 20$$

$$w_{\text{H}_2\text{O}} = 0.5 \times 18 \\ = 9$$

$$\text{wt NaOH} = \frac{20}{29} = 0.6896 \\ = 68.96\%$$

A

$$\text{wt}_{\text{H}_2\text{O}} = \frac{9}{29} = 0.3103$$

$$= 31.03\%$$

(18)

OR

Basis:

100 mol of soln

$$\text{NaOH} = 50 \text{ mol}$$

$$\text{H}_2\text{O} = 50 \text{ mol}$$

$$\text{mass of NaOH} = 56 \times 40 \\ = 2000 \text{ g} =$$

$$\text{mass of H}_2\text{O} = 50 \times 18 \\ = 900 \text{ g} =$$

$$\text{wt\%}_{\text{NaOH}} = \frac{2000}{2000+900} \times 100 = 68.96\%$$

$$\text{wt\%}_{\text{H}_2\text{O}} = \frac{900}{2000+900} \times 100 = 31.03\%$$

Ideal Gqs Calculation:-

there is no molecular force of attraction.

Boyle's Law

$$PV = \text{const} \\ \text{at fixed } T$$

Charles Law

$$\frac{V}{T} = \text{const, at fixed } P.$$

$$PV = nRT$$

Ideal gas EoS / eq of state

$$\frac{PV}{T} \propto \text{const.}$$

$$\frac{PV}{T} = R$$

R at STP (standard T & P)

(19)

Q7

$$T = 0^\circ\text{C} = 273.15\text{K}$$

$$P = 1\text{ atm}$$

$$V = 22.4143 \text{ l for 1 mol}$$

$$= \cancel{22.4143} \text{ m}^3 \text{ for 1 kmol}$$

$$= 22.4143 \text{ m}^3$$

$$1 \text{ mol} = 22.4 \text{ l}$$

$$1 \text{ mol} \times \frac{1 \text{ kmol}}{10^3 \text{ mol}} = 22.4 \text{ l}$$

$$1 \text{ kmol} = 22.4 \times 10^3 \text{ l}$$

$$= 22.4143 \text{ m}^3$$

$$R = 8.314 \text{ J/mol K, Nm}$$

at STP,

$$P = 101325 \text{ N/m}^2 (\text{or Pa})$$

$$n = 1 \text{ kmol}$$

$$V = 22.4143 \text{ m}^3$$

$$T = 273.15 \text{ K}$$

$$R = \frac{PV}{nT}$$

$$R = \frac{101325 \frac{\text{N}}{\text{m}^2} \times 22.4143 \text{ m}^3}{1 \text{ kmol} \times 273.15 \text{ K}}$$

$$= 8314.58 \frac{\text{N} \cdot \text{m}}{\text{kmol K}}$$

$$= 8.314 \text{ J/mol K}$$

Soln

Q7

Soln

Q.) Find the value of gas const R in ~~mmHg/mole~~ mmHg/m³/mol K
and Cal/mol K.

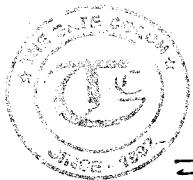
(20)

Solⁿ

$$R = \frac{PV}{nT}$$

$$= \frac{1.01325 \text{ atm} \times \frac{N}{10^2} \times 22.4143 \text{ m}^3 \times \frac{760 \text{ mmHg}}{1 \text{ Pstatm}}}{1 \text{ kmol} \times \frac{10^3 \text{ mol}}{1 \text{ kmol}} \times 273.15 \text{ K}}$$

$$= 0.08236 \text{ mmHg m}^3/\text{mol K}$$



$$= 8.314 \text{ J} \times \frac{1 \text{ cal}}{4.1858 \text{ J}}$$

$$\text{mol K}$$

$$= 1.9862 \text{ cal/mol K.}$$

Q.) Calculate the molar volume of air at 300K & 1bar.

1/mol = unit

29.09 1/mol

Solⁿ

$$\text{Vol} - \text{m}^3$$

$$\text{Vol/mass} - \text{m}^3/\text{kg}$$

$$\text{Vol/mol} = \text{m}^3/\text{mol}$$

$$PV = nRT$$

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

$$R = \frac{1.01325 \text{ bar} \times 22.4143 \text{ m}^3}{1 \text{ mol} \times 273.15 \text{ K}}$$

$$= 0.08314$$

$$= 0.08314 \frac{\text{bar} \cdot \text{L}}{\text{mol} \cdot \text{K}} \times 350 \text{K}$$

(21)

$$= 29.029 \text{ L/mol}$$

* Ideal Gas Mixtures

Mixtures - where more than 1 component are present.

Dalton's Law

$$p^{\text{tot}} = \sum \bar{p}_i$$

Valid at const volume
& temp.

$$PV = nRT$$

for component 'i',

$$\bar{p}_i V = n_i RT \quad \text{--- (1)}$$

for total mixture,

$$p^{\text{tot}} V = n^{\text{tot}} RT \quad \text{--- (2)}$$

$$\text{eqns} \quad (1) \div (2)$$

for

Ans

$$\frac{\bar{p}_i}{p^{\text{tot}}} = \frac{n_i}{n^{\text{tot}}} = y_i \text{ (mol fraction)}$$

$$\bar{p}_i = y_i p^{\text{tot}}$$

$$p\% = \text{mol}\%$$

Amagat's Law

$$V_{\text{tot}}$$

at Const Press &
temp.

$$V^{\text{tot}} = \sum V_i$$

$$PV = nRT$$

→ 3

(22)

for (i) component

$$PV_i = n_i RT \rightarrow 3,$$

for total mixture,

$$PV_{\text{tot}} = n_{\text{tot}} RT \rightarrow 4,$$

$$\text{Eq}^{\text{no.}} 13) \div 14)$$

$$\frac{V_i}{V_{\text{tot}}} = \frac{n_i}{n_{\text{tot}}} = y_i$$

$$\boxed{\text{Volume fraction} = \text{mole fraction} \approx y_i}$$

$$\boxed{\text{Vol.}\% = \text{mol.}\%}$$

for ideal gas mixture

$$\boxed{\text{Vol.}\% = \text{mol.}\% = \text{P}\%}$$

Avg. Molecular wt. :- (mixture)

valid for all cases
both Real & Ideal

$$\boxed{M_{\text{avg}} = \frac{m_{\text{tot}}}{n_{\text{tot}}}}$$

$$M_{\text{avg}} = \frac{m_{\text{tot}}}{n_{\text{tot}}}$$

$$= \frac{\sum m_i}{n_{\text{tot}}}$$

$$= \frac{\sum (n_i \times M_i)}{n_{\text{tot}}}$$

$$\boxed{M_{\text{avg.}} = \sum x_i \times M_i}$$

$$\frac{x_i}{n_{\text{tot}}} = x_i$$

Q) An analysis of the vent gases in a plant shows that it contains 70% HCl, 20% Cl₂ & rest CCl₄ by vol. (23)
 Determine the % comp by wt, Avg mol wt of gas, & at std state (kg/m³)

Soln

$$\text{Avg Mol wt} = 0.70 \times \frac{36.5}{36.5} + 0.20 \times \frac{71}{71} + 0.10 \times \frac{104}{104}$$

Basio: 100 kmol of gas

% Comp by wt \Rightarrow

$$\text{HCl} = 0.70 \times 36.5$$

Basio: 100 kmol of gas

i.)

	n_i	$m_i = n_i \times M_i$	wt%
HCl	70 kmol	$70 \times 36.5 = 2555 \text{ kg}$	$\frac{2555}{5515} \times 100 = 46.328\%$
Cl ₂	20 kmol	$20 \times 71 = 1420 \text{ kg}$	$\frac{1420}{5515} \times 100 = 25.74\%$
CCl ₄	10 kmol	$10 \times 104 = 1040 \text{ kg}$ $= 5515 \text{ kg}$	$\frac{1040}{5515} \times 100 = 27.923\%$

ii.)

$$M_{avg} = \frac{m_{tot}}{n_{tot}} = \frac{5515 \text{ kg}}{100 \text{ kmol}} = 55.15 \text{ kg}$$

$$M_{avg} = \sum n_i M_i / (0.70 \times 36.5 + 0.20 \times 71 + 0.10 \times 104)$$

$$= 55.18 \text{ kg}$$

iii)

$$\rho = \frac{m}{V}$$

at STP $\Rightarrow 22.4143 \text{ m}^3$ for 1 kmol.

$$\text{for, 100 kmol gas, } V_{tot} = 100 \times 22.4143 = 2241.43 \text{ m}^3$$

hat
Vol

$$f = \frac{5515}{2241.43} \frac{\text{kg}}{\text{m}^3} = 2.4604 \text{ kg/m}^3 \quad 24$$

f at 350K & 2bar

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

$$= 100 \text{ km} \times \frac{0.08314}{\text{bar} \cdot \text{m}^3} \frac{\text{bar} \cdot \text{m}^3}{\text{Kmol} \cdot \text{K}} \times 350 \text{ K}$$

2bar

$$V^{10^7} = 1621.23 \text{ m}^3$$

Rez

$$f = \frac{5515}{1621.23} \frac{\text{kg}}{\text{m}^3}$$

$$f = 3.4 \text{ kg/m}^3$$

$$PV = nRT$$

$$PV = \frac{m}{M_0} RT$$

$$\frac{P \cdot M_0}{RT} = \frac{m}{V}$$

$$f = \frac{PM_0}{RT}$$

1)

Nov 23, 14

(25)

6W

Material Balance

$$\text{Accumulation} = i/p - o/p$$

Accumulation = profit - loss.

$$\text{Accumulation} = (i/p + \text{Generation})$$

$$- (o/p + \text{Disappearance})$$

general MB eqn.
Material
Balance

General Mass Balance eqn

$$\text{Accumulation} = i/p - o/p$$

↳ Steady State Process \rightarrow Condition of System doesn't change w/ time

↳ Unsteady State Process \rightarrow Condition within the system changes w/ time.

$$100 \text{ kg/h}_{\text{H}_2\text{O}} \xrightarrow{\text{Sinks}} 90 \text{ kg/h}_{\text{H}_2\text{O}}$$

after 1 hr

$$i/p = 100$$

$$o/p = 90$$

$$\text{Accr} = 100 - 90 = 10$$

not feasible

$$100 \text{ kg/h}_{\text{H}_2\text{O}} \xrightarrow{\text{Sinks}} 100 \text{ kg/h}_{\text{H}_2\text{O}}$$

after 1 hr

$$i/p = 100$$

$$o/p = 100$$

$$\text{Accr} = 100 - 100 = 0$$

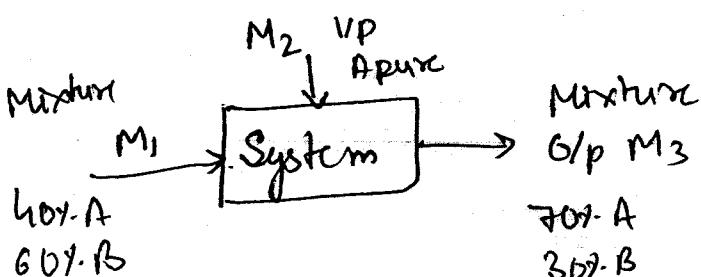
$$100 \text{ kg/h}_{\text{H}_2\text{O}} \xrightarrow{\text{Sinks}} 200 \text{ kg/h}_{\text{H}_2\text{O}}$$

after some time

$$\text{Accumulation} = i/p - o/p$$

$$i/p = o/p$$

General Mass Balance eqn
for steady state



Overall Mass Balance

$$M_1 + M_2 = M_3$$

28

Component Mass Balance

total mass of component in = total mass of component out

$$\underline{B} \quad M_1 \times 0.6 = M_3 \times 0.3$$

$$\underline{A} \quad M_1 \times 0.4 + M_2 = M_3 \times 0.7$$

profit-loss.

MB eqn.
rial
ance

Material Balance for unit Operation (w/o chem rxn):-

tie Component :-

The amount of the component doesn't change during the process.

Drying & Evaporation

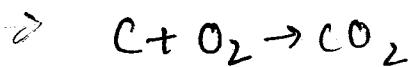
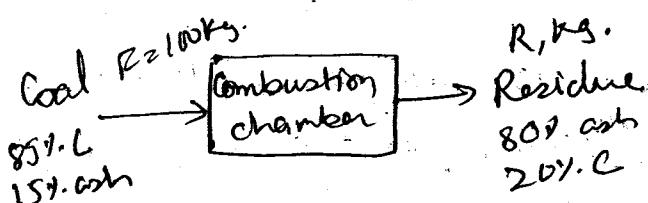
Mixing \rightarrow Distillation
 \rightarrow Absorption
 \rightarrow Extraction.

id tgm.
100 kg/h
H₂O

= 0

Q. A coal containing 15% Ash & 85% C, is burn in a combustion chamber and the residue we get found to contain 80% ash & 20% carbon. Find out the amt. of residue formed for 100 kg of coal.

Basis: 100 kg of coal.



$$C \rightarrow 100 \times 0.85 = 85 \text{ kg}$$

$$\text{ash} \rightarrow 100 \times 0.15 = 15 \text{ kg}$$

eqn

tie component \Rightarrow ash

(27)

Sol

Component Balance for tie component/ash

$$\text{total ash i/p} = \text{total ash o/p}$$

$$F \times 0.15 = R \times 0.80$$

$$100 \times 0.15 = R \times 0.80$$

$$R = 18.75 \text{ kg.}$$

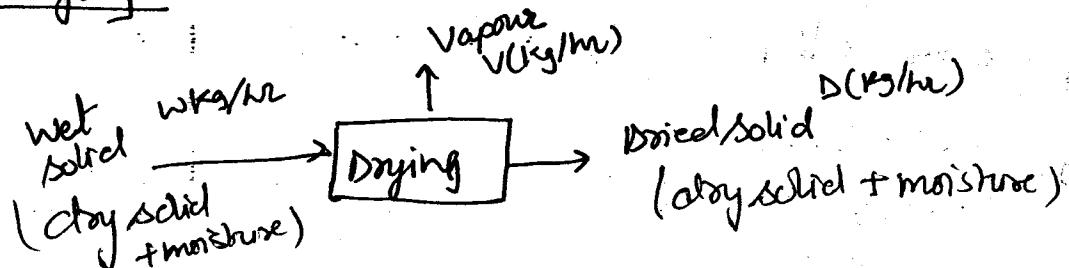
G_1 = geo leaving

$$F = G_1 + R$$

$$100 = G_1 + 18.75$$

$$G_1 = 81.25 \text{ kg}$$

* Drying



Overall M.B

$$W = V + D$$

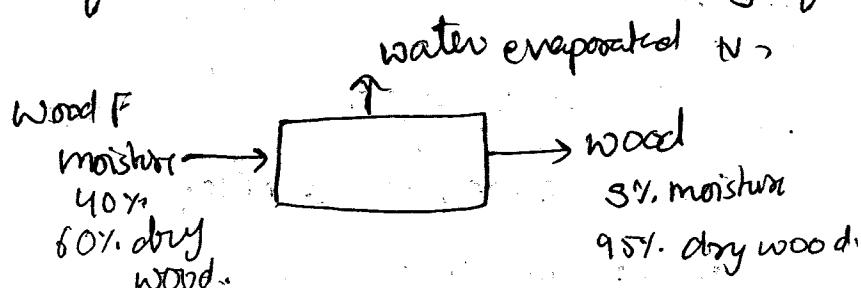
Dry solid Mass Balance

$$W \times x_W = 0 + D \times x_D$$

Moisture Mass Balance

$$W \times x_m = V \cdot 1 + D \times x'_D$$

- Q: A wood containing 40% moisture is dried up to 5% moisture. What mass of water evaporated in per kg of dry wood.



Solⁿ

(28)

Basis:- 1kg of ~~red~~ wood

$$\text{dry wood} = 1 \times 0.6 = 0.6 \text{ kg.}$$

$$\text{moisture} = 1 \times 0.4 = 0.4 \text{ kg.}$$

Overall MB

$$F = P + V$$

$$P + V = 1 \rightarrow 1b$$

Component mass balance ~~of~~ over dry wood.

$$F \times 0.6 = P \times 0.95$$

$$0.6 = 0.5 \times P$$

$$P = \frac{0.6}{0.5} = 1.2 \text{ kg.}$$

water vapourised

$$V = 1 - P$$

$$= 1 - 0.6315$$

$$V = 0.3685 \text{ kg}$$

$$\frac{\text{kg of water evap}}{\text{kg of dry wood}} = \frac{0.3685 \text{ kg}}{0.6 \text{ kg}}$$
$$= 0.614$$

moisture

wood.

Basis:- 1kg of dry wood

$$\text{mass of dry wood in feed} = F \times 0.6 = 1 \text{ kg}$$

$$F = \frac{1}{0.6} = 1.666$$

$$\text{water in feed} = F - 1 \text{ kg of dry}$$

$$= 1.667 - 1 = 0.667 \text{ kg.}$$

$$\text{dry wood in ppt} = P \times 0.95 = 11 \text{ kg}$$

(29)

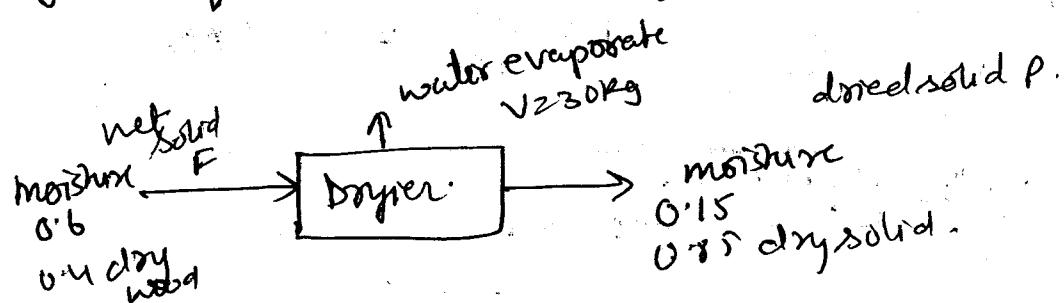
* E

$$= P = \frac{1}{0.95} = 1.0526 \text{ kg}$$

$$\text{water in ppt} = 1.0526 - 1 \\ = 0.0526 \text{ kg}$$

$$\text{water evaporated} \Delta V = 0.667 - 0.0526 \\ = 0.6144 \text{ kg}$$

Q.2) A wet solid contains 60% of moisture is dried upto 15% of moisture by wt. If the water evaporated is 30 kg, Then find out the mass of wet solid.



Basis: 30 kg of water evaporated.

Overall MB, $F = V + P$

$$F - P = 30 \text{ kg}$$

Component MB,

H_2O

$$F \times 0.6 = V + P \times 0.15$$

$$0.6 F = 30 + 0.15 P$$

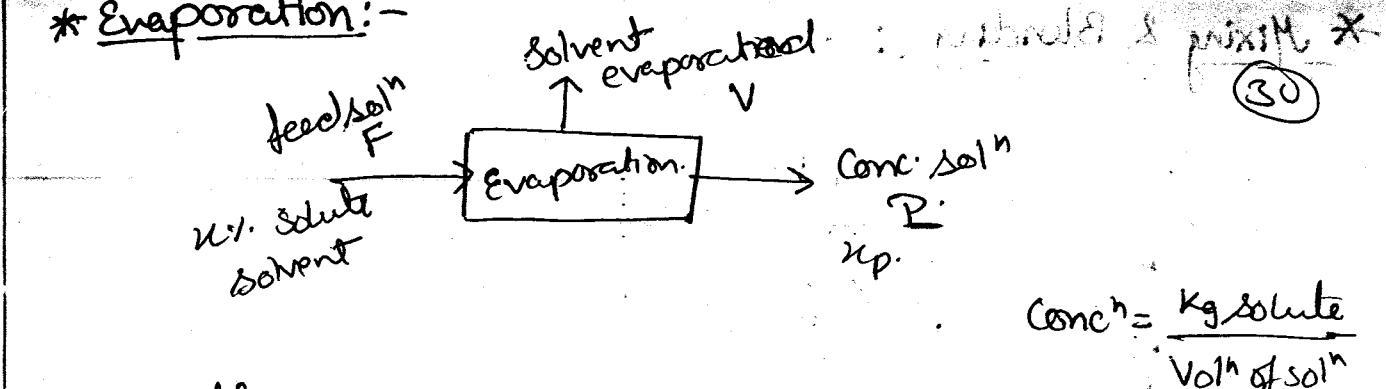
$$0.6 (30 + P) = 30 + 0.15 P$$

$$18 + 0.6 P = 30 + 0.15 P$$

$$P = 26.66$$

$$F = P + V = 36.666 \text{ kg}$$

* Evaporation: -



Solute MB

$$F \cdot x = P \cdot x_p$$

upto

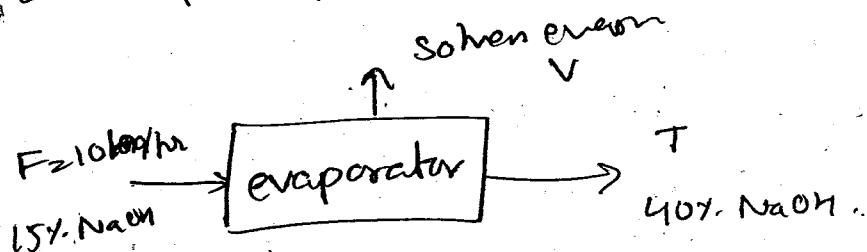
Solvent MB

$$F \cdot x' = V + P \cdot x_p'$$

Evaporator Capacity = kg water vapour produced / hr

Evaporator Economy = kg of water vapour produced / kg of steam fed.

Q.) A single effect evaporator is fed with 10 tons/hr feed solution containing 15% NaOH by wt. and is concentrated to 40% NaOH soln. Calculate thick liquid produced and water vapour produced.



$$F = V + T$$

$$10 = V + T$$

$$0.15 \times 10 = 0.40 T$$

$$1.5 = 0.40 (10 - V)$$

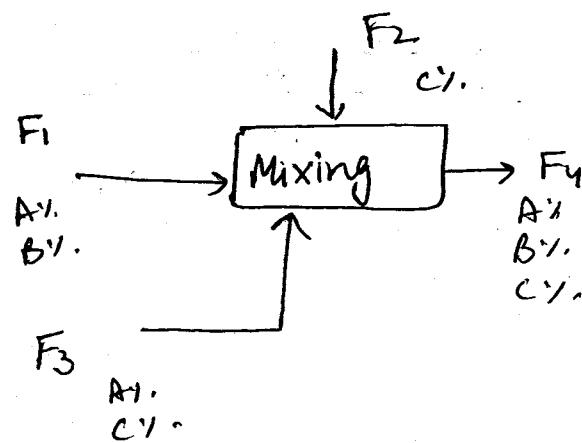
$$1.5 = 8.0 - 0.4V$$

$$V = 6.25 \text{ ton/hr.}$$

$$T = 3.75 \text{ ton/hr.}$$

* Mixing & Blending :-

(31)



Overall MB

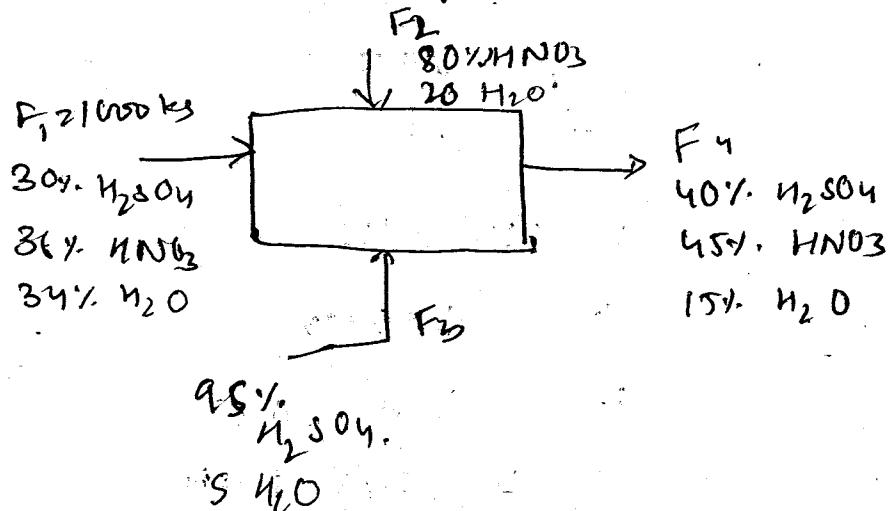
$$F_1 + F_2 + F_3 = F_4$$

Component MB

$$A: \quad F_1 x_A' + F_3 x_A'' = F_4 x_A^4$$

$$B: \quad F_1 x_B' + F_3 x_B'' = F_4 x_B^4$$

Q.) 1000 kg of mixed acid of composition 40% H₂SO₄, 45% HNO₃ and rest water is to be produced by mixing waste acid of 30% H₂SO₄, 36% HNO₃ & 34% H₂O with 95% H₂SO₄ soln and 80% HNO₃ soln. How many kg of these acids will be required to prepare the desired (by wt%)



$$F_1 + F_2 + F_3 = F_4$$

$$1000 = F_4 - (F_2 + F_3)$$

for H_2SO_4

$$1000 \times 0.3 + 0.95 F_3 = F_4 \times 0.4$$

for HNO_3

$$1000 \times 0.36 + 0.80 F_2 = F_4 \times 0.45$$

for N_2O

$$1000 \times 0.34 + 0.15 F_4 - 0.20 F_2 - 0.05 F_3$$

$$F_4 = 2266.66$$

$$F_2 = 660$$

$$F_3 = 606.664$$

$$360 + 0.95 F_3 = (1000 + F_2 + F_3) 0.4$$

$$360 + 0.95 F_3 = 400 + 0.4 F_2 + 0.4 F_3$$

$$0.55 F_3 - 0.4 F_2 = 100$$

$$360 + 0.8 F_2 = 450 + 0.45 F_2 + 0.45 F_3$$

$$0.35 F_2 - 0.45 F_3 = 90$$

$$340 = 180 + 0.15 F_2 + 0.15 F_3 - 0.2 F_2$$

$$- 0.05 F_3$$

$$190 = 0.1 F_3 - 0.05 F_2 = 190 =$$

$$F_1 = 20724$$

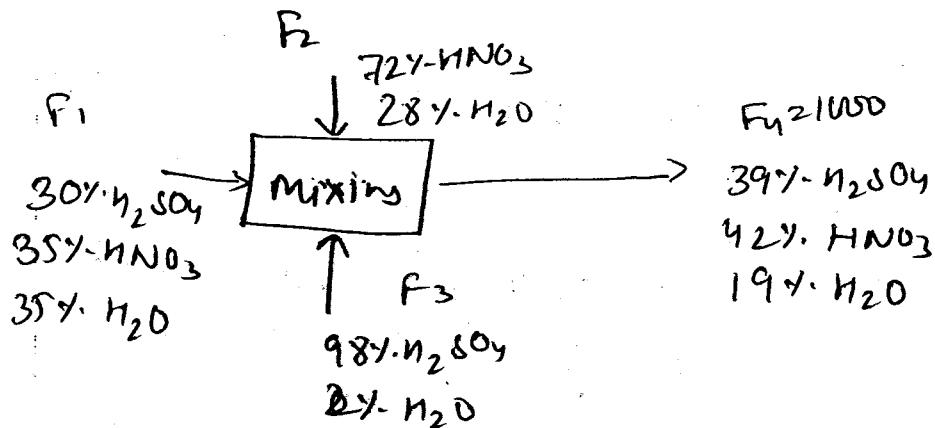
$$2 = 330.90$$

$$3 = 348.92$$

45% waste
5% if added
+ 1%)

(53) Nov. 27

Q7 The waste acid from nitration process contains 30% H_2SO_4 , 25% HNO_3 & rest water is mixed with 98% H_2SO_4 soln and 72% HNO_3 soln. To concentrate the acid upto 39% H_2SO_4 , 42% HNO_3 & rest water. Calculate the quantities of 3 acid required to produce the 1000 kg of mixed acid.



$$F_1 + F_2 + F_3 = 1000$$

H_2SO_4

$$0.30F_1 + 0.98F_3 = 0.39 \times 1000$$

HNO_3

$$0.35F_1 + 0.72F_2 = 0.42 \times 1000$$

H_2O

$$0.35F_1 + 0.28F_2 + 0.02F_3 = 0.19 \times 1000$$

$$390 = 0.98F_3 + 0.38$$

feed $F_1 = 90.04 \text{ kg}$

HNO_3 $F_2 = 539.56 \text{ kg}$

H_2SO_4 $F_3 = 370.39 \text{ kg}$

F_{F2}

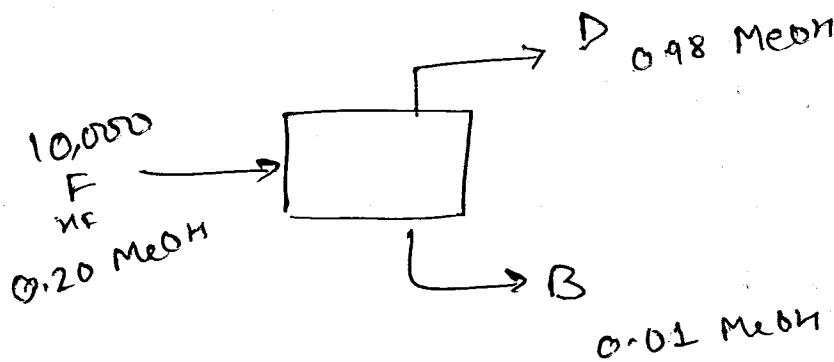
$$F_1 = 90.04$$

$$F_2 = 539.56$$

$$F_3 = 370.39$$

(35) *

Q7 10,000 kg/hr of solution containing 20% MeOH, is continuously fed to a distillation column. Distillate contains 98% methanol & ~~waste~~ waste belt contain 1% MeOH only. Calculate the mass flow rate of distillate & bottom pdl as well as % loss of MeOH.



$$10000 = D + B$$

$$2000 = 9800 - 15000B + 0.01B$$

$$0.98(10000 - B)$$

$$2000 = 10000 - 15000B$$

$$B = 8041.33 \text{ kg/hr}$$

$$D = 1958.76 \text{ kg/hr}$$

$$\% \text{ loss} = \frac{\text{Amt of MeOH in } B}{\text{Amt of MeOH in } F} \times 100$$

$$= \frac{4.02 \times 0.01}{F \times 0.20} \times 1000$$

$$= 4.02 \%$$

Pump

Compressor \rightarrow gas sp. volume large hence that's why we use compressor.

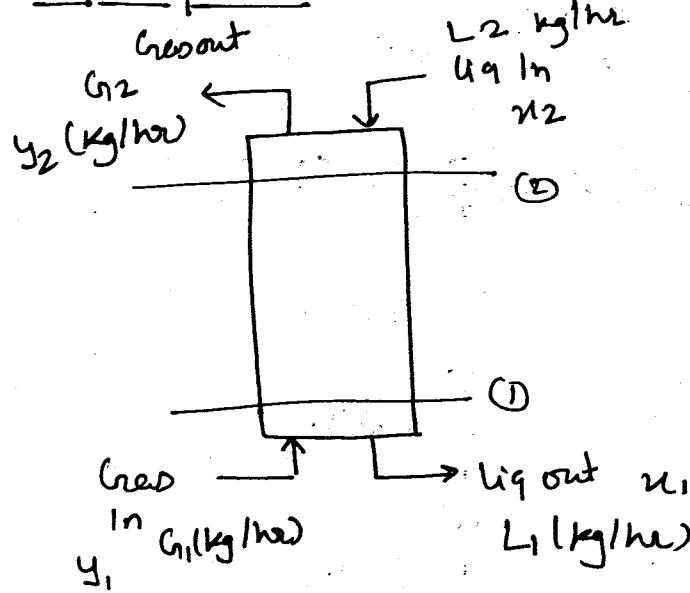
tinously

by

from pdl

* Absorption

(38)



Overall M/B

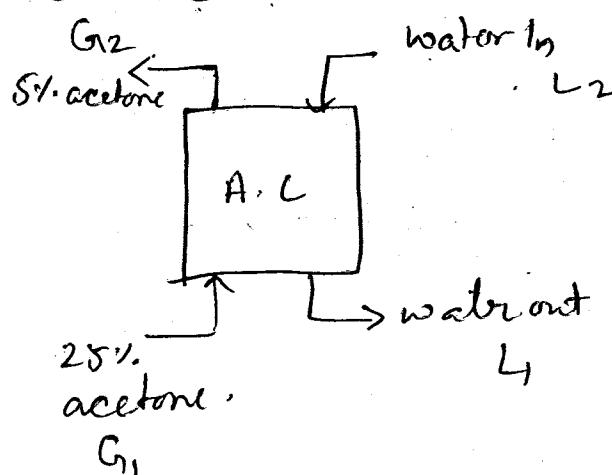
$$G_1 + L_2 = G_2 + L_1$$

Component M/B

$$G_1 y_1 + L_2 x_2 = G_2 y_2 + L_1 x_1$$

D + 26¹³

Q.) Acetone is recovered from acetone-air mix. containing 25% Acetone by volume. It is scrubbed with water. Assume that air is insoluble in water. Determine the % of acetone absorbed if gas leaving the column contains 5% acetone.



$$\% \text{ acetone absorbed} = \frac{\text{Amt of Acetone transferred to liquid}}{\text{Amt of acetone fed}} \times 100$$

37

Acetone out from gas stream = Acetone In to the liq. stream.

Basis: 100 kmol of gas mixture feed. (G_1)

$$\text{Acetone in feed gas} = G_1 \times 0.25 \\ = 100 \times 0.25 \\ = 25 \text{ kmol/hr.}$$

$$\text{Air in feed gas} = 100 - 25 \\ = 75 \text{ kmol/hr.}$$

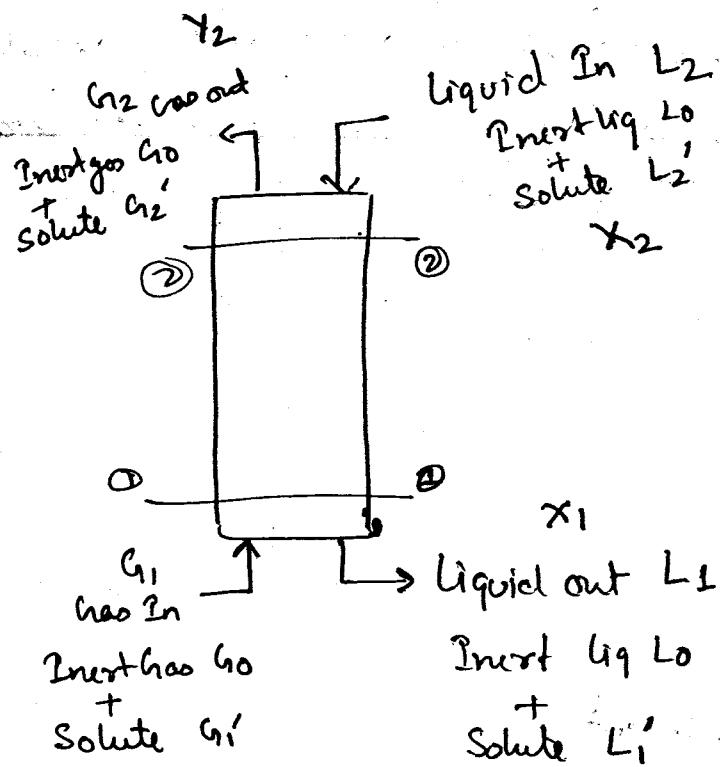
$$\text{Acetone present in outlet gas stream} = G_2 \times 0.05$$

$$\text{Air in gas leaving outlet} = G_2 \times 0.95$$

$$75 = G_2 \times 0.95 \\ G_2 = 78.947 \text{ kmol/hr.}$$

$$\text{Acetone in outlet stream} = G_2 \times 0.05 \\ = 78.947 \times 0.05 \\ = 3.947 \text{ kmol/hr.}$$

$$\% \text{ Acetone absorbed} = \frac{25 - 3.947}{25} \times 100 \\ = 84.21 \text{ kmol/hr.}$$



$$\gamma_1 = \frac{\text{mass of Solute}}{\text{mass of Inert gas}}$$

$$L_2 = L_0 + L_2'$$

$$L_1 = L_0 + L_1'$$

$$G_1 = G_0 + G_1'$$

$$G_2 = G_0 + G_2'$$

Overall MB

$$G_1 + L_2 = G_2 + L_1$$

Component MB

$$\text{Component In} = \text{Comp O/p}$$

$$G_0 \cdot \gamma_1 + L_0 \cdot x_2 = G_0 \gamma_2 + L_0 \cdot x_1$$

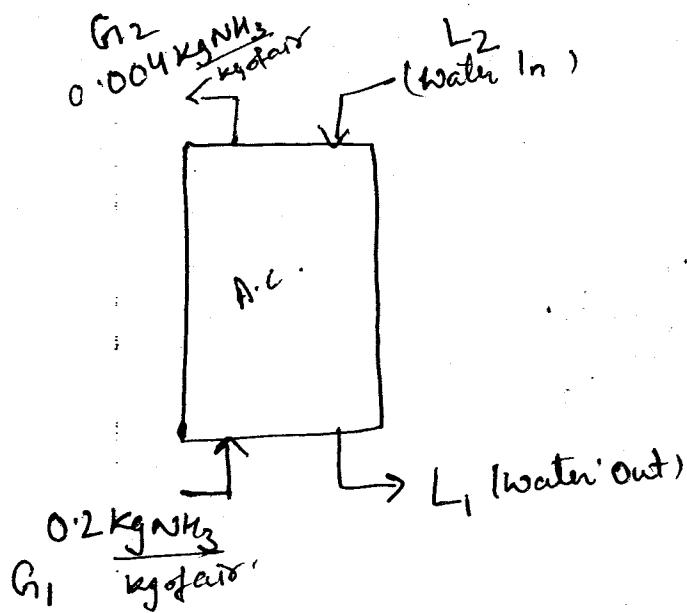
$$G_1 \times y_1$$

$$\frac{\text{total flow rate}}{\text{inert gas flow rate}} \times \frac{\text{mass of solute}}{\text{total mass}}$$

$$\frac{\text{inert gas flow rate}}{\text{inert gas flow rate}} \times \frac{\text{mass of solute}}{\text{mass of inert}}$$

Q.) The NH_3 -air mix containing 0.2 kg NH_3 per kg of air (39) enters into a absorption column. Where NH_3 absorb in water. The gas leaving the system found to contain 0.004 kg NH_3 /kg of air. find % recovery of air.

Ex



Basis : 100 kg of gas mixture feed

1 kg of air feed.

$$\text{NH}_3 \text{ in gas inlet} = 1 \text{ kg air} \times \frac{0.2 \text{ kg NH}_3}{\text{kg of air}} \\ = 0.2 \text{ kg NH}_3$$

$$\text{NH}_3 \text{ in gas outlet} = 1 \text{ kg of air} \times \frac{0.004 \text{ kg NH}_3}{\text{kg of air}}$$

Nov

$$\% \text{ Recovery} = \frac{\text{NH}_3 \text{ inlet} - \text{NH}_3 \text{ outlet}}{\text{NH}_3 \text{ feed}} \times 100$$

$$= \frac{0.2 \text{ kg} - 0.004 \text{ kg}}{0.2 \text{ kg}} \times 100 \\ = 98\%$$

Ore

Filt

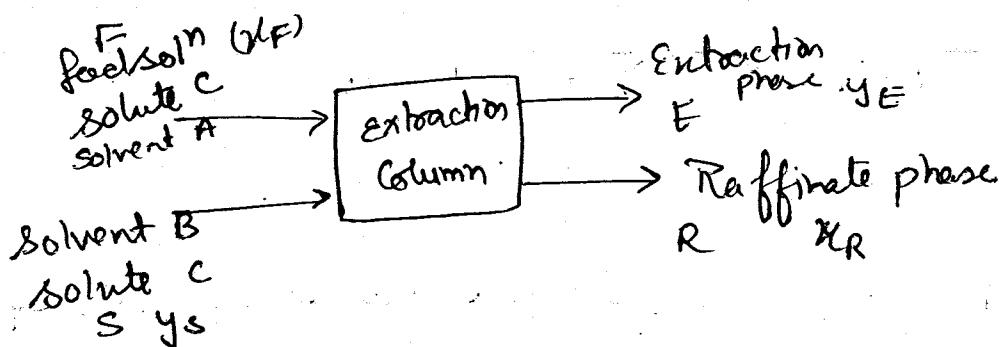
air

boots

contains

Extraction :-

40



Overall MB

$$F + S = E + R$$

Component MB

Solute: $F \cdot x_F + S \cdot y_S = E \cdot y_E + R \cdot x_R$

Solvent A :-

$$F \cdot x_{FA} + S \cdot y_{SA} = E \cdot y_{EA} + R \cdot x_{RA}$$

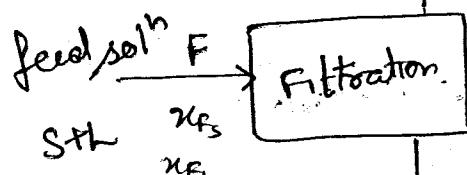
Solvent B :-

$$F \cdot x_{FB} + S \cdot y_{SB} = E \cdot y_{EB} + R \cdot x_{RB}$$

Nov 30, 14

$$\% \text{ Recovery} = \frac{E \cdot y_E}{F \cdot x_F} \times 100$$

Filtration :-



$\frac{S}{W} \frac{W_{WS}}{W_L}$

Overall MB

$$F = W + P$$

Overall MB: $F = W + P$. Involves overall retention factors and overall recovery is maintained with overall retention factors.

Component M/B

(4)

Solid

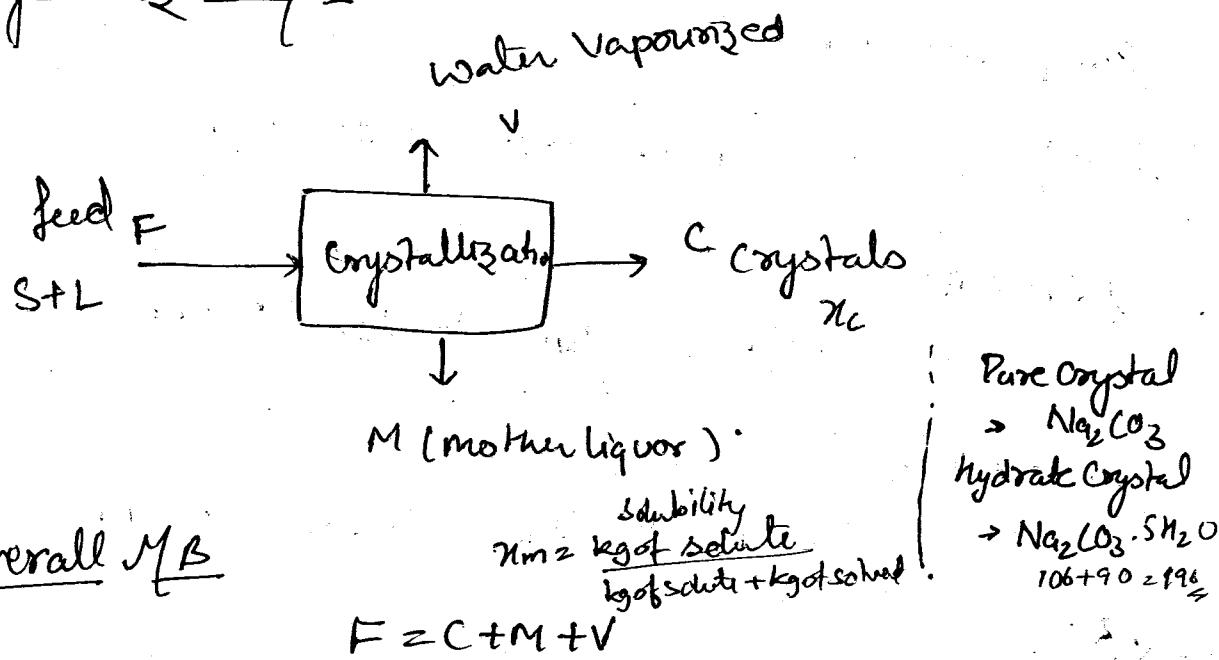
$$X_{F_S} \cdot F = W \cdot X_{W_S} + P \cdot X_{P_S}$$

Liquid

$$F \cdot X_{F_L} = W \cdot X_{W_L} + P \cdot X_{P_L}$$

★ ★ In eqns, we calculate values by $(n-1)$ eqns
and we use n^{th} eqn to cross verify our result.

Crystallization -



Overall M/B

Component M/B

Solute

$$F \cdot X_F = C \cdot X_C + M \cdot X_M$$

Water

$$F \cdot X_W = V + C \cdot X_{W_C} + M \cdot X_{W_M}$$

Solubility of NaCl

$$\frac{2 \text{ kg of NaCl}}{100 \text{ kg of H}_2\text{O}}$$

Molar fraction of NaCl

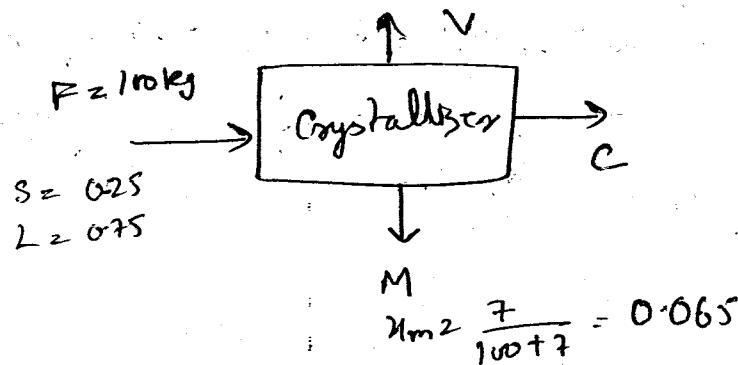
$$\frac{2}{100+2}$$

Q7 A crystallizer is charged with 100kg of a solution containing 25% $\text{Ba}(\text{NO}_3)_2$ in water. On cooling, 10% of the original water evaporated. Calculate the yield of crystal produced when the solution is cooled to 253K

The solubility of $\text{Ba}(\text{NO}_3)_2$ at 253 K is given as

$\frac{7 \text{ kg } \text{Ba}(\text{NO}_3)_2}{100 \text{ kg of } \text{H}_2\text{O}}$

(42)



Basin: 100 kg of soln

$$F = C + M + V$$

$$100 = C + M + V$$

Solute

$$F \times R = C \cdot 2L + 2M_m$$
$$100 \times 0.25 = C \cdot 1 + M \cdot 0.65$$

$$25 =$$
$$100 - M - V$$
$$+ 0.65$$

$$\text{Water in feed} = F \times 0.75 = 75$$

$$V = 10\% \text{ of } 75 \text{ kg} = 7.5 \text{ kg}$$

$$C + M + 7.5 = 100$$

$$C + M = 92.5 \quad (i)$$

Solute Balance

$$F \times 0.25 = C \times 1 + M \times 0.65$$

$$25 = C + (92.5 - C) 0.65$$

$$= 0.935$$

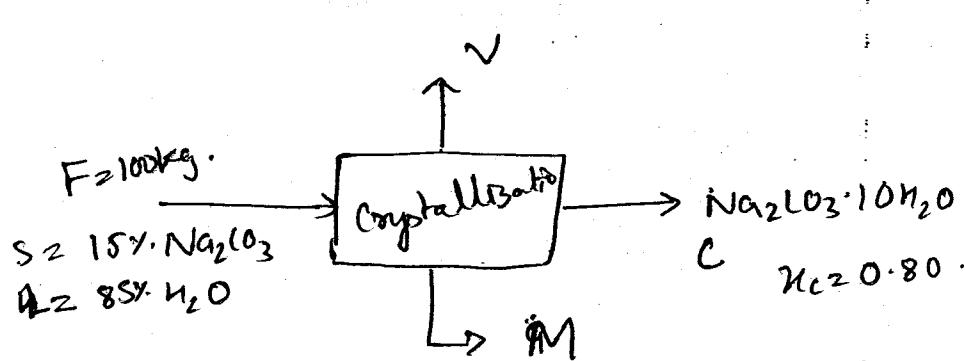
$$C = 20.307 \text{ kg}$$

$$M = 72.192 \text{ kg}$$

Q2) An aq. solution Na_2CO_3 : Containing 15% Na_2CO_3 43
 85% water is cooled to a temp of 278 K & we
 recovered hydrated crystal of $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$

The solubility of Na_2CO_3 at 278 K is 9% by wt ^{mass/mass}
 for 100 kg of feed soln. Find out the amt of crystal
 produced & water evaporated. If 80% of Na_2CO_3
 is recovered as hydrated crystals.

Soln



$$x_m = \frac{9}{109} = 0.0825$$

$$F = C + M + V$$

Soln

$$V = \frac{C \times 0.80 + M \times 0.0825}{109 + 180} \times 0.09$$

$$F \times 0.15 = M \times 0.09 + C \times \frac{106}{286}$$

$$\text{Na}_2\text{CO}_3 \text{ initially} = F \times 0.15 = 15 \text{ kg.}$$

$$80\% \text{ Na}_2\text{CO}_3 = 12 \text{ kg.}$$

$$C \times \frac{106}{286} = 12$$

$$C = 32.37 \text{ kg.}$$

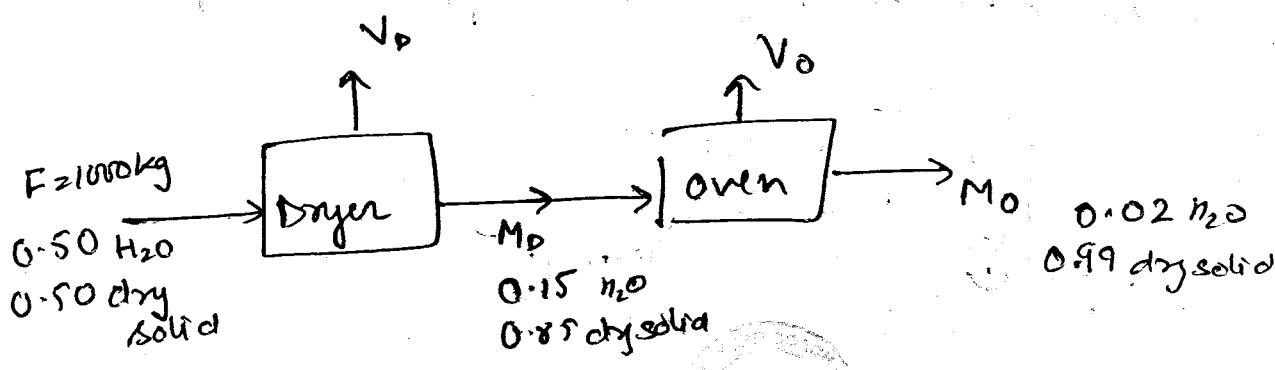
M = 33.36 kg

V = 34.26 kg

44

st
and
stal
CO₂

- Q) A drier is fed with 2 wet solid to reduce the moisture content from 50% to 15%. The exit leaving the drier is admitted to an oven with further brings down the moisture 2%. If the drier can handle 1000 kg wet solid per day. Calculate the pds leaving the drier & oven resp.
- ii) % of original water removed in drier & oven resp.



$$F = V_D + M_D$$

$$1000 = V_D + M_D$$

Moisture

$$5000 = V_D + 0.15 M_D$$

$$5000 = 1000 - M_D + 0.15 M_D$$

$$M_D = 588.235 \text{ kg/day}$$

$$V_D = 411.76$$

$$M_O = V_O + M_D$$

$$M_O = 588.235 = V_O + M_D$$

$$588.235 \times 0.15 = V_O + M_D \times 0.02$$

$$M_D = 510.203$$

$$M_D = 421.968 = V_O = 78.03 \text{ kg/day}$$

45

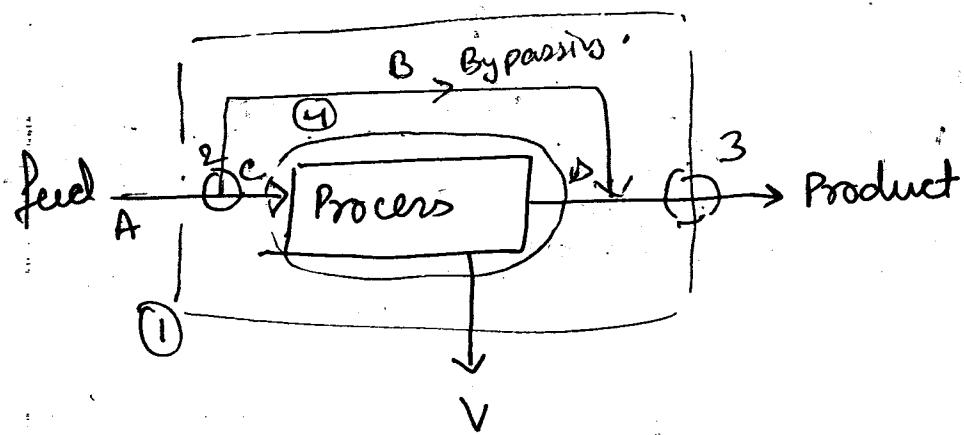
$$\% \text{ water recover from drier} = \frac{F \times x_F - M_0 x_D \times 100}{F \times x_F} \\ = 82.35\%$$

~~88.23%~~

$$\% \text{ water recover from oven} = \frac{M_0 x_D - M_0 x_O \times 100}{M_0 x_D \times 0.5} \\ = 90.15606\%$$

By Part 2 Recycling

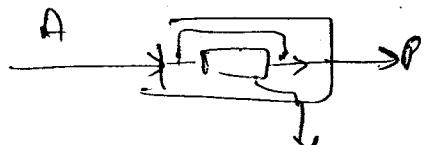
↳ to control the regulation in product composition.



at 1

Overall MB

$$A = P + V$$



Over 2 (Splitting pt)

Overall MB

$$A = B + C$$

Here composition is
done, so component balance
is used.

Over 3 (Mixing pt)

Overall MB

$$B + D = P$$

Component MB

$$B x_B + D x_D = P x_P$$

x100

on processing unit 4

(48)

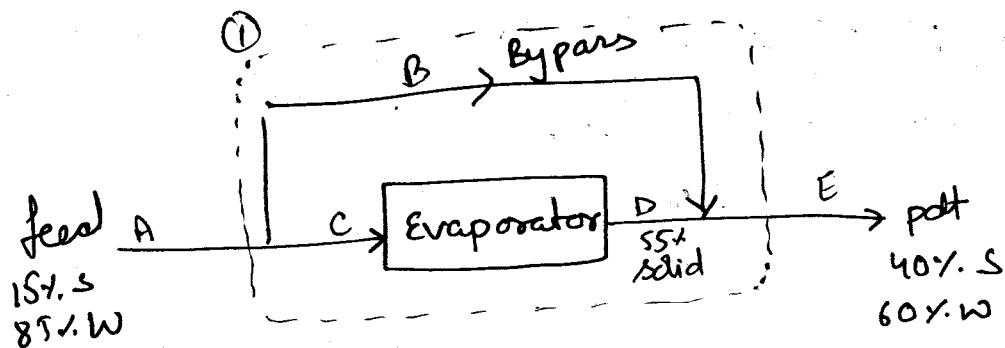
overall MB



$$C = D + V$$

$$C \pi_C = D \pi_D + V \pi_V$$

Q) Fresh juice contains 15% solid & 85% water is to be concentrated upto 40% solid in a single evaporation system. It is found to contain a bad taste. So to make it proper a part of fresh juice is by-passed evaporator and add to melt stream. The operation is shown as



Calculate fraction of juice that by-pass the evaporator & the concentrated juice produced per 100 kg of fresh juice.

By Pass Ratio = $\frac{\text{Amt of Bypass Stream}}{\text{Amt of fresh feed}} = \frac{B}{A}$ (from example)

Basis: 100 kg of fresh juice

Overall MB

$$A = E \quad , \quad 100 = E$$

$$A \pi_A = E \pi_E$$

Solid

$$15 = E \cdot 40$$

$$E =$$

$$C = D$$

$$C K_C = D K_D$$

$$C 0.15 = D 0.55$$

At min pt.

$$D + B = E$$

$$D 0.55 + B 0.15 = E \times 0.40$$

$$D 0.55 + \frac{37.5}{100} - D 0.15 = 40$$

$$0.55 D + 15 - 0.15 D = 40$$

$$0.4 D = 4$$

$$D = 62.5 \text{ kg}$$

$$B = 37.5 \text{ kg}$$

(*)

$$\text{By part ratio} = \frac{B}{100} \times 100$$
$$= 37.5$$
$$= 0.375 =$$

Volume
soth

Basis: 100 kg of fresh juice

MB for solid

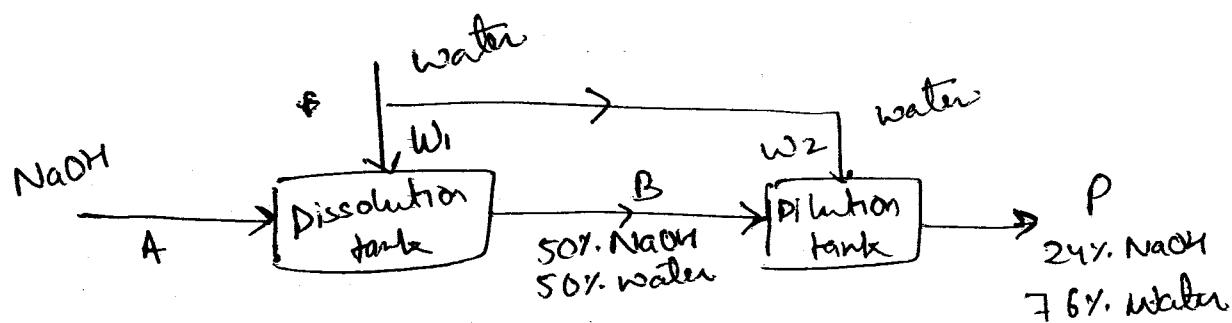
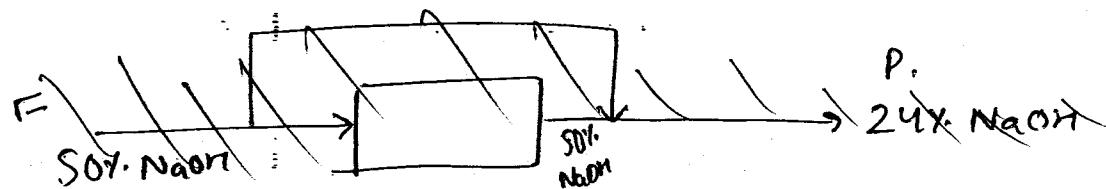
$$F \times 0.15 = P \times 0.4$$

$$P = \frac{100 \times 0.15}{0.4}$$

$$P = 37.5 \text{ kg}$$

(*) { same as above

Q.) In a textile industry, it is desired to produce 24% NaOH solⁿ by wt (w/w). Bc^r of very heat of solⁿ of NaOH in water, the above solⁿ is prepared by 2-step process. Firstly NaOH is dissolved in the correct quantity of water in a dissolution tank to prepare 50% solⁿ by wt (w/w). After dissolution & Cooling is complete. ~~This~~ This solution is taken to dilution tank where some more water is added for producing 24% solⁿ. Assuming no evaporation loss of water in any tank. Calculate the wt. ratio of water feed to the dissolution tank to be per water to dilution tank.



Basis:- 100 kg of 24% NaOH solⁿ

Over dilution tank

$$P_1 + P_2 = P$$

NaOH balance

$$P_1 \times 0.5 \pm P_2 \times 0.24$$

$$P_1 = 48 \text{ kg}$$

$$W_2 = 32 \text{ kg}$$

Mass Balance over dissolution tank

49

$$F + w_1 = P_1$$

f

Component Mass Balance

NaOH

$$F_{x1} = P_1 \times 0.5$$

$$F = 24 \text{ Kg}$$

$$w_1 = 24 \text{ Kg}$$

$$\Rightarrow \frac{w_1}{w_2} = \frac{24}{52} = 0.4615$$

Dec
1/1

1
2
3
4

5

27

37

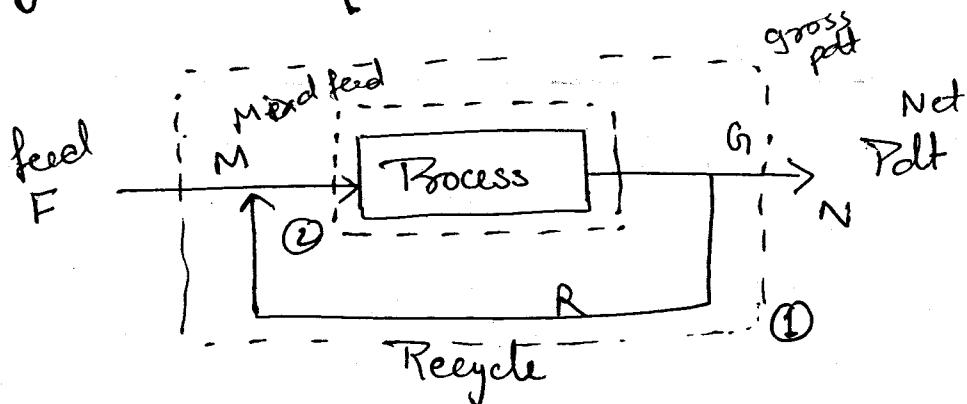
47

1R

Dec 06, 14

(80)

Recycle Operation



- to improve conversion
- to improve the purity of product
- to conserve energy.

1) Overall MB

$$F = N$$

Component MB $F x_F = N x_N$

2) Over processing Unit

$$M = G$$

Component MB $M x_M = G x_G$

3) Mixing -

$$R + F = M$$

Component MB $R x_R + F x_F = M x_M$

4) Splitting

$$G = N + R$$

Recycling Ratio (R) :-

Amount of stream recycled to the amt of stream in net pdt

$$= \frac{\text{Amt of stream recycled}}{\text{Amt of Stream in fresh feed}}$$

Material Balance With chem rxn

$$\text{Rate of Mass} \underset{\text{Accumulated}}{=} \text{Rate of Mass In} - \text{Rate of Mass out}$$

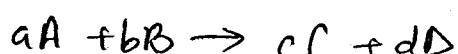
at steady state

$$\text{Rate of Mass In} = \text{Rate of Mass Out}$$

In terms of mole

$$\text{Rate of Moles Accumulated} = \text{Rate of Moles In} - \text{Rate of Moles out} + \text{Rate of Moles generated} - \text{Rate of Moles consumed}$$

Stoichiometric coefficient



$$\nu_A A + \nu_B B + \nu_C C + \nu_D D = 0$$

$$-aA + (b)B + cC + dD = 0$$

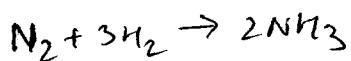
$$\boxed{aA + bB = cC + dD}$$

Stoichiometric ratio

$$\text{for A \& C} = \frac{a}{c}$$

Stoichiometric proportion

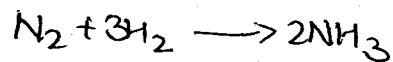
When the reactants are present in their stoichiometric ratio.



If $\frac{N_2}{H_2} = \frac{1}{3}$ or given in 1:3 ratio then they are in stoichiometric proportion.

Limiting Reactant

(52)



If 5 mol N_2 , 12 mol H_2 is given.

$$1 \text{ mol } N_2 = 3 \text{ mol } H_2$$

$$5 - N_2 = \frac{3 \text{ mol } H_2}{1 \text{ mol } N_2} \times 5 \text{ mol } N_2$$

$$= 15 \text{ mol } H_2$$

The component which exhaust first in the rxn.

Excess Reactant

The component which remain in excess & also available in ppt mixture after rxn complet'.

% Excess

$$\% \text{ Excess} = \frac{\text{Moles of reactant Supplied or fed} - \text{Moles of the reactant required}}{\text{Moles of reactant required}} \times 100$$

% Conversion :-

$$\frac{\text{Moles of A reacted}}{\text{Total Moles of A fed}} \times 100$$

$$= \frac{\text{Moles of A feed} - \text{Moles of A out}}{\text{Moles of A feed}} \times 100$$

Yield (Y) :-

$$\frac{\text{Moles of desired ppt formed to the total moles of A reacted}}{\text{Total moles of A reacted}}$$

$$\text{Initial A} = 10 \text{ mol}$$

$$\text{Free A} = 1 \text{ mol}$$

$$\text{Conv of A} = \frac{10-1}{10} = 90\% ; \frac{\text{Moles of B formed}}{9} = 20.6$$

$$A \rightarrow B \quad \text{Yield} = 60\% \Rightarrow 0.6 \times 9$$

$$A \rightarrow C \quad \text{Yield} = 40\% \Rightarrow 0.4 \times 9$$

moles formed
yield

Selectivity :-

(53)

$$S_{B/C} = \frac{\text{Moles of B formed}}{\text{Moles of C formed}}$$

$$\Rightarrow \text{If } S_{B/C} = 3.2$$

If 1 mole of C is formed then, 3.2 mole of B is formed.

Q) CO reacts with H_2 to produce methanol. Calculate

i) Stoichiometry ration of $\text{CO}_2 : \text{H}_2$

ii) Kmole of methanol produced per kmole of CO reacted.

iii) wt ratio of CO to H_2 if both are feed. Stoichiometry proportion.

iv) Qty of CO required for 1000 kg Mton production.



i) $1/2$

ii) 1 Kmole.

iii) 7 : 1 | $\frac{\text{CO}}{\text{H}_2} = \frac{1}{2} \times \frac{28}{2} = \frac{7}{1}$

iv) 875 kg

2 CO

Molar Calculation

Basic: 1000 kg of CH_3OH

$$n_{\text{CH}_3\text{OH}} = \frac{1000 \text{ kg}}{\frac{32 \text{ kg}}{\text{Kmol}}}$$

$$231.25 \text{ Kmol.}$$

1 kmol of CH_3OH produced by \approx 1 kmol of CO . (54)

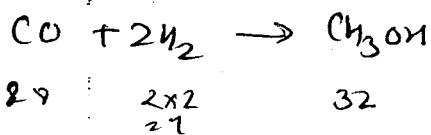
$$31.25 \text{ kmol of } \text{CO} \quad = 31.25 \text{ kmol of } \text{CO}$$

$$\text{mass of } \text{CO} \text{ required} = 31.25 \times 28 \frac{\text{kg}}{\text{kmol}}$$

$$= 875 \text{ kg.}$$

* Molar Calculation :-

Ratio: 1000 kg of CH_3OH



$$32 \text{ kg } \text{CH}_3\text{OH} \text{ prod} = 28 \text{ kg of } \text{CO}$$

$$1000 \text{ kg } \text{CH}_3\text{OH} \quad \approx \frac{28}{32} \times 1000$$

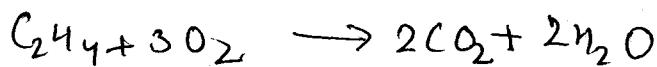
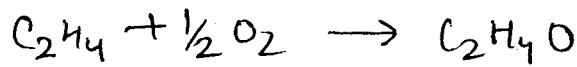
$$= 875 \text{ kg.}$$

Q) for the ammonia synthesis how much kg/hr of NH_3 will be produced. If % is 25% & feed rate of N_2 25 kmol/hr.

Q3 Ethylene oxide is prepared by 100 kmol of ethylene & 100 kmol of O₂ are fed to a reactor. The % conv. of Ethylene is 85% & % yield of C₂H₄O is 94.12%. Calculate the composition of product stream on mole basis.

$$X = 85\% \text{ (C}_2\text{H}_4\text{)}$$

$$Y_{\text{C}_2\text{H}_4\text{O}} = 94.12\%$$



Basis :- 100 kmol of C₂H₄
100 kmol of O₂

$$\text{Moles of C}_2\text{H}_4 \text{ reacted} = 100 \times 85 = 100 \times 0.85$$

$$\begin{aligned} \text{Moles of C}_2\text{H}_4\text{O formed} &= 85 \times 0.9412 \\ &= 80.0002 \text{ kmol.} \end{aligned}$$

for Rxn 1

$$\begin{aligned} 1 \text{ kmol C}_2\text{H}_4\text{O reqd} &= 1 \text{ kmol C}_2\text{H}_4 \\ 80.0002 &= 80.0002 \text{ kmol C}_2\text{H}_4 \end{aligned}$$

$$\begin{aligned} 1 \text{ kmol of C}_2\text{H}_4\text{O reqd} &= 0.5 \text{ kmol O}_2 \\ 80.0002 &= 40.001 \text{ kmol O}_2 \end{aligned}$$

for Rxn 2

$$\begin{aligned} \text{C}_2\text{H}_4 \text{ reacted} &= 85 - 80.002 \\ &= 4.998 \text{ kmol} \end{aligned}$$

$$1 \text{ kmol C}_2\text{H}_4 \text{ prod} = 2 \text{ kmol CO}_2$$

Sol'n

224
ethylene
conv. of
%

basis.

$$4.998 \text{ — } = 9.996 \text{ kmol } \text{O}_2$$

$$9.99 \text{ — } = 9.991 \text{ kmol } \text{H}_2\text{O}$$

(58)

1 kmol of C_2H_4 = 3 kmol O_2

$$4.998 \text{ — } = 3 \times 4.998$$

$$= 14.994 \text{ kmol } \text{O}_2$$

$$\text{O}_2 \text{ remaining. } = 100 - 40.001 - 14.999$$

$$= 45.005 \text{ kmol.}$$

C_2H_4	15
$\text{C}_2\text{H}_4\text{O}$	80.002
O_2	45.005
CO_2	9.996
H_2O	9.996

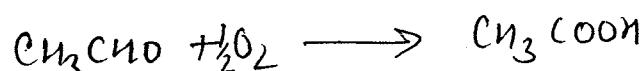
220-85

mol.

Q) In a manufacturing of CH_3COOH by oxidation of CH_3CHO which is fed to a reactor per/hr. The pvt leaving the reactor contains 14.81% CH_3CHO , 39.26% CH_3COOH & rest oxygen of mole basis. Find out % of CH_3COOH .

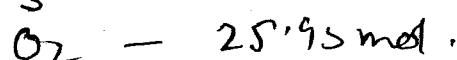
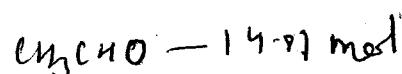
12593

Soln



Basis 100 mol of pvt.

$$100 - n = 14.81\%$$



$$\frac{100}{285.19}$$

1 mol of CH_3COOH prod by 2 1 mol CH_3CHO

(57)

$$59.26 \text{ mol} = 59.26 \text{ mol } \text{CH}_3\text{CHO}$$

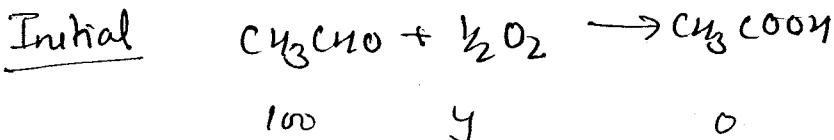
total acetaldehyde = $14.81 + 59.26$

$$= 74.07 \text{ mol}$$

$$x = \frac{59.26}{74.07} \times 100 = 80.005\%$$

OR

Basis : 100 mol CH_3CHO



finally let 'x' mol reacted acetaldehyde

$$(100-x) \quad (y-x/2) \quad x$$

$$\text{total final moles} = (100-x) + (y-x/2) + x$$

$$n_{\text{tot}} = 100 + y - x/2$$

for CH_3CHO ,

$$\frac{n_{\text{CH}_3\text{CHO}}}{n_{\text{tot}}} = 0.148$$

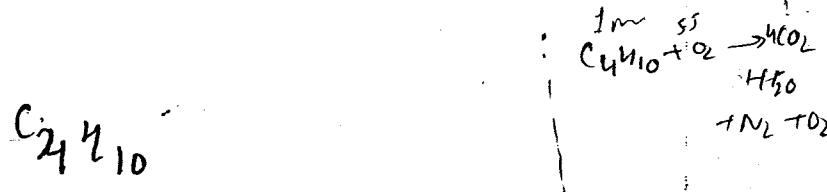
$$\frac{100-x}{100+y-x/2} = 0.148 \quad (1)$$

for CH_3COOH

$$\frac{x/2}{100+y-x/2} = 0.8926 \rightarrow x$$

$$x = 80.005 \text{ mol}$$

Q7 A combustion chamber is fed with butane & (58)
 excess air. Combustion of butane is complete. The
 composition of combustion gases on vol% basis is given
 as $\text{CO}_2 \rightarrow 9.39\%$, $\text{H}_2\text{O} \rightarrow 11.73\%$, $\text{O}_2 \rightarrow 4.7\%$, $\text{N}_2 \rightarrow 74.18$.
 Find the % excess of fuel & moles air ~~per~~ per mole
 of air.



* In gaseo, volume % is same as ~~geo~~ mole %.

Ar $\hookrightarrow 79\% \text{ N}_2$
 $\hookrightarrow 21\% \text{ O}_2$

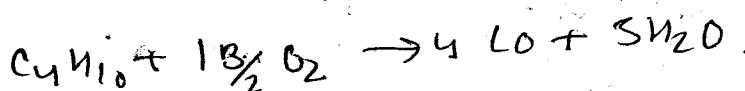
Basis: 100 mol of combustion gases.

CO₂ - 939%.

$$O_2 = 4.7 \text{ mol}$$

$$\text{H}_2\text{O} = 11.73 \text{ mol}$$

$$N_2 \rightarrow 74.18 \text{ mol.}$$



$$4 \text{ mol CO}_2 \text{ resp.} = 1 \text{ mol Butane}$$

$$9.39 \text{ mol} \text{ Cu}_{4}H_{10} \times \frac{1}{4} = 2.3475 \text{ mol Cu}_{4}H_{10}$$

$$4 \text{ mol } \text{CO}_2 \text{ reqd} = \frac{18}{2} \text{ mol } \text{O}_2$$

$$9.39 = \frac{15}{2x_{\text{H}_2}} \times 9.37 = 15.2587 \text{ mol O}_2$$

O₂ supplied 15.2587 + 4.7

= 19.9387 mol O₂

$$(\text{O}_2)_{\text{med}} \text{ in air} = \text{air} \times 0.21$$

(59)

Dec

Q7

→

80

$$\text{moles of air} = \frac{\text{moles of O}_2}{21}$$

$$\text{Air reqd} = \frac{\text{O}_2 \text{ reqd.}}{0.21} = \frac{15.2587}{0.21} = 72.6604 \text{ kmol}$$

$$\text{Air supplied} = \frac{\text{O}_2 \text{ supp}}{0.21} = \frac{19.9582}{0.21}$$

$$\% \text{ excess} = \frac{19.9582 - 72.6604}{72.6604} \times 100$$

$$= 30.80\%$$

$$\frac{\text{Harm}}{\text{H.bur}} = \frac{95.01}{234.75} \times 40.486$$

$$\% \text{ excess air} = \% \text{ excess O}_2$$

$$\frac{\text{air feed} - \text{air reqd.}}{\text{air reqd.}} \times 100\%$$

$$\frac{\text{air feed} \times 0.21 - \text{air reqd} \times 0.21}{\text{air reqd} \times 0.21}$$

$$\frac{\text{O}_2 \text{ feed} - \text{O}_2 \text{ reqd.}}{\text{O}_2 \text{ reqd.}}$$

Dec 13, 14

(60)

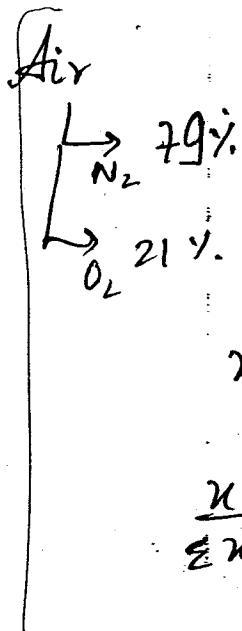
Q) 15% H₂, 85% C, 1 kg petrol, pdt (dry basis) If 15% excess air was used by mol/mol.

→ How much amt of air is reqd for complete combustion.

9 Kmols

Sol

for gases
vol.-%
mol.-%



$$\chi_{N_2} = \frac{0.79}{1}$$

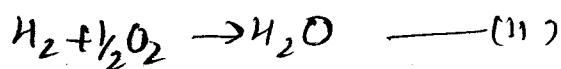
$$\frac{\chi}{\sum \chi} = \frac{\chi_{N_2}}{\chi_{N_2} + \chi_{O_2}} = \frac{0.79}{0.79 + 0.21} = \frac{0.79 \times 28}{0.79 \times 28 + 0.21 \times 32} \\ = 0.7669$$

Basic 1 Kg of petrol



$$C = 0.85 \text{ kg}$$

$$H_2 = 0.15 \text{ kg}$$



Molar Basis

$$\text{kg atom of } C = \frac{0.85}{12} \text{ kg} = 0.0708 \text{ kg atom}$$

$$\text{kg moles of } H_2 = \frac{0.15}{2} \text{ kg} = 0.075 \text{ kg mol}$$

from rxn (I)

$$1 \text{ kg atom } C \text{ reqd} = 1 \text{ kg mol of } O_2$$

$$0.0708 \text{ kg mol } C = 0.0708 \text{ kg mol } O_2$$

from QAA 2

(61)

$$0.075 \text{ kmol H}_2 \text{ reqd} = \frac{1}{2} \times 0.075 \text{ kmol O}_2 \\ = 0.0375 \text{ kmol O}_2$$

$$\text{total O}_2 \text{ reqd} = 0.0708 + 0.0375 \\ = 0.1083 \text{ kmol O}_2$$

$$\text{total air reqd} = \frac{0.1083}{0.21} \\ = 0.5158 \text{ kmol air}$$

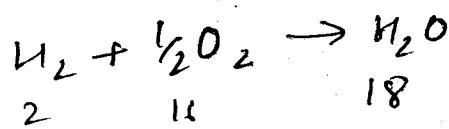
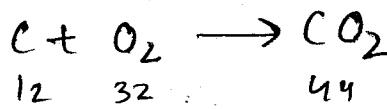
$$\text{Air reqd} = 0.5158 \text{ kmol air} \times 0.28.84 \frac{\text{kg}}{\text{kmol}} \\ = 14.87 \text{ kg air}$$

Molar Basis

Basis: 1 kg of petrol

$$\text{C} - 0.85 \text{ kg}$$

$$\text{H}_2 - 0.15 \text{ kg}$$



$$12 \text{ kg C reqd} = 32 \text{ kg O}_2$$

$$0.85 \text{ kg C} \xrightarrow{\text{molar ratio}} \frac{32}{12} \times 0.8 = 2.26 \text{ kg O}_2$$

$$2 \text{ Kg } \text{H}_2 \text{ reqd} = 16 \text{ Kg } \text{O}_2$$

$$0.15 = \frac{16 \text{ Kg } \text{O}_2}{2 \text{ Kg } \text{H}_2} \times 0.15 \text{ Kg } \text{H}_2$$
$$= 1.2 \text{ Kg } \text{O}_2$$

$$\text{total } \text{O}_2 \text{ reqd} = 3.46 \text{ Kg } \text{O}_2$$

$$\text{air reqd} = \frac{3.46}{0.23} = 5.217 \text{ Kg}$$

$$\text{O}_2 \text{ reqd} = 3.46 \text{ Kg}$$

(excess)

$$\text{O}_2 \text{ supplied} = 3.46 + 3.46 \times 0.15$$
$$= 3.979 \text{ Kg}$$

$$\text{O}_2 \text{ remaining} = 3.979 - 3.46$$
$$= 0.513 \text{ Kg}$$

$$\text{N}_2 \text{ fed} = 15.06 \times 1.15 \times 0.77$$
$$= 13.343 \text{ Kg.}$$

$$12 \text{ Kg C} = 44 \text{ Kg } \text{CO}_2$$

$$0.85 \text{ Kg} = \frac{44}{12} \times 0.85 = 3.116 \text{ Kg } \text{CO}_2$$

Q) A feed containing 60% A, 30% B, 10% inert. (63) Q)
 enters a reactor. The exit stream leaving the reactor
 contains 2% A. Then find %age conversion of A.
 If the rxn takes place as $2A + B \rightarrow C$

Sol^h

<u>Basis</u>	100 mol of feed	$\gamma \cdot x_A = \frac{\text{mole A feed - A out}}{\text{mole A feed}} \times 100$
A	$\rightarrow 60 \text{ mol}$	
B	$\rightarrow 30 \text{ mol}$	
I	$\rightarrow 10 \text{ mol}$	

Initially



$$60 + 30 + 0 + 10 \text{ mol I} = 100 \text{ mol}$$

let x mol A reacted

finally

$$(60-x) + (30-\frac{x}{2}) + \frac{x}{2} + 10 \text{ mol I} = 100 - x$$

$$y_A = \frac{n_A}{n_{\text{total}}}$$

$$0.02 = \frac{60-x}{100-x}$$

$$x = 59.18 \text{ mol}$$

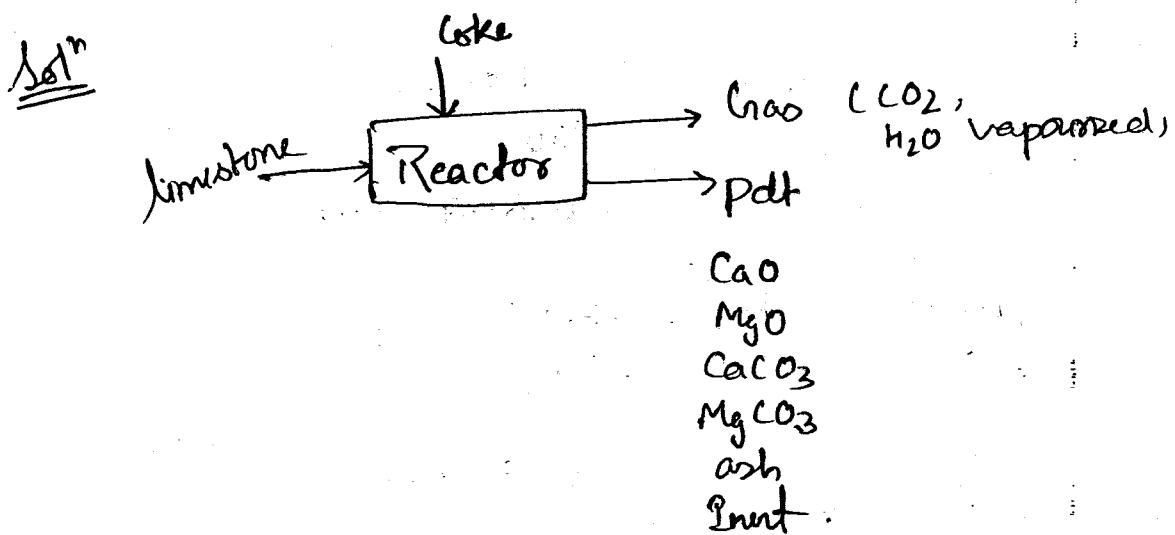
$$x_A = \frac{60 - (60 - 59.18)}{60} \times 100$$

$$\approx 98.63\%$$

L.
reactor
of A.

Q) Limestone mixed with coke is being burnt in a kiln. An (44)
avg. analysis of limestone is 84.5% CaCO_3 , 11.5% MgCO_3
& rest inert. Coke contains 76% C, 21% ash, rest moisture
content. The calcination of CaCO_3 is only 95% & MgCO_3 is 90%.
The C in coke is completely burned into CO_2 . The kiln is fed
with 1 kg coke/kg of limestone. Calculate the wt% of
CaO in pdt leaving the kiln. Assume that moisture
present in the feed is completely vapourised.

Mol wt MgCO_3 - 84
 CaCO_3 - 100



Basics :- 1 kg Coke & 5 kg limestone

Coke

$$\begin{aligned} \text{C} &\rightarrow 0.76 \text{ kg} \\ \text{ash} &\rightarrow 0.21 \text{ kg} \\ \text{moist} &\rightarrow 0.03 \text{ kg} \end{aligned}$$

Limestone

$$\begin{aligned} \text{CaCO}_3 &\rightarrow 5 \times 0.845 \\ &= 4.225 \text{ kg.} \end{aligned}$$

$$\begin{aligned} \text{MgCO}_3 &\rightarrow 5 \times 0.115 \\ &= 0.575 \text{ kg} \end{aligned}$$

$$\text{Inert} \rightarrow 5 \times 0.04 = 0.2 \text{ kg}$$

(65)

$$\text{CaCO}_3 \text{ reacted} = 4.225 \text{ kg} \times 0.95 \\ = 4.01375 \text{ kg}$$

$$\text{CaCO}_3 \text{ unreacted} = 4.225 - 4.01375 \\ = 0.21125 \text{ kg}$$

$$\text{MgCO}_3 \text{ unreacted} = 0.575 \text{ kg} - 0.575 \times 0.9 \\ = 0.0575 \text{ kg}$$

$$\text{CaCO}_3 \text{ reacted} = \frac{4.01375 \text{ kg}}{160} \\ = 0.0401375 \text{ kmol}$$

$$\text{MgCO}_3 \text{ reacted} = \frac{0.575 \times 0.9}{84} \text{ kg} \\ = 0.00616 \text{ kmol}$$

$$\text{CaO produced} = 0.0401375 \text{ kmol} \\ = 0.0401375 \times 56 \\ = 2.2477 \text{ kg}$$

1 mol CaCO₃ — 1 mol CaO

CaO_{mm} = 56

$$\text{MgO produced} = 0.00616 \text{ kmol}$$

$$= 0.00616 \text{ kmol} \times 40 \frac{\text{kg}}{\text{kmol}} \\ = 0.2464 \text{ kg}$$

Component	wt %
CaCO_3	0.21125
MgCO_3	0.0575
CaO	2.2477
MgO	0.2464
Ash	0.21
Inert	0.2
	<u>3.17285</u>

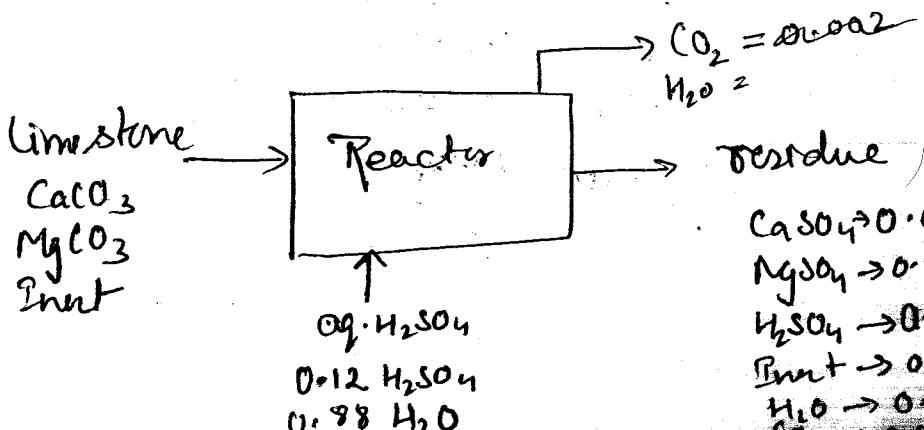
$$\text{CaO} = \frac{2.2477}{3.17285} = 0.7084$$

= 70.84%

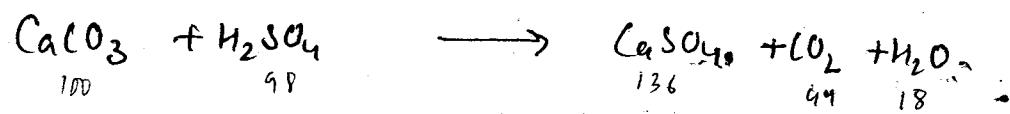
Q) Pure CO_2 may be prepared by treating lime stone with $\text{aq. H}_2\text{SO}_4$. The lime stone used contain CaCO_3 & MgCO_3 & rest inert. $\text{aq. acid used contain 12\% H}_2\text{SO}_4$ by wt & rest water. The residue from the process found to contain CaSO_4 9%, MgSO_4 5%, H_2SO_4 1.2%, inert 0.5%, CO_2 0.2% & H_2O 84.1%.

During the process the mass was heat up and CO_2 & H_2O vapour was removed.

- Calculate analysis of limestone used. (composition)
- % excess of acid used.
- Mass of water vapourized per 100 kg of lime stone.



$\text{CaSO}_4 \rightarrow 0.09\%$
 $\text{MgSO}_4 \rightarrow 0.05\%$
 $\text{H}_2\text{SO}_4 \rightarrow 0.12\%$
 $\text{Inert} \rightarrow 0.005$
 $\text{H}_2\text{O} \rightarrow 0.841$



$$\frac{100}{136} \times 0.09 \times 100$$

$$\text{CaCO}_3 = 0.0661 \text{ kg}$$

$$\frac{84}{120} \times 0.05 \times 100$$

$$\text{MgCO}_3 = 0.035 \text{ kg}$$

$$\text{Residue} = 0.005 \text{ kg}$$

Basis. — 100 kg of Residue.

$$\text{Residue} = 0.5 \text{ kg}$$

$$\text{CaSO}_4 = 9 \text{ kg}$$

$$\text{MgSO}_4 = 5 \text{ kg}$$

$$\text{H}_2\text{SO}_4 = 1.2 \text{ kg}$$

$$\text{CO}_2 = 0.2 \text{ kg}$$

$$\text{H}_2\text{O} = 84.1 \text{ kg}$$

$$1 \text{ kmol } \text{CaSO}_4 \text{ produced by } = 1 \text{ kmol } \text{CaCO}_3$$

$$0.06617 \text{ kmol } \text{CaCO}_3$$

$$1 \text{ kmol } \text{MgSO}_4 \text{ } \Rightarrow 1 \text{ kmol } \text{MgCO}_3$$

$$0.0416 \text{ kmol } \text{MgCO}_3$$

$$\text{CaCO}_3 \text{ reqd } \approx 0.06617 \text{ kmol} \times 100 \frac{\text{kg}}{\text{kmol}}$$

$$\approx 0.617 \text{ kg}$$

$$\text{MgCO}_3 \text{ reqd } \approx 0.0416 \text{ kmol} \times 84 \frac{\text{kg}}{\text{kmol}}$$

$$\approx 3.5 \text{ kg}$$

$$\text{Lime stone} \approx 6.617 \text{ kg } \text{CaCO}_3 + 3.5 \text{ kg } \text{MgCO}_3 + 0.5 \text{ kg}$$

$$\approx 10.617 \text{ kg.}$$

$$\text{Lime stone} \rightarrow \text{CaCO}_3 - 62.32\%$$

$$\text{MgCO}_3 - 32.96\%$$

$$\text{Blast} - 4.71\%$$

ii.) from rxn (1)

$$1 \text{ kmol } \text{CaSO}_4 \text{ reqd } = 1 \text{ kmol } \text{H}_2\text{SO}_4$$

$$0.06617 \text{ kmol } \text{CaSO}_4 \text{ } \Rightarrow 0.06617 \text{ kmol } \text{H}_2\text{SO}_4$$

from rxn (2)

$$1 \text{ kmol } \text{MgSO}_4 \text{ reqd } = 1 \text{ kmol } \text{H}_2\text{SO}_4$$

$$0.0416 \text{ kmol } \text{MgSO}_4 \text{ } \Rightarrow 0.0416 \text{ kmol } \text{H}_2\text{SO}_4$$

$$\text{total } \text{H}_2\text{SO}_4 \text{ reqd } \approx 0.06617 + 0.0416 \approx 0.1077 \text{ kmol } \text{H}_2\text{SO}_4$$

$$\text{H}_2\text{SO}_4 \text{ reqd } \approx 0.1077 \times 98 \frac{\text{kg}}{\text{kmol}}$$

$$\approx 10.561 \text{ kg}$$

% excess H_2SO_4

(69)

$$\begin{aligned} \text{Acid reqd} &= \frac{10.561}{0.12} \\ &= 88.0083 \text{ kg} \end{aligned}$$

$$\begin{aligned} H_2SO_4 \text{ feed} &= (10.561 + 1.2) \text{ kg} \\ &= 11.761 \text{ kg} \end{aligned}$$

$$\begin{aligned} \text{Acid feed} &= \frac{11.761}{0.12} \\ &= 98.0083 \text{ kg} \end{aligned}$$

$$\begin{aligned} \% \text{ excess acid} &= \frac{\text{amt feed} - \text{amt reqd}}{\text{amt reqd}} \times 100 \\ &= \frac{98.0083 - 88.0083}{88.0083} \times 100 \\ &= 11.36\% \end{aligned}$$

iii) Amt of lime stone = 10.6176 kg

$$\text{Acid feed} = 98.0083 \text{ kg}$$

$$\text{Water feed} = 98.0083 \times 0.88$$

$$= 86.247 \text{ kg}$$

for exm (ii)

1 kmol $CaSO_4$ react with = 1 kmol of H_2O

$$0.06617 \text{ kmol} \xrightarrow{\quad} 6.6617 \text{ kmol } H_2O$$

Q3 T
24.
SOOT
all
as
Sta
as
4

for oxn (2)

$$1 \text{ kmol of } \text{MgSO}_4 \text{ prod} = 1 \text{ kmol } \text{H}_2\text{O}$$

$$0.0415 = 0.0415 \text{ kmol } \text{H}_2\text{O}$$

$$\text{total } \text{H}_2\text{O} \text{ produced} = 0.06617 + 0.0416$$

$$= 0.10777 \text{ kmol}$$

$$= 0.10777 \text{ kmol} \times 18 \frac{\text{kg}}{\text{kmol}}$$

$$= 1.939 \text{ kg}$$

$$\text{total } \text{H}_2\text{O} \text{ present in process} = \text{H}_2\text{O feed} + \text{H}_2\text{O prod.}$$

$$= 86.247$$

$$= 86.247 + 1.939$$

$$= 88.186 \text{ kg}$$

$$\text{H}_2\text{O vaporized} = 88.186 - 84.1$$

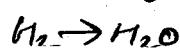
$$= 4.086 \text{ kg}$$

$$\text{With } 10.617 \text{ kg limestone} = 4.085 \text{ kg } \text{H}_2\text{O}$$

$$100 \text{ kg} = \frac{4.085}{10.617} \times 100$$

$$= 38.485 \text{ kg}$$

Q) The analysis of coal indicates 70% carbon, 20% H₂ & 2% S & rest ash by wt. The coal is burnt at the rate of 5000 kg/hr. feed rate of air to the furnace is 50 kmol/min. all of ash and 6% of C in the fuel leave the furnace as a molten slag. The remainder of the carbon leave in the slag gas as CO & CO₂ (rest C). The hydrogen in coal is oxidised as water and S emerges as SO₂. The selectivity of CO₂/CO



in pdt gases is $10/1$ ($S_{CO_2/CO} = 10/1$)

(71)

Se

i) % excess of air present fed.

125.63%

ii) mole fraction of gaseous pollutants (CO_2 & SO_2)

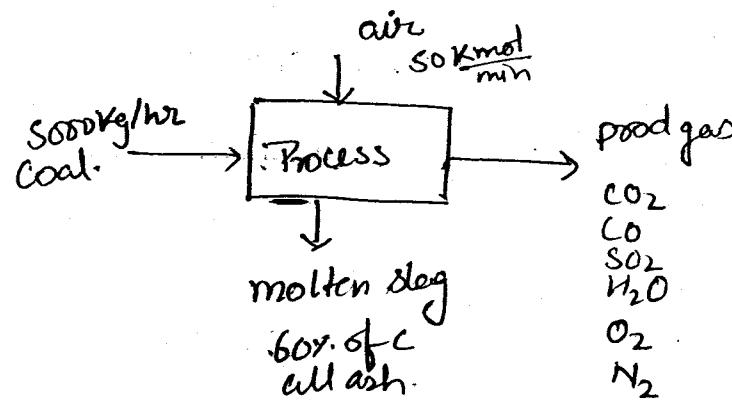
iii)

Material Balance w/ chem rxn (Recycle)

F

Solⁿ

72



Basin: 5000 kg/hr of coal & 50 kmol/min of air.

Coal

$$C = 5000 \times 0.7 = 3500 \text{ kg/hr}$$

$$H_2 = 5000 \times 0.2 = 1000 \text{ kg/hr} = \frac{1000}{2} = 500 \text{ kmol/hr}$$

$$S = 5000 \times 0.02 = 100 \text{ kg/hr} = \frac{100}{32} = 3.125 \text{ kmol/hr}$$

$$\text{ash} = 5000 \times 0.08 = 400 \text{ kg/hr}$$

$$C \text{ in molten slag} = 3500 \times 0.06 = 210 \text{ kg/hr}$$

$$C \text{ reacted} = 3500 - 210 = 3290 \text{ kg/hr}$$

$$C \text{ reacted} = \frac{3290}{12} \text{ kg/hr}$$

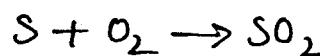
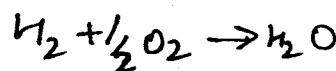
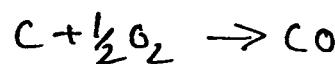
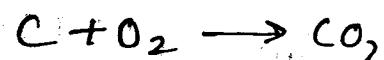
$$= 274.166 \text{ kmol/hr}$$

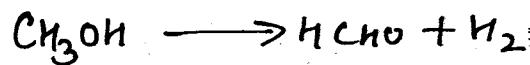
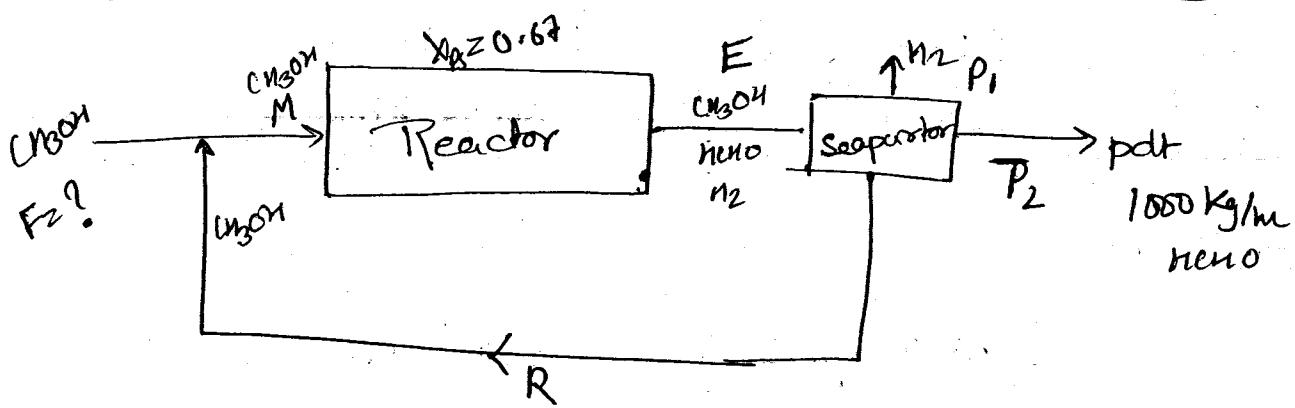
Air

$$\frac{50 \text{ kmol}}{\text{min}} \times 60 \frac{\text{min}}{\text{hr}} = 3000 \text{ kmol/hr}$$

$$N_2 = 3000 \text{ kmol} \times 0.79 = 2370 \text{ kmol/hr}$$

$$O_2 = 3000 \times 0.21 = 630 \text{ kmol/hr}$$





Ratio :— $1000 \cdot \text{kg/hr}$ Hno produced.

$$\text{HCHO reqd} = \frac{1000 \text{ kg/hr}}{30 \text{ kg/kmol}} = 33.33 \text{ kmol/hr}$$

Let M kmol/he is in mixed feed

$$\text{MeOH reacted} = M \times 0.67 \text{ kmol/m}$$

Mean Unscattered = $m \times 0.33 \text{ kmol/hr}$

1 kmol MeOH prod = 1 kmol HClO

$$M \times 0.67 = M \times 0.67 \text{ kmol/hr HClO}$$

Amnt of radio in pelt will be same as in the reactor outlet stream before separator.

$$M \times 0.67 = 33.33 \text{ Kmol/m}^2$$

$$M = 49.751 \text{ kmol/m}$$

Unreacted monomer is being completely recycled,

$$R = M \times 0.33 \\ = 16.417 \text{ Kmol/hr}$$

from mixing pt,

$$F + R = M$$

74

$$F = 49.751 - 16.417$$

$$= 33.33 \text{ Kmol/hr.}$$

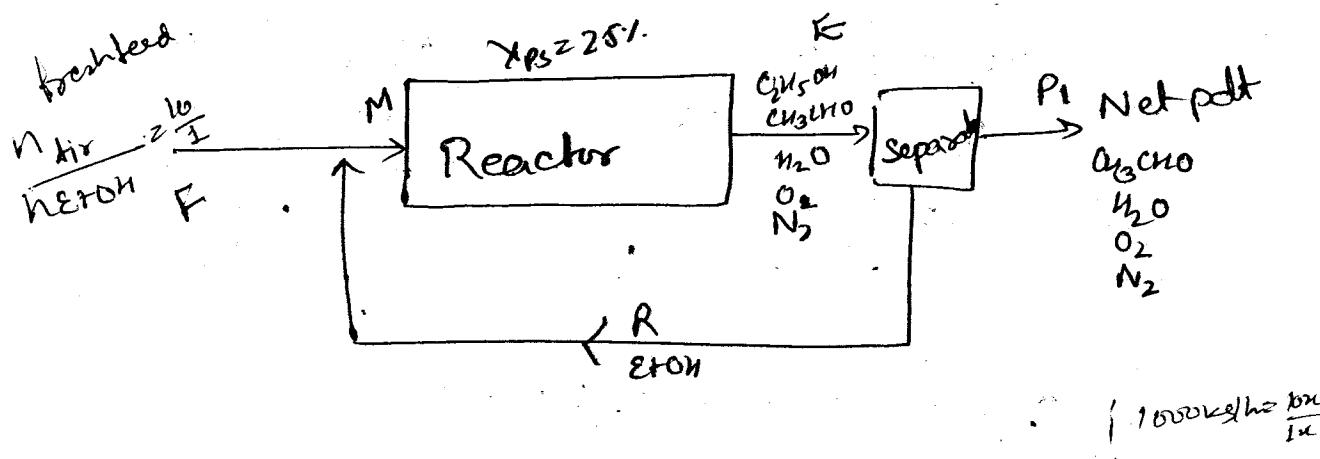
g/hr
no

$$\text{Combined feed ratio} = \frac{49.751}{33.33} = 1.492$$

$$\text{MeOH reqd} = 33.33 \frac{\text{Kmol}}{\text{hr}} \times 32 \frac{\text{kg}}{\text{Kmol}} = 1066.66 \text{ kg/hr.}$$

Q.) It is proposed to produce acetaldehyde by oxidation of EtOH in the gas phase rxn. $\text{C}_2\text{H}_5\text{OH} + \frac{1}{2}\text{O}_2 \rightarrow \text{CH}_3\text{CHO} + \text{H}_2\text{O}$
 The ratio of air to EtOH in fresh feed is 10:1. The conversion of EtOH on a single pass is 25%. The unreacted EtOH is completely separated from outlet & recycle. What is the ratio of recycle stream to the fresh feed & the composition of outlet stream from reactor. (in mol% & wt%)

per
wt 67%.



Series

1 mol EtOH & 10 mol air.

fresh feed air, $\text{N}_2 = 7.9 \text{ mol}$
 $\text{O}_2 = 2.1 \text{ mol}$

Mixed feed

overall MB

$$F + R = M$$

$$M = R + 11$$

O₂ — 2.1 mol,

N₂ — 7.9 mol.

Etoh — (1+R) mol.

(75)

Q9
*

$$X_{ps} = 0.25$$

$$\text{Etoh reacted} = (1+R) \times 0.25 \text{ mol}$$

$$\text{Etoh unreacted} = (1+R) \times 0.75 \text{ mol}$$

Et in Recycle stream = Etoh entering in separator

$$R = (1+R) \times 0.75$$

$$R = 3$$

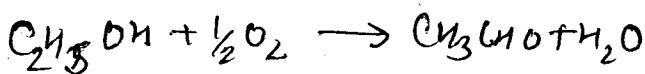
$$P = 11$$

$$\frac{R}{P} = \frac{3}{11}$$

	<u>n</u>	<u>m</u>	<u>mol %</u>	<u>wt %</u>
N ₂	7.9 mol	0.2821	54.48	46.82%
C ₂ H ₅ OH	1		6.89	9.31%
C ₂ H ₅ OH	3		20.68	29.21%
O ₂	2.1 - 1/2 = 1.6		11.03	10.83%
H ₂ O	1		6.89	3.78%
	<u>14.5</u>			

Q.7

1



for
for
A, T
0.5

P_{atm}
1.71

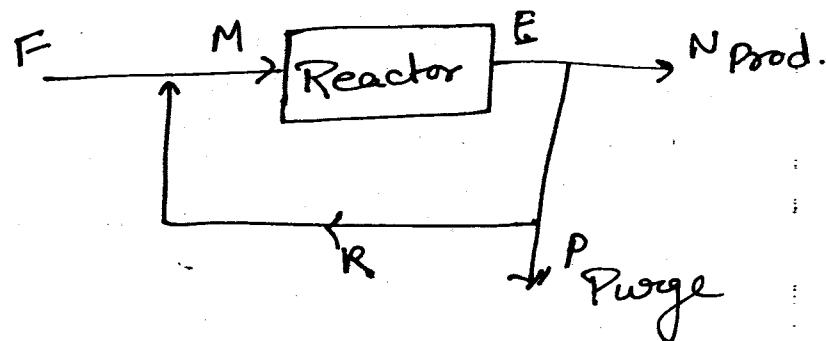
0

11.1

11.1

*Purging :-

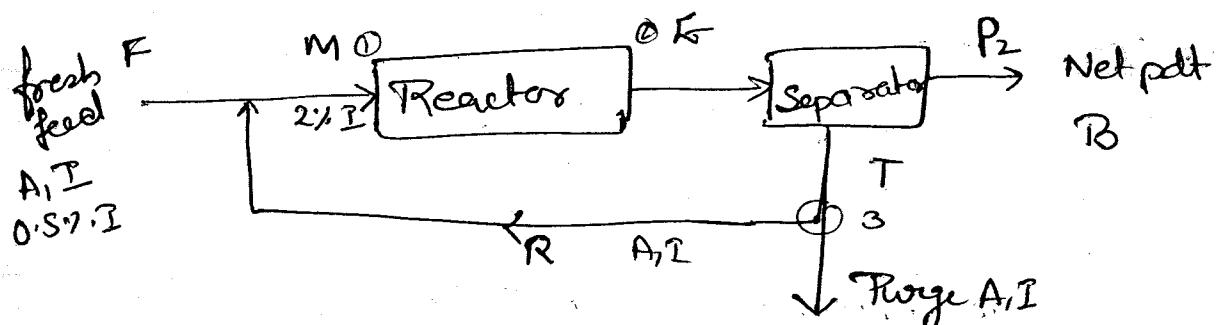
Removal of the fract^h of recycle stream. Such that the amount of Inert in purge stream is same as amt. of Inert in fresh feed.



at steady state,

$$F \times \eta_F = P \cdot \eta_P$$

Q.) For the rxn, $A \rightarrow B$. The process flow diagram is given as the fresh feed of A contains 0.5% inert by mole. 60% conversion of A per pass is achieved. The concentration of inert going into the reactor is 0.1 must be held at 2% by mol.



Process is at steady state. Calculate

- How many moles have to be recycled per mole of total feed at ~~at~~ pH(1) to reactor
- How many moles need to be purge
- Over conversion of A

Basis

1 mol of feed, 0.5 mol A & 0.5 mol B

(77)

for inert

$$F + R = M$$

$$0.5 + R = M$$

$$R = 1.5 \text{ mol}$$

$$F_{nF} + R_{nR} = M_{nM}$$

$$0.5 + R_{nR} = M \times 0.02$$

$$A_{\text{reacted}} = M \times 0.60$$

$$A_{\text{unreacted}} = M \times 0.40$$

Basis

1 mol of mixed feed at 1,

$$A \text{ in MF} = 0.98 \text{ mol}$$

$$\text{Inert in MF} = 0.02 \text{ mol.}$$

at Reactor outlet

$$A_{\text{reacted}} = 0.98 \times 0.6$$

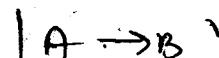
$$= 0.588 \text{ mol}$$

$$A_{\text{unreacted}} = 0.98 - 0.588$$

$$= 0.392 \text{ mol}$$

$$B = 0.02 \text{ mol}$$

$$B = 0.588 \text{ mol}$$



Over separator

overall Mole Balance

(78)

$$E = T + P_2$$

A1 Balance

$$(0.392 + 0.62 + 0.588) = T + 6.588$$

$$T = 0.412 \text{ mol.}$$

χ_A in T

$$\chi_A = \frac{0.392}{0.412} = 0.9514$$

$$\chi_P = 1 - 0.9514 = 0.0485.$$

at splitting pt (3)

overall mole Balance

$$P + R = T = 0.412$$

over mixing pt

$$F + R = M = 1 \quad F = 1 - R$$

I Balance

$$F \times 0.005 + R \times 0.0485 = 0.02 \times 1$$

$$F = 0.655 \text{ mol} \quad \left. \right\}$$

$$R = 0.344 \text{ mol.}$$

$$P + R = T = 0.412$$

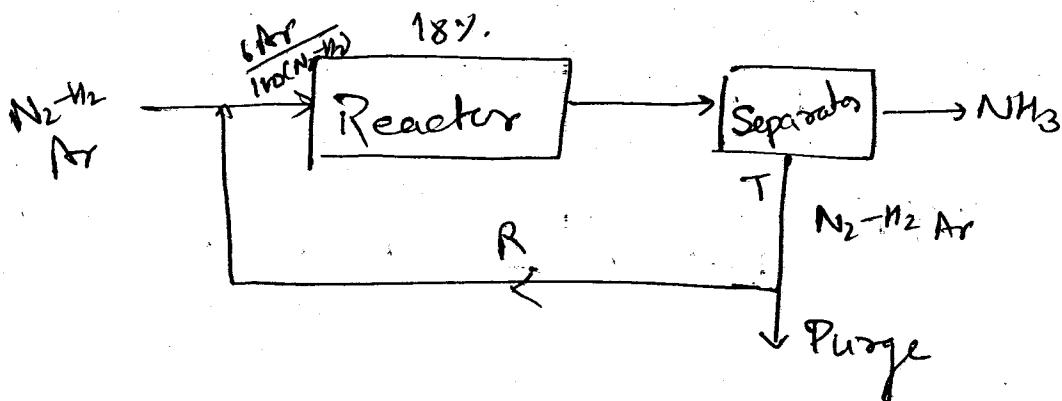
$$P = 0.068 \text{ mol.}$$

$$X_A = \frac{F \times 0.995 - P \times 0.9514}{F \times 0.995} \times 100$$

79

$$X_A = 90.19\%$$

Q.) N₂ & H₂ mixture with molar ratio 1:3 is used for manufacturing of NH₃, where 18% conversion is achieved after separating NH₃ from the product, gases are recycled. The feed contains 0.2 mol of Ar/100 mol of N₂&H₂ mix. The tolerance limit of Ar entering the reactor is 6 part Ar/100 part (N₂-H₂) by mol. Calculate the fraction of recycle stream that must be continuously purged & overall yield of ammonia.

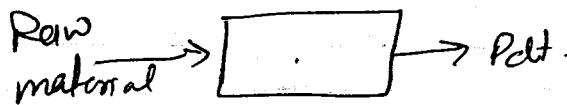


$$\frac{P}{T} =$$

$$\text{Purge Ratio} = \frac{P}{R}$$

Energy Balance

(80)



for
cheered
ycled
 \rightarrow mix
is
action
object

Law of Energy Conservation

Energy can't be generated or destroyed, only can be changed to diff form.

$$\rightarrow PE = mg.h$$

$$\rightarrow KE = \frac{1}{2}mv^2$$

$$\rightarrow IE = \alpha - w$$



Q: A body of mass 75kg is lifted through a distance of 10m, what is the work done if it takes 2.5mins for lifting the mass.

$$m = 75$$

$$h = 10m$$

$$t = 2.5\text{ min}$$

$$W = ?$$

$$P.H = F \times h \times g \times t$$

$$= (7357.5)$$

$$W = F \times d \times z = 49.05$$

$$W = F \times d \times z$$

$$F = mg$$

$$W = mg \cdot \Delta z$$

$$= 75 \times 9.81 \times 10$$

$$= 7357.5 \frac{\text{kgm}}{\text{N}} \cdot \text{m} = 7357.5 \text{ J}$$

$$P = \frac{W}{t}$$

$$= \frac{7357.5}{2.5 \text{ min}} \text{ J} \times \left(\frac{1 \text{ min}}{60 \text{ sec}} \right)$$

$$= 49.05 \text{ W},$$

(31)

Q.) PE of a body of mass 10 kg is 15 kJ. What is the height of body from ground in ft. If a body of mass 10 kg has KE 12 kJ. What will be the momentum then?

$$PE = mgh$$

$$15 \text{ kJ} = 10 \text{ kg} \times 9.81 \times h$$

$$\frac{15 \times 10^3}{10 \times 9.81} = h$$

$$h = 152.90 \text{ m} \times \frac{1 \text{ ft}}{0.3048 \text{ m}}$$

$$= 501.65 \text{ ft.}$$

$$KE = \frac{1}{2} mv^2$$

$$12 \text{ kJ} = \frac{1}{2} \times 10 \times v^2$$

$$v = 48.9897$$

$$mv = 489.89 \text{ kg m/sec}$$

Specific heat

$$\begin{array}{ll} \rightarrow C_p & \text{for const } P \\ \rightarrow C_v & \text{for const } V \end{array} \quad \left. \begin{array}{l} \\ \end{array} \right\} \frac{KJ}{kg \cdot K}$$

(8)

Enthalpy

the
means
when?

$$H = U + PV$$

at const press

$$dH = ?$$

$$\begin{array}{c} h_2 \\ h_1 \\ T_2 \\ T_1 \end{array}$$

$$Q = \Delta U + PV$$

$$Q = \Delta H = \int_{T_1}^{T_2} C_p \cdot dT$$

$$\begin{array}{l} dH = C_p dT \\ \Delta H = \int_{T_1}^{T_2} C_p dT \end{array}$$

$$dU = C_v dT$$

$$Q = \Delta U = \int_{T_1}^{T_2} C_v dT$$

for const volume

$$\text{If } C_p = f(T)$$

$$C_p = a + bT + cT^2 + dT^3 + \dots$$

for unit mass

$$dH = C_p dT$$

$$\Delta H = h_2 - h_1 = \int_{T_1}^{T_2} C_p dT = \int_{T_1}^{T_2} (a + bT + cT^2 + dT^3) dT$$

$$\Delta H = a(T_2 - T_1) + \frac{b}{2}(T_2^2 - T_1^2) + \frac{c}{3}(T_2^3 - T_1^3) + \frac{d}{4}(T_2^4 - T_1^4)$$

$$\text{if } C_p \neq f(T)$$

for unit amount

$$dH = C_p dT$$

$$\boxed{\Delta H = C_p(T_2 - T_1)}$$

Mean heat Capacity

(83)

for the constant composition, varying temp.

$$C_{p\text{mean}} = \frac{\int_{T_1}^{T_2} C_p dT}{\int_{T_1}^{T_2} dT}$$

If temp is constant then the mean heat capacity for a mixture,

$$\bar{C}_{p\text{mix}} = \sum x_i C_{pi}$$

If $C_{pi} \rightarrow \frac{\text{kJ}}{\text{kg}\cdot\text{k}}$; molal heat capacity.

$x_i \rightarrow$ molar fraction.

If $C_{pi} \rightarrow$ molar heat capacity $\frac{\text{kJ}}{\text{kmol}\cdot\text{k}}$

$x_i \rightarrow$ mol. fraction.

Q.) The molal heat capacity of CO is given by $C_p = \frac{26.586}{+7.582} + 7.582 \times 10^{-3}T - 1.2 \times 10^{-6}T^2$

$C_p = 26.586 + 7.582 \times 10^{-3}T - 1.2 \times 10^{-6}T^2$ where $C_p \text{ kJ/kg}\cdot\text{k}$

Calculate mean heat capacity for the temp range of 500-1000K.

CO enters a heat exchanger at a rate of $500 \text{ m}^3/\text{hr}$ at STP. Calculate the heat supply to gas to raise its temp from 500 to 1000K.

$$\dot{m} = \frac{m}{n}$$

$$C_p = 26.586 + 7.582 \times 10^{-3} T - 1.12 \times 10^{-6} T^2 \quad (84)$$

$$= \int_{T_1}^{T_2} C_p dT$$

$$= 26.586 (1000 - 500) + \frac{7.582 \times 10^{-3}}{2} (1000^2 - 500^2)$$

$$- \frac{1.12 \times 10^{-6}}{3} (1000^3 - 500^3)$$

$$(1000 - 500)$$

$$= \frac{13293 + 2843.25 - 326.666}{500}$$

$$= 31.6191 \text{ kJ/kgK}$$

for 1 mol

$$\Delta H = \int_{T_1}^{T_2} C_p dT$$

for m mol

$$\Delta H = m \int_{T_1}^{T_2} C_p dT$$

at STP

$$n = \frac{PV}{RT}$$

$$= \frac{1 \times 500}{8.314 \times}$$

$$22.4 \text{ m}^3 = 1 \text{ kmol}$$

$$500 \text{ m}^3 = \frac{1}{22.4} \times 500 \text{ kmol}$$

$$n = 22.32 \text{ kmol/m}$$

Ans

$$Q = \Delta H =$$

85

$$m = \frac{n \times m_w}{\text{mole}} \\ = 22.32 \times 28$$

$$= 625 \text{ kg/hr}$$

$$Q = \Delta h = 625 \text{ kg/hr} \times 31.8191 \frac{\text{kJ}}{\text{kg K}} \times (1100 - 800) \text{ K}$$

$$> 9880968.75 \text{ kJ/hr}$$

$$= 9880.96 \text{ MJ/hr}$$

Q) Calculate the heat that must be removed to cooling up 32 kg O₂ from $\frac{488 \text{ K}}{T_1} - \frac{313 \text{ K}}{T_2}$ using heat capacity eqn $C_p = a + bT + cT^2 + dT^3$, C_p

	a	b $\times 10^3$	c $\times 10^6$	d $\times 10^9$
O ₂	26.025	11.755	-2.3426	-0.5223

$$C_p = 26.025 (488 - 313) + \frac{11.755 \times 10^3}{2} (488^2 - 313^2)$$

$$+ \frac{-2.3426 \times 10^6}{3} (488^3 - 313^3) - \frac{0.5223 \times 10^9}{4} (488^4 - 313^4)$$

$$(488 - 313)$$

$$= \frac{4554.375 + 823.878 - 66.803 - 6.15199}{175}$$

$$= 30.3159$$

$$\Delta H = m \int_{T_1}^{T_2} C_p dT$$

86

298-523

2 32 x

$$= 169769.372 \text{ KJ/K}$$

200) K

$$= 169.769 \text{ MJ/K}$$

↳ energy is release.

Q.) A natural gas containing 84% CH_4 , 13% C_2H_6 and 3% N_2 . Calculate the heat to be added for heating 10 kmol natural gas from 298 - 523 K using heat capacity eqn.

	a	$b \times 10^3$	$c \times 10^6$	$d \times 10^9$	$\frac{\text{KJ}}{\text{kmolK}}$
CH_4	19.2494	52.1135	11.973	-11.317	
C_2H_6	5.4129	1780.87	-67.3799	8.714	
N_2	29.5909	-5.141	13.1829	-4.96	

[Ans 1028 MJ]

$$\Delta H = n \int_{T_1}^{T_2} C_{p\text{mix}} dT$$

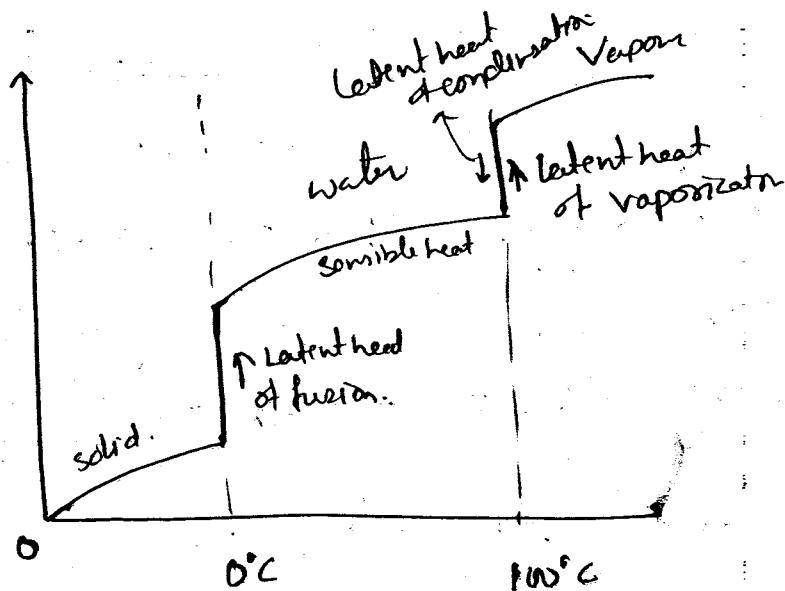
$$C_{p\text{mix}} = \sum x_i C_{p_i}$$

1084-313

1028

Energy balance for phase change

87



$$(\text{Latent heat of Condensation}) = - (\text{Latent heat of Vaporization})$$

Saturated L @ 1 atm & 100°C

Sub-cooled L @ 1 atm & < 100°C

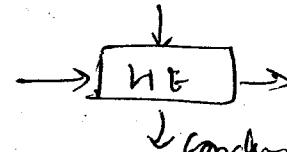
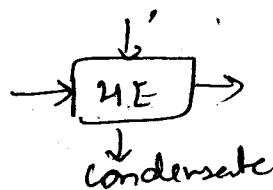
Saturated V @ 1 atm & 100°C

Superheated V @ 1 atm > 100°C

$$\Delta H = m C_p \Delta T$$

$$\Delta H = m \lambda$$

Saturated Steam & Superheated Steam



in which condition we use these.

Q) 1 kg of water is heated from 250K-400K at 1 atm
 atm pressure. How much heat is required for this.
 Mean heat capacity of ice = 2.037 kJ/kgK for the
 temp range of 250K-273.15K. The mean heat capacity
 of water $75.726 \frac{\text{kJ}}{\text{kmolK}}$ @ 273.15K-373.15K & the
 the heat capacity of water vapour is given by

$$C_p = 30.475 + 9.652 \times 10^{-3} T + 1.189 \times 10^{-6} T^2, \text{ kJ/kmol}$$

at 1 atm $[L_{\text{fusion}} = 6012 \text{ kJ/kmol}, L_{\text{vapour}} = 40608 \text{ kJ/kmol}]$

$$\begin{aligned}
 C_{p\text{mean}} &= \frac{30.475 + 9.652 \times 10^{-3} (400 - 373.15) + 1.189 \times 10^{-6} \frac{(400^2 - 373.15^2)}{3}}{(400 - 373.15)} \\
 &= \frac{30.475 (400 - 373.15) + 9.652 \times 10^{-3} (400^2 - 373.15^2)}{(400 - 373.15)} \\
 &= \frac{818.25375 + 100.183 + 4.7727}{(400 - 373.15)} \\
 &= 34.3839 \cdot \frac{\text{kJ}}{\text{kmolK}}
 \end{aligned}$$

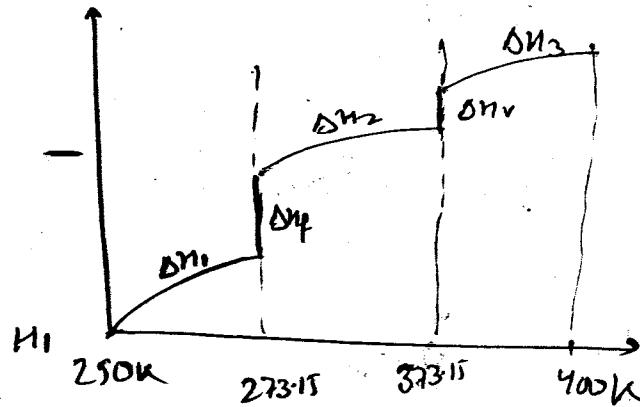
$$L_{\text{H}_2} = \frac{2.037 \text{ kJ}}{\text{kgK}} \times 6012 \frac{\text{kJ}}{\text{kmol}}$$

$$+ 75.726 \times 40608 + 34.3839 \times (-40608)$$

no.

capacity

re.



$$Q = \Delta H_1 + \Delta H_f + \Delta H_2 + \Delta H_v + \Delta H_3$$

$$= \frac{1}{18} \times 2.037 \times (273.15 - 250) + \frac{1}{18} \times 6012$$

$$+ \frac{1}{18} \text{ kmol} \times \frac{75726 \text{ kJ}}{\text{kmol}} \times \frac{18 \text{ kmol}}{\text{kg}} (373.15 - 273.15)$$

$$+ \frac{780}{18} \times 40608 + \frac{1}{18} \times 34.3839 \frac{\text{kJ}}{\text{kg}} (400 - 373.15)$$

$$= 2.6198 + 334 + 420.7$$

$$2256 + 51.2893$$

$$= 3064.609 \text{ kJ}$$

Q9) A high boiling organic fluid at 650K is mixed with CCl₄ at 295K in the wt. ratio of 1:1. The pressure is 1 atm. What will be the equilibrium temp of the mix. The heat capacity of organic fluid $C_f = 0.16 + 4.78 \times 10^{-3} T$

$$C_{CCl_4} = 6.7933 + 1.298 \times 10^{-4} T \frac{\text{kJ}}{\text{kg}\cdot\text{K}}$$

$$\text{b.p of CCl}_4 = 349.9 \text{ K} \text{ & } \Delta V_{CCl_4} = 195 \frac{\text{kJ}}{\text{kg}\cdot\text{K}}, C_{p,CCl_4,vp} = 0.4693 \frac{\text{kJ}}{\text{kg}\cdot\text{K}}$$

Heat released by organic fluid = Heat gained by CCl_4 . 90

$$\Delta H_{\text{of}} = \Delta H_{\text{CCl}_4}$$

$$-\int_{650}^T C_{p\text{ of}} dT = \int_{295}^T C_{p\text{ CCl}_4} dT$$

| firstly we assume
| liquid.

$$T = 573.15 \text{ K}$$

| check
| our own approach
| is proved wrong.

$$\Delta H_{\text{of}} = \Delta H_{\text{CCl}_4}$$

$$\int_{650}^T C_{p\text{ of}} dT = \int_{295}^{349.9} C_{p\text{ dT}} + \Delta H_v + \int_{349.9}^T C_{p\text{ CCl}_4} dT$$

for

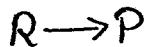
$$T = 540 \text{ K}$$

g.

H

Energy balance for chemical rxn

91



$$\sum v_i A_i = 0$$

Heat of Rxn

for 1 mol

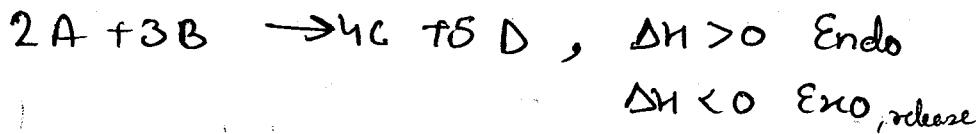
$$\Delta H = \sum H_{\text{Pdt}} - \sum H_{\text{React.}}$$

$$\Delta H_{\text{rxn}} = \sum v_i \Delta H_i$$

for 1 mol

$$\Delta H_{\text{rxn}} = \sum |v_i| H_{\text{Pdt}} - \sum |v_i| H_{\text{Reactant}}$$

for 1 mol



$$\Delta H_{\text{rxn}} = (4H_C + 5H_D) - (2H_A + 3H_B)$$

total

$$\Delta H_{\text{rxn}} = n \cdot \Delta H_{\text{rxn}} \text{ J/mol}$$

Standard heat of rxn :- $(\Delta^{\circ}H_{\text{rxn}})$

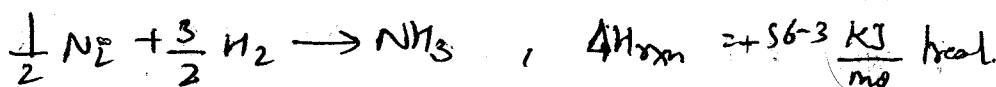
$$\Delta H^{\circ}_{\text{rxn}} = \sum |v_i| H_{\text{Pdt}}^{\circ} - \sum H_{\text{React}}^{\circ}$$

Reactant @ NTP

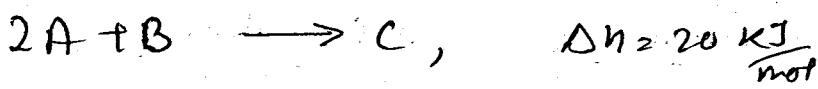
Pdt @ NTP

(reqd)

Heat of formation H_f



$$\Delta H_{\text{rxn}} = -56.3 \text{ kJ/mol}$$

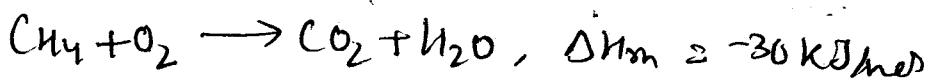


(92)

$$H_f^{\circ} = 20 \text{ kJ}$$

B1

\rightarrow Heat of Combustion H_c
(Heat released)



$$H_c^{CH_4} = 30 \text{ kJ},$$

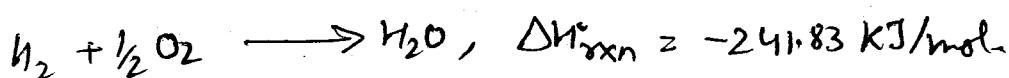
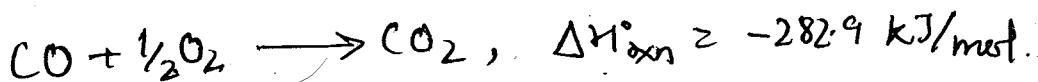


$$H_c^A = -40 \text{ kJ/mol.}$$

$$\boxed{\Delta H_{rxn}^{\circ} = \sum |v_i| H_f^{\text{prod}} - \sum |v_i| H_f^{\text{reactant}}} \quad \left. \right\} \begin{array}{l} \text{NTP} \\ 25^\circ\text{C} \\ \text{atm} \end{array}$$

$$\boxed{\Delta H_{rxn}^{\circ} = \sum |v_i| H_c^{\text{reactant}} - \sum |v_i| H_c^{\text{prod}}}$$

Q.) A gas mixture analysing 20 mole% CO, 30 mole% H₂ & 50% mole% H₂ is completely burn in air. following heat of rxns are available.



H

Calculate

- Amnt of heat liberated for 100 mol of gas mixture
- Amnt of heat liberated for 100 mol of gas if 90% CO & 80% H₂ is converted only.

Q1
Basic: 100mol of gas mixture

CO - 20 mol.

H₂ - 30 mol

N₂ - 50 mol

$$1 \text{ mol CO} = 282.91 \text{ KJ/mol}$$

$$20 \text{ mol} = 20 \times 282.91 \text{ KJ/mol} \\ = 5658.2 \text{ KJ}$$

$$30 \text{ mol H}_2 = 30 \times 241.83 \text{ KJ/mol} \\ = 7254.9 \text{ KJ}$$

total heat liberated

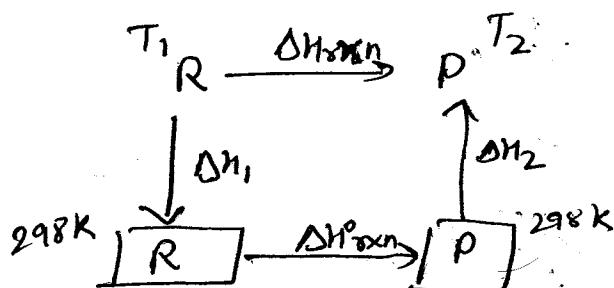
$$= 12913.1 \text{ KJ}$$

ii) CO reacted = 20×0.9
 $= 18 \text{ mol}$

$$\text{H}_2 \text{ reacted} = 30 \times 0.8 \\ = 24 \text{ mol.}$$

$$\text{Total heat Liberated} = 18 \times 282.91 + 24 \times 241.83 \\ = 10920.3 \text{ KJ}$$

Hess's Law

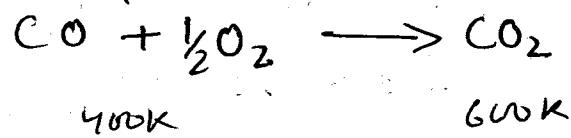


$$\Delta H_{\text{rxn}} = \Delta H_1 + \Delta H_{\text{rxn}} + \Delta H_2$$

(a) Pure CO is mixed with 100% excess air and completely burn at constant pressure. The reactants are originally at 400K. Determine the heat added or removed. If the pilot leaves at 600K. Standard state heat of rxn is given as 282.99 kJ/mol of CO burned. $C_p\text{mean}$ applicable in the temp range are

$C_p\text{mean}$ 29.10, 29.70, 29.10 & 41.45 $\frac{\text{kJ}}{\text{kmol}\cdot\text{K}}$

for: CO O₂ N₂ CO₂ ~~depth~~



Basic 1 kmol CO

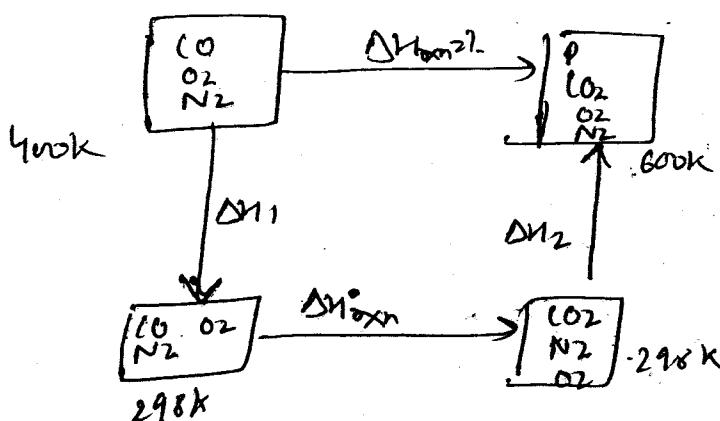
O₂ feed =

$$1 \text{ kmol CO} \approx 0.5 \text{ kmol O}_2$$

$$\text{O}_2 \text{ feed} = 0.5 + 0.5 \quad | \text{ 100% excess.}$$

$$= 1 \text{ kmol}$$

$$\text{N}_2 \text{ feed} \approx \frac{1}{0.21} \times 0.79 = 3.7619 \text{ kmol}$$



sketchy
finally
the
is

like

✓
mol·k

p

$$\Delta H_1 = \left[1 \times 29.10 \frac{\text{KJ}}{\text{Kmol K}} + 3.762 \times 29.10 + 1 \times 29.70 \right] \text{N}_2 \text{O}_2 \quad (90)$$

$$\Delta H_1 = -17163.9684 \text{ KJ} \parallel$$

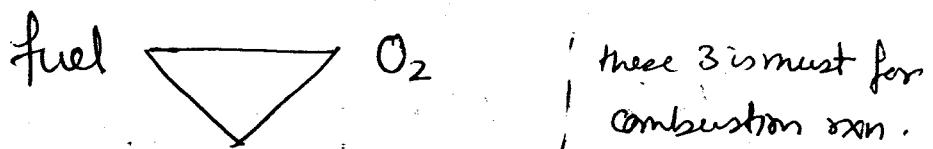
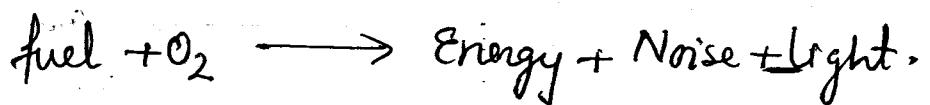
$$\Delta H_{rxn}^{\circ} = 1 \text{ Kmol} \times 282.99 \frac{\text{KJ}}{\text{mol}} \times \left(\frac{10^3 \text{ mol}}{1 \text{ Kmol}} \right)$$
$$= 282.99 \times 10^3 \text{ KJ} \parallel$$

$$\Delta H_2 = \left[1 \times 41.45 + 3.762 \times 29.10 + 0.5 \times 29.70 \right] \text{N}_2 \text{O}_2 \quad (600-298)$$
$$= 50063.80 \text{ KJ} \parallel$$

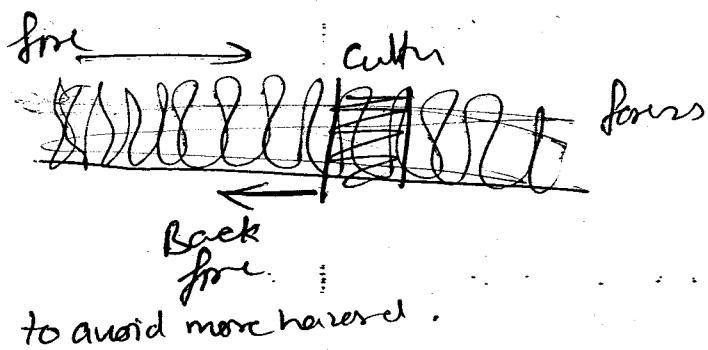
$$\Delta H_{rxn} = \Delta H_1 + \Delta H_{rxn}^{\circ} + \Delta H_2$$
$$= 313889.84 \text{ KJ} \parallel$$
$$= 313889 \text{ MJ} \parallel$$

* Fuels & Combustion

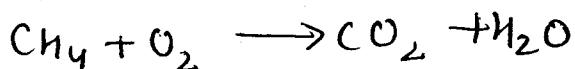
Q6



Ignition temp.



Orsat Analysis



Orsat analysis is a dry basis analysis

component we consider

except $\underline{\text{H}_2\text{O}}$

GCV & NCV

Calorific Value

Unit mass fuel is burnt and energy released is known as calorific value

\hookrightarrow GCV - Gross cv $\text{H}_2\text{O(l)}$

\hookrightarrow NCV - Net cv $\text{H}_2\text{O(v)}$

$$NCV = GCV - n\lambda$$

97

$$GCV = NCV + n\lambda$$

Q.) Crude oil is analysed to contain 87% C, 12.5% H₂ & 0.5% S by wt. Calculate the NCV of crude oil at 298K if GCV of crude oil at 298 K = 45071 kJ/kg oil. & at 298 K $\lambda_w = 2442.5 \text{ kJ/kg}$.

$$n\lambda = \frac{w}{m_w}$$

$$NCV = 45071 - \times 2442.5$$

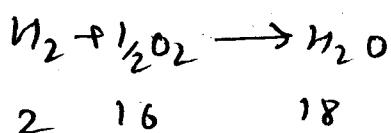
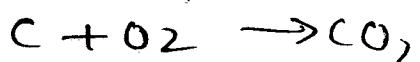
$$= 21739$$

Basio:

1 kg crude oil

$$C = 0.87 \text{ kg}$$

$$H_2 = 0.125 \text{ kg}$$



$$2 \text{ kg } H_2 \text{ prod} = 18 \text{ kg } H_2O$$

$$0.125 = \frac{18}{2} \times 0.125$$

$$= 1.125 \text{ kg } H_2O$$

$$NCV = GCV - n\lambda$$

$$= 45071 - 1.125 \times 2442.5$$

$$= 42323.187 \text{ kJ/kg}$$

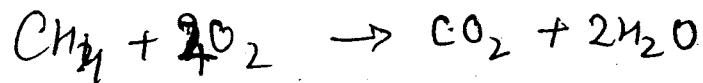
Q. A hydrocarbon mixture is burned with excess air. The orsat analysis of flue gas show 10.81% CO_2 , 3.78% O_2 & 85.4% N_2 by mole. Calculate the atomic ratio of C/H in hydrocarbon mixture & % excess of air.

Soln

CO_2 10.81

O_2 3.78

N_2 85.4



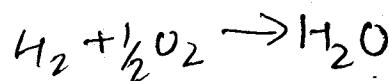
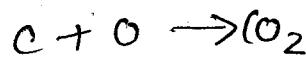
Basis: —

100 mol of ppt gases based on orsat analysis

CO_2 — 10.81 mol

O_2 — 3.78 mol

N_2 — 85.4 mol.



1 mol of CO_2 reqd = 1 g-atom C

10.81 ————— = 10.81 g-atom C

1 mol CO_2 reqd = 1 mol O_2

10.81 ————— = 10.81 mol O_2

air.

$$\text{Air feed} = \frac{85.4}{0.79} = 108.101 \text{ mol} \quad (99)$$

$$\text{O}_2 \text{ feed} = 108.101 \times 0.21 = 22.7012 \text{ mol}$$

$$\text{O}_2 \text{ consumed in } \text{exn}(2) = 22.7012 - \frac{10.81}{3.78} = 8.1112 \text{ mol}$$

$$\frac{1}{2} \text{ mol O}_2 \text{ reacted with} = 2 \text{ g-atom of H}$$

$$8.1112 \times \frac{2}{0.5} = 32.4498 \text{ g-atom H}$$

$$\frac{C}{n} = \frac{10.81}{32.4498} = 0.3331$$

$$\begin{aligned} \% \text{ excess air} &= \frac{\text{O}_2 \text{ feed} - \text{O}_2 \text{ reqd}}{\text{O}_2 \text{ reqd}} \times 100 \\ &= \frac{22.7012 - 18.921}{18.921} \times 100 \\ &= 19.97 \% \end{aligned}$$

100

$$F = C - \gamma(P) + 2 - \gamma - S$$

$C =$ No. of components

$\gamma =$ No. of indep. chem rxn

$S =$ " " " constraints

$T/P =$ " " " phases

* for azeotrope $S = 1$, as $n = 4$.

* at fixed / particular $T \& P$

$$R = 2 - 2 - z_0 =$$

- PC Extra

Material Balance :-

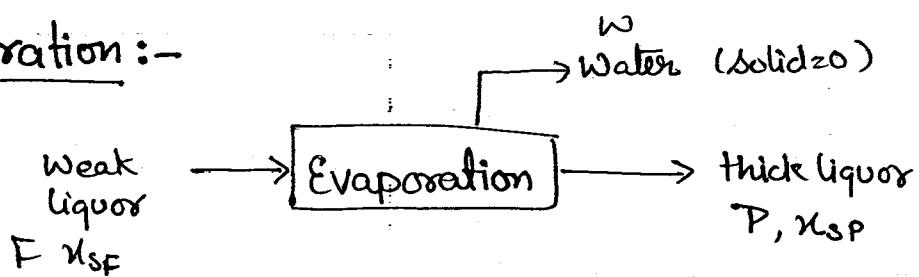
Input - Output = accumulation

at steady state

Input = Output.

- i) Overall Material Balance
- ii) Component Material Balance.

Evaporation :-



Overall MB

$$F = P + W$$

$x_{SF} \Rightarrow$ fraction of solid in feed.

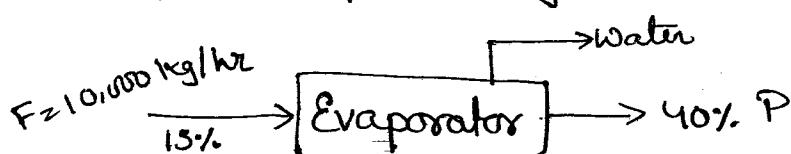
Component MB

$$F x_{SF} = P x_{SP}$$

Q) A single effect evaporator is fed with 10,000 kg/hr weak liquor containing 15% NaOH by wt. and is concentrated to get thick liquor containing 40% caustic soda (NaOH). Calculate

i) kg/hr of water evaporated.

ii) kg/hr of thick liquor coming out.



$$F x_F = P x_P$$

$$10000 \times \frac{0.15}{40} \times 100 = \frac{0.40}{40} \times 100 \times P$$

$$P = 3750 \text{ kg/hr}$$

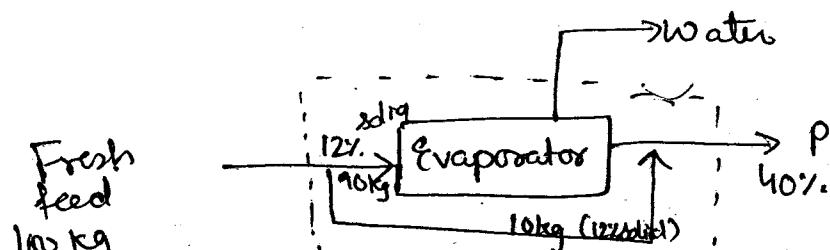
$$F = P + W$$

$$10000 = 3750 + W$$

$$W = 6250 \text{ kg/hr.}$$

Q.) Fresh orange juice contains 12% by wt solid & rest water. 90% of the fresh juice is sent to evaporator to remove water and subsequently mixed with remaining 10% of fresh juice. The resultant prod contain 40% solid. The kg of water removed from 1 kg of fresh juice is?

Soln. Basis Feed is 100 kg.



$$NSF = 0.12$$

$$F x_F = P x_S$$

$$100 \times 0.12 = P \times 0.4$$

$$P = 30$$

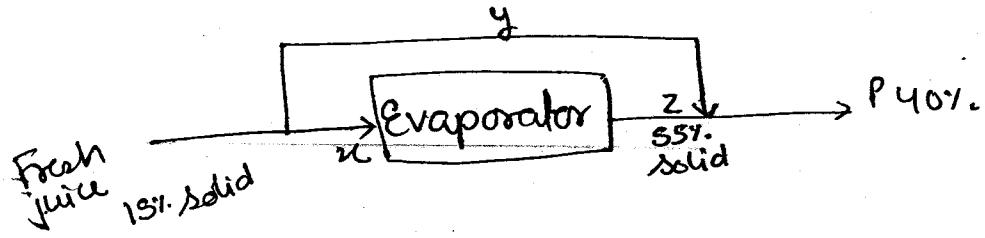
$$W = 70$$

$$= \frac{70}{100} = 0.7 \text{ kg/hr. Ans.}$$

Q.) A fresh juice contains 15% solid & 85% water by wt. and is to be concentrated to contain 40% solid by wt. In a single evaporation system, it is found that volatile constituents of juice escape with water leaving the concentrated juice with flat taste. In order to overcome this problem part of fresh juice by-passes the evaporator. The operation is shown in fig. Calculate

i) fraction of juice that by-pass the evaporator.

ii) Concentrated juice produced containing 40% solid/100 kg of fresh juice fed to the process.



Basis 100 kg of feed

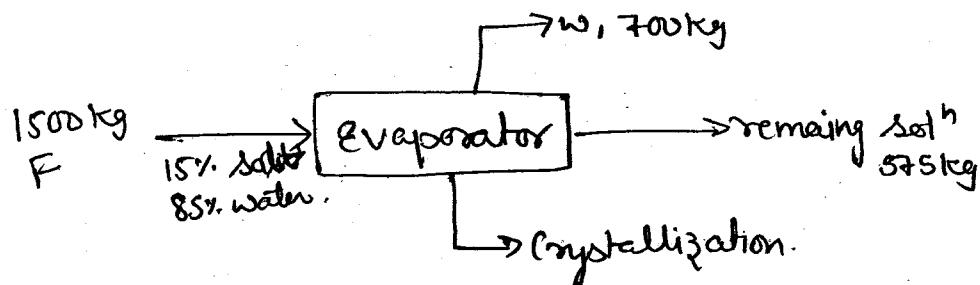
$$x+y=100$$

$$0.15x=0.55z$$

$$y+z=P$$

$$0.15y+0.55z=0.4P.$$

- Q) A soln of $K_2Cr_2O_7$ Potassium dichromate contains 15% by wt. Calculate the amt. of $K_2Cr_2O_7$ crystals that can be produced 1500 kg of soln. If 700 kg of water is evaporated & remaining soln is cooled to 293K. Solubility of $K_2Cr_2O_7$ at 293K = 115 kg/1000 kg water.



$$F_{\text{water}} = 1500 \times \frac{85}{100} = 1275 \text{ kg.}$$

$$\text{remaining water} = 1275 - 700 = 575 \text{ kg.}$$

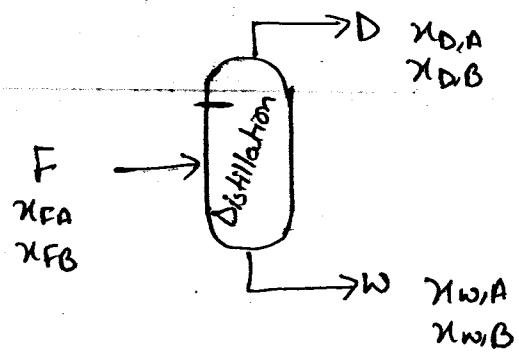
$$\text{Solubility of } K_2Cr_2O_7 = \frac{115}{1000} \times 575 \\ = 66.125 \text{ kg.}$$

$$= 225 - 66$$

$$= 158.8 \text{ kg.}$$

105

Distillation Column :-

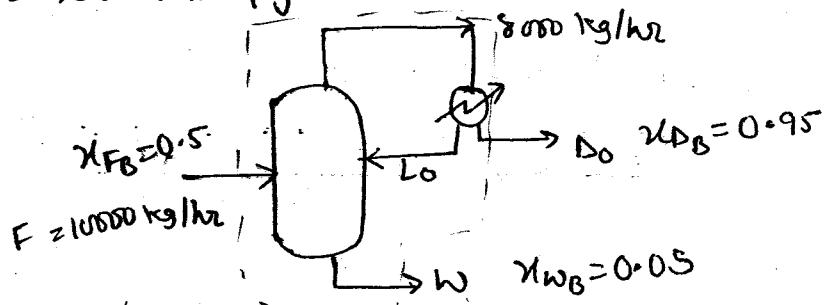


$$F = D + W \quad \text{overall M.B}$$

$$\text{MB of A} \quad Fx_{FA} = Dx_{D,A} + Wx_{W,A}$$

$$\text{MB of B} \quad Fx_{FB} = Dx_{D,B} + Wx_{W,B}$$

Q) A distillation column separates 10000 kg/hr benzene & toluene mixture as shown in fig.



$$\text{Find reflux ratio} = \frac{L_0}{D}$$

$$F = D + W$$

$$10000 = D + W$$

$$W = 10000 - D$$

$$Fx_F = Dx_D + Wx_B$$

$$10000 \times 0.5 = D \cdot 0.95 + (10000 - D) \cdot 0.05$$

$$D = 5000$$

$$W = 5000$$

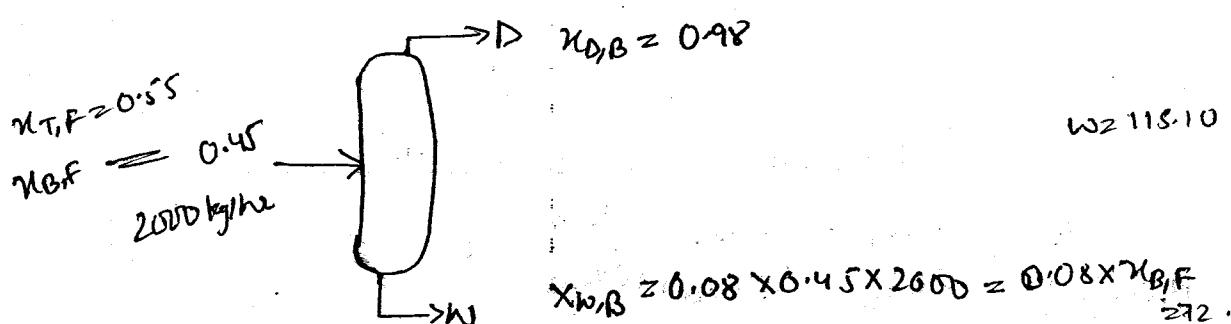
$$L_0 + D = 8000$$

$$L_0 = 3000$$

$$\text{Reflux ratio} = \frac{L_0}{D} = \frac{3000}{5000} = 0.6$$

Q.7 Benzene & Toluene are to be separated by distillation. The feed contains 40% by wt. benzene. After distillation the overhead pdt contain. 98% benzene. The btm pdt. Contain 8% of total benzene.

G.S.H.



$$F = D + W \rightarrow D = 2000 - W$$

$$F x_F = D x_{D,B} + W x_{W,B}$$

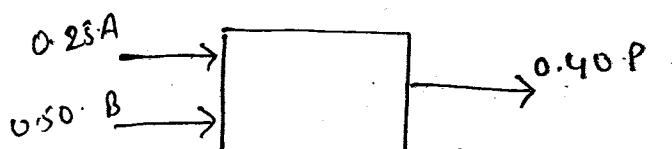
$$2000 \times 0.45 = D \times 0.98 + W \times 72$$

$$900 = 2000 \times 0.98 - 0.98 + 72W$$

$$\frac{I}{W} = \frac{1083.10}{115.10} \times 100$$

AB2

Q.8 It is desired to make 100 kg of a soln containing 40% salt by mixing the solution A containing 25% salt, and solution B containing 50% salt. Find the mass of solution A in kg.



$$A + B = P = 100$$

$$0.25A + 0.50B = 0.40 \times 100$$

$$A = 100 - B$$

$$25 - 0.25B + 0.50B = 40$$

$$25 + 0.25B = 40$$

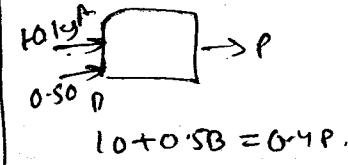
$$B = 10 \text{ kg}$$

$$A = 40 \text{ kg}$$

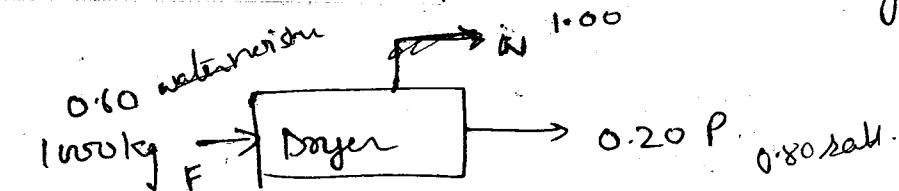
b) find the amt of salt in A & B.

$$\text{for A} = 0.25 \times 40 \\ = 10 \text{ kg.}$$

$$\text{for B} = 0.50 \times 40 \\ = 20 \text{ kg.}$$



2) 1000 kg of wet solid are to be dried from 60% to 20% moisture by wt. Calculate the amount of moisture removed in kg.



$$0.40 \text{ salt.} \\ 0.60 \times 1000 = 0.20 P + W \\ + W$$

$$F = W + P$$

$$1000 = P + W$$

$$600 + W = 0.20 P \\ 600 + (1000 - P) = 0.20 P \\ 1600 = 1.20 P$$

$$1000 \times 0.4 = 0.8 \times P$$

$$P = 500$$

$$F = P + W \\ W = 500$$

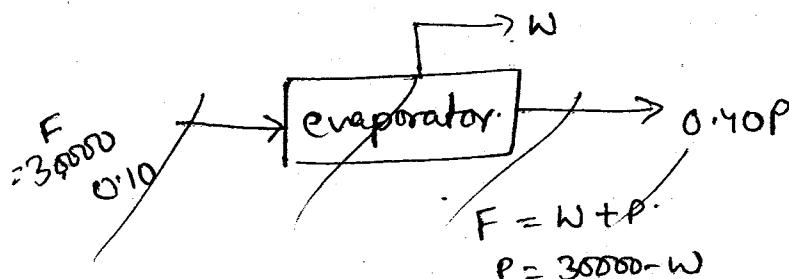
$$600 = 0.20 P + 1000 - P$$

$$0.8 P = 400$$

$$P = 500 \text{ kg.}$$



Q) An evaporator while concentrating an aqueous salt from 10-40% solid evaporates 30,000 kg of water. Find the amt of solid handled by the system in kg.



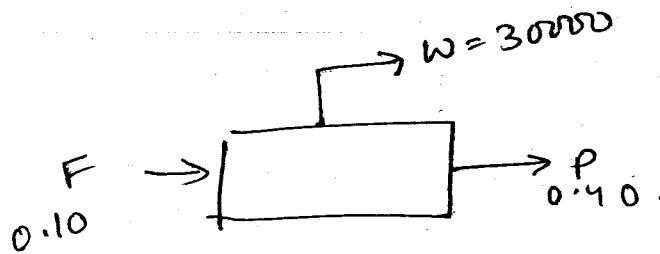
$$0.10 \times 30000 = W + 0.210P$$

$$0.10 \times 30000 = 30000 - P + 0.40P$$

$$30000 - 0.6P =$$

$$P = 45000$$

$$W =$$



Drier
or
Evaporator
→ W
re salt in kg.

$$F = W + P$$

$$F = 30000 + P$$

Debt balance

$$0.1F = 0.4P$$

$$30000 + 0.1P = 0.4P$$

$$F = 10000 \text{ kg}$$

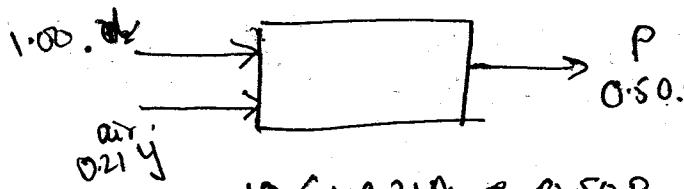
$$\text{Solid in } F = \frac{10000 \times 0.40}{30000 + 10000} = \underline{\underline{4000 \text{ kg}}}$$

$$F = 40000 \text{ kg}$$

$$\text{Solid in } F = 40000 \times 0.10$$

$$= \underline{\underline{4000 \text{ kg}}}$$

Q) Pure oxygen is mixed with air to produce an enriched air containing 50 mole volume % oxygen. Calculate the ratio of air to oxygen used.



$$10x + 0.21y = 0.50P$$

$$x + y = P$$

$$n+y = P$$

$$n+0.21y = 0.50P$$

$$x + 0.21y = 0.50(x+y)$$

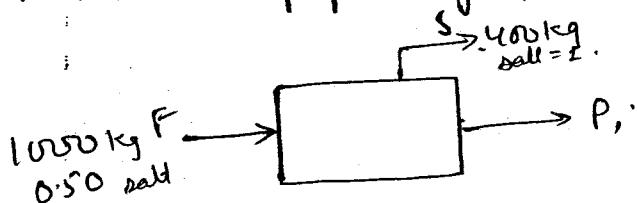
$$0.50x = 0.29y$$

$$\frac{x}{y} = \frac{0.50}{0.29}$$

$$= 1.724$$

Ans

Q) 1000 kg of a soln containing 50% by wt of a salt dissolved in it is cooled. 400 kg of anhydrous salt is separated out. What is the solubility of salt at lower temp. per 100 kg of water?



$$F = S + P$$

$$1000 = 400 + P$$

$$P = 600$$

$$0.50 \times 1000 = 400 \times 1 + P \times P$$

$$500 - 400 = P \times P$$

$$\frac{\text{salt}}{\text{salt + water}} \frac{100}{600} = P \quad (\text{salt})$$

$$P = 0.166$$

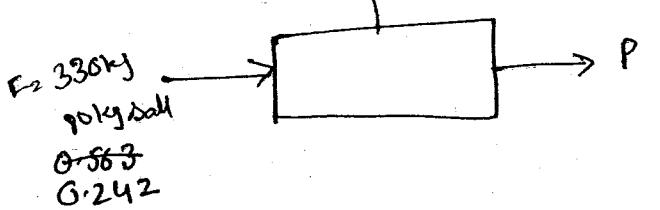
$$\frac{\text{salt}}{\text{water}} = \frac{1}{5}$$

$$= \frac{1}{5} \times 100$$

$$= 20\%$$

Q) If 80 kg of Sodium Sulphate Na_2SO_4 (142 g/mol) is present in 330 kg of an aqueous solution and the solution is cooled such that 80 kg of $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$ crystals are separated out. Find the wt. fraction of Na_2SO_4 in remaining soln.

$$\frac{80 \text{ kg} \cdot \frac{142}{142+180}}{330 \text{ kg}} = 0.44$$



$$F = B + P$$

$$330 = 80 + P$$

$$P = 250$$

$$330 \times 0.58 + 0.56 = P x_8$$

$$x_8 = 0.241$$

$$0.24 \times 330 \neq 0.44 \times 80 + P x_5$$

$$x_5 = 0.176$$

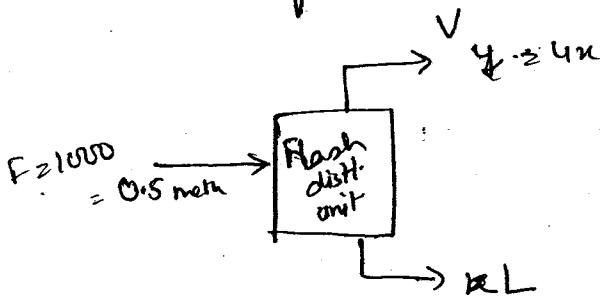
Or

$$80 = 0.44 \times 80 + P x_5$$

$$x_5 = 0.176 \approx 0.18$$



Q) A flash distillation column is used to separate methanol/water mixture. The mole fraction of methanol in the feed is 0.5 and the feed flow rate is 1000 kg mole/hr. The vapor/liquid phase mole fraction of methanol is related as $y = 4x$. Find the mole fraction of methanol in distillate if the ratio of distillate to feed is 0.5



$$\frac{4x}{F} =$$

$$F = V + xL$$

~~$$1000 = 9x \quad 1000 - L = V$$~~

~~$$x = 2/9$$~~

~~$$y = 8/9$$~~

$$0.5 = \frac{V}{F} \frac{V}{F}$$

$$0.5 = \frac{1000 - L}{1000} \Rightarrow$$

$$500 = 0.5L = 1000$$

$$SOD = 1000 - L$$

$$L = 500$$

$$V = 500$$

$$0.5 \times 1000 = SOD \times 4\kappa + 500\kappa$$

$$SOD = 2000\kappa + 500\kappa$$

$$SOD = 2500\kappa$$

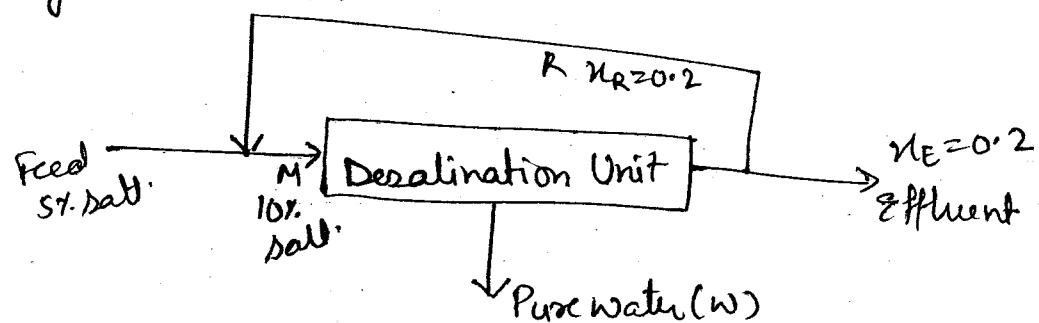
$$\kappa = 0.2$$

$$y = 4\kappa$$

$$y = 4 \times 0.2$$

$$\boxed{y = 0.8}$$

Q) Pure water (w) is to be obtained from feed containing 5% salt. using a desalination unit as shown in fig. If the overall recovery of pure water is 0.75 kg/kg feed. Then what will be the recycle ratio (R_F)



Basis

$$\text{Feed} = 1 \text{ kg.}$$



$$F + R = M$$

$$0.05 + 0.2R = 0.1M$$

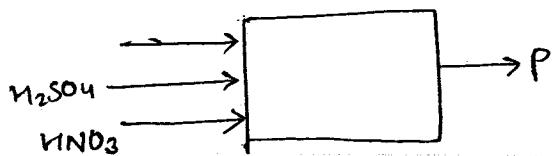
$$0.05 + 0.2R = 0.1 + 0.1R$$

$$0.1R = 0.05$$

$$\boxed{R = 0.05 / 0.1} \quad \boxed{M = 1.5}$$

$$= \boxed{\frac{R}{F} = \frac{0.05}{1} = 0.5}$$

Q) The waste acid from nitrating process contains 30% H_2SO_4 , 35% HNO_3 & 35% water. The acid to be concentrated to contain 39% H_2SO_4 , 42% HNO_3 . By the addition of concn H_2SO_4 containing 98% & concn HNO_3 containing 72% HNO_3 . It is desired to obtain 1000 kg of mixed acid. Find the amount of 3 acids to be mixed.

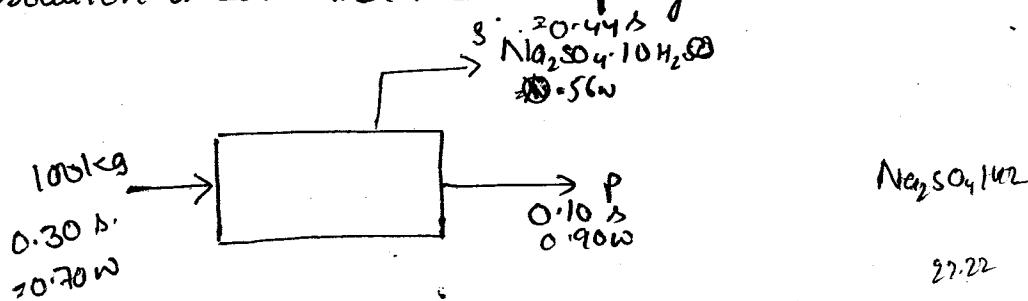


water
 $\xrightarrow{H_2SO_4}$
 $\xrightarrow{HNO_3}$
 \xrightarrow{P}

H_2SO_4
 HNO_3
 $Z = 370$

July 10, 14

Q) $Na_2SO_4 \cdot 10H_2O$ crystals are formed by cooling 1000 kg $Al_2(SO_4)_3$ of 30% by wt aq. solution of Na_2SO_4 sodium sulphate. The final concentration of solute in the solution is 10%. Find the wt. of crystals.



$$F = S + P$$

$$1000 = S + P$$

$$1000 \times 0.30 = S + 0.10 \quad (1000 - S)$$

$$30 = S + 0.900 + 10$$

$$20 = 0.900$$

$$30 = 0.340 + 10$$

$$S = 58.82 \text{ kg}$$

Sal balance.

Water balance

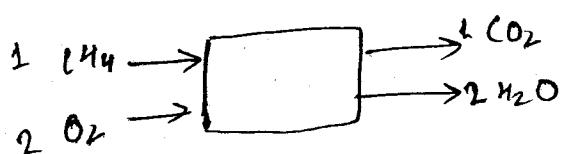
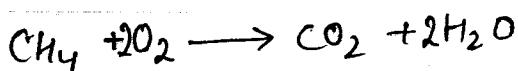
$$F = W + P$$

$$0.70 \times 100 = 0.56 W + 0.90 P$$

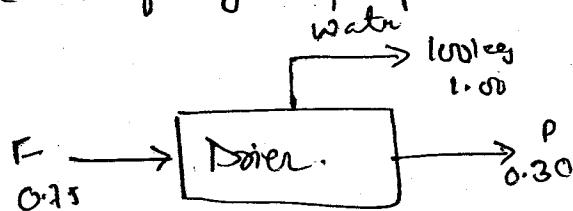
$$P = 0.56 W + 90 - 0.9 W$$

$$W = 58.82$$

Q.) Methane is mixed with stoichiometric proportion of oxygen and completely combusted. Find the no. of additional specifications required to determine the pdt flow rate and the composition.



Q.) A wet pulp paper contains 75% water after removing 100 kg of water using drier, it is found that the pulp is now containing 30% water. Calculate the wt. of original pulp.



$$F = W + P$$

$$F = 100 + P$$

$$0.75 = 100 + P \times 0.30$$

$$75 + 0.75P = 100 + 0.30P$$

$$P = 144.44$$

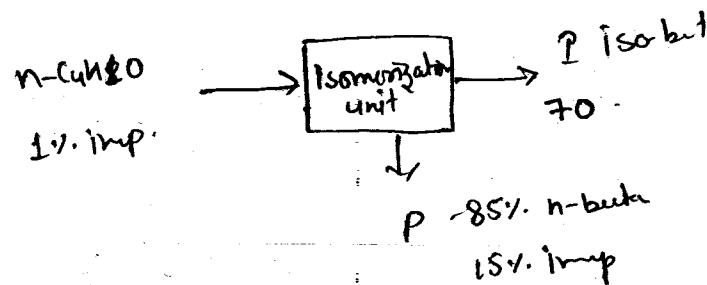
$$25 = 0.45P$$

$$P = 55.55$$

$$F = 100 + 55.55$$

$$= 155.55 \text{ kg.}$$

Q) Butane isomerization process produces 70 kmol/hr of pure isobutane. A purge stream removed continuously contains 85% n-butane & 15% impurity by mole. Find the flow rate of purge stream if feed stream contains 1% impurity.



purge stream
↓
waste stream

$$F = P + I$$

$$F = P + 70$$

Impurity

$$F \times 0.01 = 0.15P + 70$$

$$\begin{aligned} 0.1P + 70F &= 0.15P + 70 \\ 0.01P + 0.7 &= 0.15P \\ 69.3 &= 0.14P \\ P &= 495 \\ F &= \end{aligned}$$



$$0.01F = 0.15P$$

$$0.01P + 0.7 = 0.15P$$

$$0.7 = 0.14P$$

$$P = 5 \text{ kmol/hr.}$$

$$F = 5 + 70 = 75$$

Q) An aq. soln of 2.45% by wt H_2SO_4 having sp. gravity 1.011. Find normality of sulphuric acid.

$$1.011 = \frac{S}{S_w}$$

$$N = \frac{\text{moles of solute} \times \text{val.}}{\text{Vol of sol (L)}}$$

$$S = 1.011 \text{ g/l} \times 1000$$

Basis 100 g. of mass

$$S_{H_2SO_4} = 1011 \text{ g/l}$$

$$\begin{aligned} V &= \frac{100}{1011} \\ &= 0.0989. \end{aligned}$$

Mass wt% of solute = 2.45

M.M. = 98

$$= \frac{2.45 \times 2}{98} \\ = 0.0989$$

$$N = 0.505 =$$

Q) If $N = 0.505$, Sp. gr. = 1.011 find wt% -

$$\text{wt of Solute} = \frac{N \times M_{\text{sol}} \times \text{Mol. wt}}{3 \times \text{Valency}}$$

$$= \frac{0.505 \times 100 \times 98 \times 1000}{1.011 \times 2}$$

$$= 2.45$$

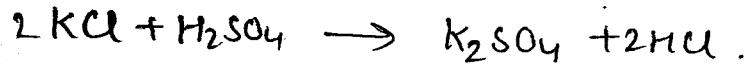
Q) A mixture of NaCl & KCl was treated with H_2SO_4 to produce mixture of sulphates. (Na_2SO_4 & K_2SO_4). The desired mixture amount is 1.175 kg. Find the % of chlorine in the original sample. If the original sample is 1 kg.

$$NaCl = 58.5$$

$$KCl = 74.5$$

$$Na_2SO_4 = 142$$

$$K_2SO_4 = 174$$



$$NaCl = m \\ KCl = 1 - m$$

$$2 \times 58.5 \text{ NaCl} = 1 \times 142 \text{ Na}_2SO_4$$

$$1g NaCl = \frac{142}{2 \times 58.5} g Na_2SO_4$$

$$mg NaCl = \frac{142 \times m}{2 \times 58.5} Na_2SO_4$$

$$2 \times 74.5 \text{ KCl} = 1 \times 174 \text{ K}_2SO_4$$

$$1g KCl = \frac{174}{2 \times 74.5} K_2SO_4$$

$$(1 - m) KCl = \frac{174(1 - m)}{2 \times 74.5} K_2SO_4$$

LHS = RHS
what we know
what we have to find

$$\frac{142m}{2 \times 58.5} + \frac{174(1-m)}{2 \times 74.5} = 1.175$$

$$1.2136m + 1.1677 - 1.1677m = 1.175$$

$$m = 0.159 \text{ kg}$$

$$\text{amt of NaCl} = \frac{1.175 - 1.1677}{1.2136 - 1} \quad 0.159 \text{ kg} \quad 0.09$$

$$\text{amt of KCl} = 0.841 \text{ kg.} \quad 0.04$$

$$58.5 \text{ NaCl.} = 35.5 \text{ Cl}$$

$$1 \text{ NaCl} = \frac{35.5}{58.5} \text{ Cl}$$

$$0.159 \text{ NaCl} = \frac{35.5}{58.5} \times 0.159 \text{ Cl}$$

$$= 0.09 \text{ Cl}$$

$$74.5 \text{ KCl} = 35.5 \text{ Cl}$$

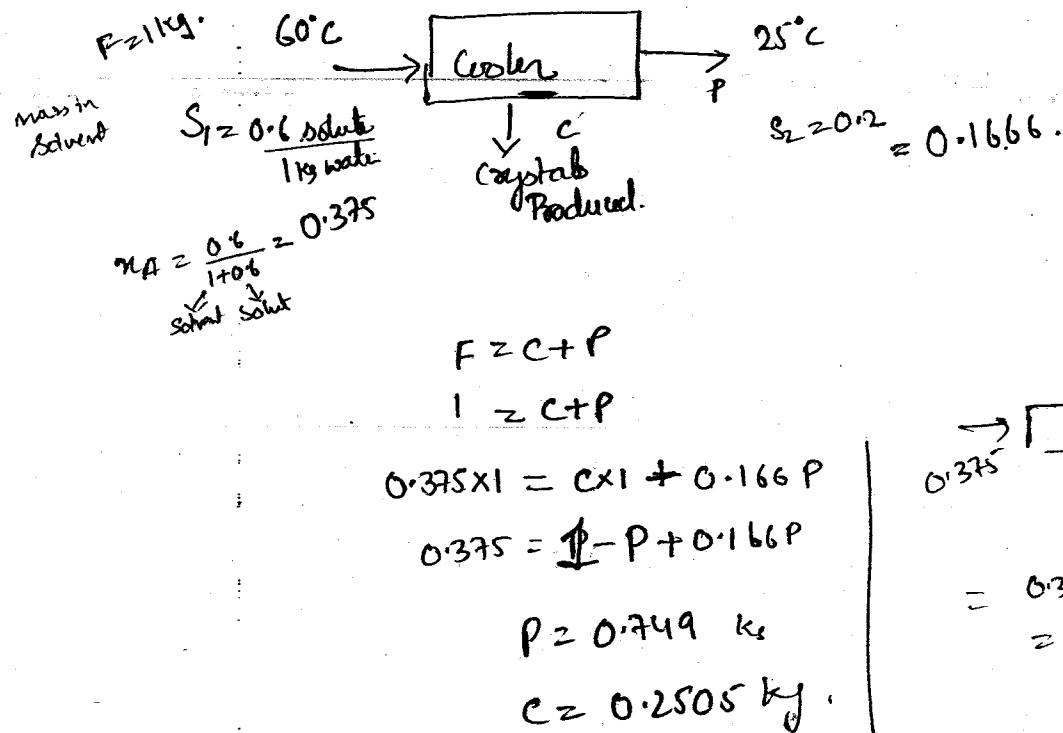
$$1 \text{ KCl} = \frac{35.5}{74.5} \text{ Cl}$$

$$0.841 \text{ KCl} = \frac{35.5}{74.5} \times 0.841 \text{ Cl}$$

$$= 0.4 \text{ Cl.}$$

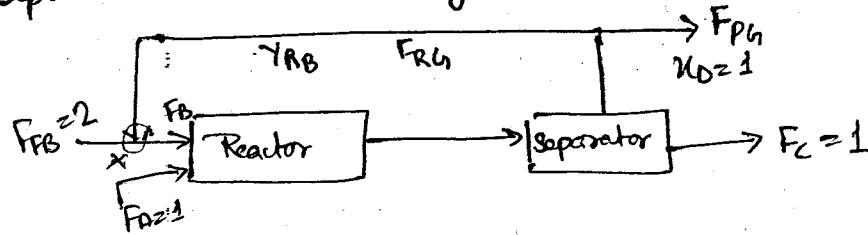
amount of Cl

- Q) 1 kg of saturated aq. solution of highly soluble component A at 60°C is cooled. The solubility limits of A are 0.61 kg A/kg water - at 60°C and the solubility limits of A at 25°C is 0.2 kg A/kg water. Calculate the amount of crystals produced in kg.



$$\begin{aligned}
 & \xrightarrow{0.375} \boxed{\quad} \xrightarrow{0.625} \\
 & \text{Solute} = 0.2 \times 0.625 \\
 & = 0.125 \text{ kg} \\
 & = 0.375 - 0.125 \\
 & = 0.25 \text{ kg.}
 \end{aligned}$$

Q) The reaction $A + B \xrightarrow[\text{geo.}]{} C + D$, is carried out in a reactor followed by separator as shown in fig.



F_B = flow rate of fresh feed B

$F_B = \text{ " " " } B$

$F_A = \text{ " " " } A$

$F_{Rg} = \text{ " " " } \text{ recycle gas.}$

$F_{PG} = \text{ " " " } \text{ Purge gas.}$

$F_C = \text{ " " " } C$

$$\frac{F_B}{F_A} = 5$$

$$F_A = 1$$

$$F_B = 5$$

Y_{RB} = fraction of B in recycle stream.

x_D = fraction of D.

Q) Find. i.) Recycle ratio of recycle gas to purge gas if $Y_{RB} = 0.3$
 ii.) Y_{RB} , if ratio of recycle gas to purge gas is 4.

$$\frac{F_{Rg}}{F_{PG}} = ?$$

$$Y_{RB} = ?$$

$$F_{PB} + F_A = F_{PA} + F_C$$

$$2 + 1 = F_{PA} + 1$$

FD 3/9

$$F_{PA} = 2$$

To find F_{RB} ; for component B at X

$$F_{FB} + F_{RG} = F_B$$

$$2 + F_{RG} = F_B$$

$$F_{FB} \times 1 + F_{RG} \times Y_{RB} = F_B \times 1$$

~~$$2 \times 1 + 0.3 F_{RG} = F_B \times 2 + F_{RG}$$~~

$$2 \times 1 + 0.3 F_{RG} = 5$$

$$0.3 F_{RG} = 3$$

$$F_{RG} = 10$$

i.)

$$2 \frac{F_{RG}}{F_{RG}} = \frac{10}{2} = 5$$

ii.)

Given

$$\frac{F_{RG}}{F_{RG}} = 4$$

$$F_{RG} = 4 \times 2 = 8$$

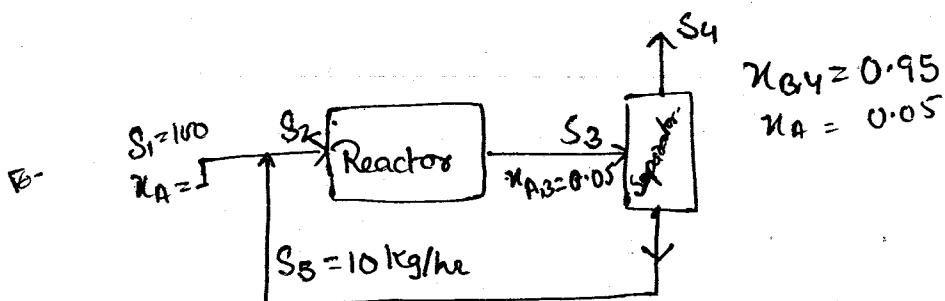
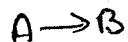
$$F_{FB} + Y_{RB} F_{RG} = F_B$$

$$2 + Y_{RB} 8 = 5$$

$$Y_{RB} = 3/8$$

July 11/14

- Q.) A feed stream S_1 at 100 kg/hr containing only A mixes with recycle stream S_5 before entering the reactor and the reaction is A goes B. The operation is at steady state. The stream S_3 coming out from the reactor is separated without any phase or composition change into two streams S_4 & S_5 . If the mass fraction of B in S_4 is 0.95 for B component. Find the ratio of S_3 & S_5 and the mole fraction of A in S_3 and the amount of A in S_3 .



$$S_1 + S_5 = S_2$$

$$100 + 10 = S_2$$

$$S_2 = 110 \text{ kg/hr.}$$

at steady state

$$S_2 = S_3$$

$$S_3 = 110$$

$$\frac{S_3}{S_5} = \frac{110}{10} = 11.$$

$$S_1 x_A = S_4 x_A$$

$$100 = S_4 0.05$$

$$\text{amt of } S_4 = 110 S_3 \times x_{A,3}$$

$$= 110 \times 0.05$$

$$= 5.5 \text{ kg.}$$

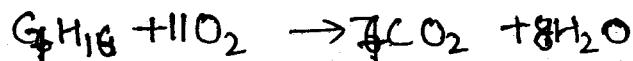
- Q.) The molar composition of the gas is 10% hydrogen H_2 , 10% O_2 , 30% CO_2 and rest water (H_2O). Find 50% of the water condensed. Find the mole % of H_2 on dry basis in the gas.

$$= \frac{10}{50} \times 100 = 20\%$$

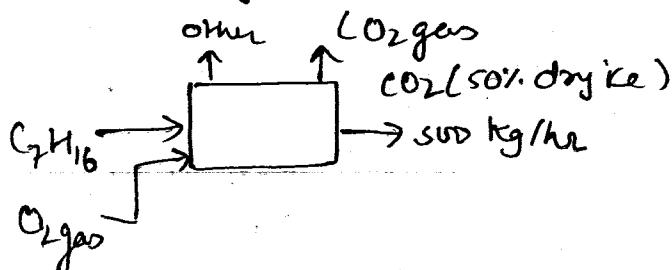
$$\text{If wet basis} \\ 50\% \text{ H}_2 \text{ on dry basis condense} = \frac{10}{75} \times 100$$

wet basis = 100
dry basis = 50

Q7 In the combustion of heptane, CO_2 is produced.



Assume that you want to produce 500 kg of dry ice and 50% of CO_2 can be converted into dry ice. How many kg of heptane must be burnt. fig is as shown in fig.

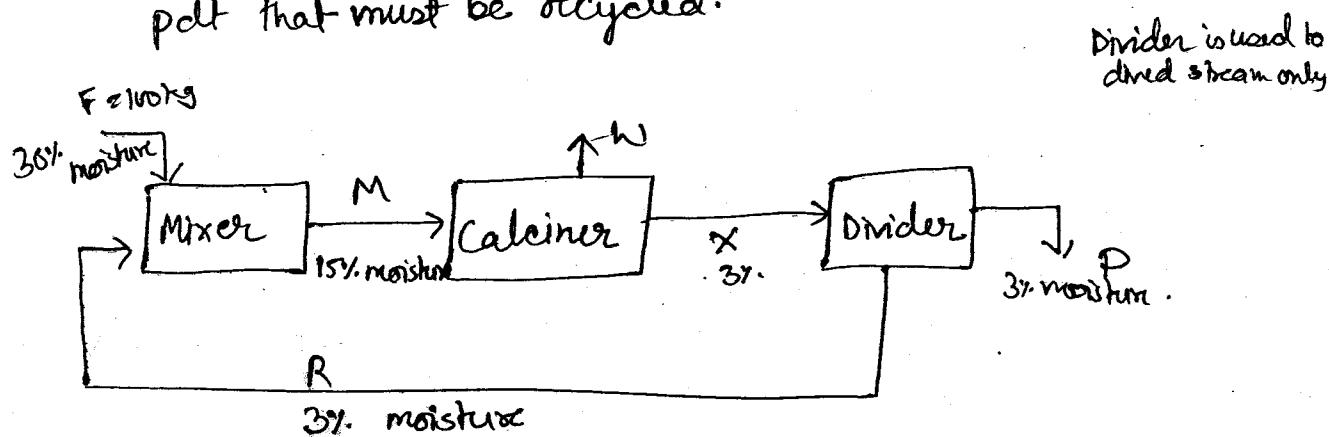


$$100 \text{ kg of C}_7\text{H}_{16} = 308 \text{ kg of CO}_2$$

$$\frac{100}{308} \times 1000 = 324.67 \text{ kg/hr}$$

$$= 324.67 \text{ kg/hr}$$

Q7 In a particular drying operation it is required to have the moisture content of feed to calciner is 15% by wt. in order to prevent lumping & sticking. This is achieved by mixing the feed having 30% by wt moisture with a recycle stream of dried material having 3% by wt. moisture. The drying operation is shown in fig. Find the fraction of dried ppt that must be recycled.



$$F + R = M$$

$$100 \times 0.30 + R \times 0.03 = M \times 0.15$$

$$30 + 0.03R = (100 + R) \times 0.15$$

$$15 = 0.12R$$

$$R = 125$$

$$M = 225$$

Now again

$$M = W + X$$

$$225 = W + X$$

$$225 \times 0.15 = W \times 1 + X \times 0.03$$

$$33.75 = (225 - X) + 0.03X$$

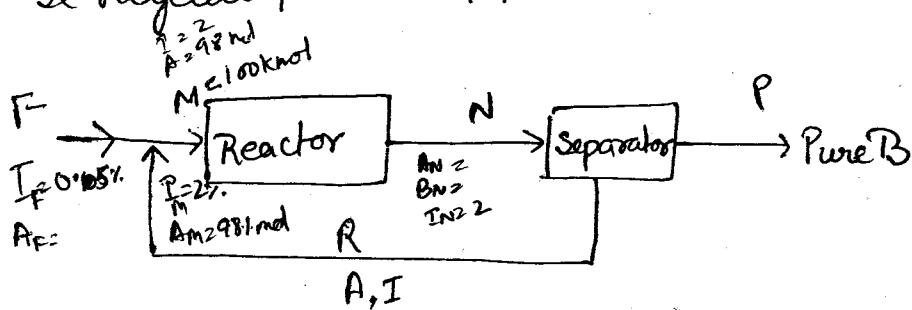
$$X = 197.16$$

$$\frac{R}{X} = \frac{125}{197.16} = 0.6339$$

$$= 0.6339 \times 100 \%$$

$$= 63.39 \%$$

- Q) For the reaction $A \rightarrow B$, Process flow diagram is shown in fig. The fresh feed A contains 0.05 inert by volume 60% conversion per pass of A into the reactor is obtained. The concentration of inert going into the reactor must be held at 2% by volume. All the stream are ideal gases and steady state process. How many moles need to be recycled per mole of feed to the reactor.



If recycle stream ka composition given ni hota to M ke basis kuch & in vice-versa con F ke basis kabis.

$$\frac{R}{M} = ?$$

Basis $M = 100 \text{ kmol}$

$$\begin{aligned} F + R &\approx M \\ F + R &= 100 \\ F \times 0.5 + R \times 0.02 &\neq M \end{aligned}$$

$$\begin{aligned} BN &= 0.6 \times 98 \\ &= 58.8 \end{aligned}$$

$$AN = 39.2$$

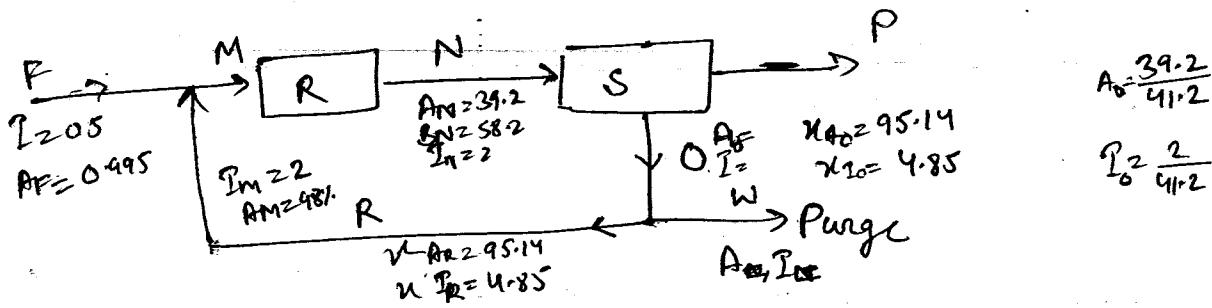
$$R = 41.2$$

$$\frac{R}{M} = 0.412$$

$$\begin{aligned} R_N &= AN + IN \\ &= 39.2 + 2 \\ &= 41.2 \end{aligned}$$

bcz B pure hi us side hogya.

Q7 Ask the same question.



02 Feb 13

$$F \not\vdash R \vdash M$$

$$F+R=100$$

Balance of A

$$0.995F + 0.9514R = 100 \times 0.98$$

$$0.995(100-R) + 0.4514R = 98$$

99-5-

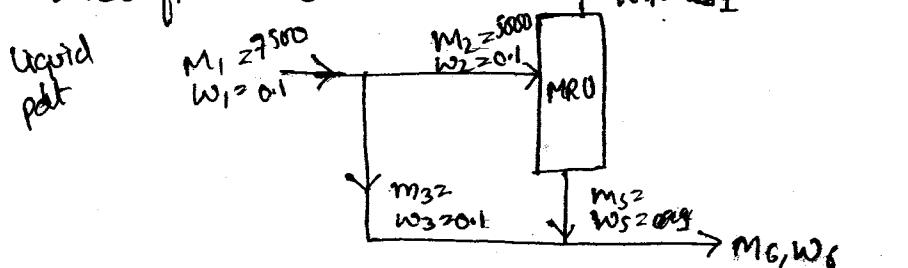
R = 34.40

$$F = 65.59$$

$$\therefore \frac{R}{M} = \frac{34.40}{100} \times 100$$

2 6341.

2) A metal recovery unit (MRU) of intake capacity 5000 kg/hr treats a liquid product from a plant and recover 90% of metal in the pure form. The unRecovered metal and associated liquid are sent to disposal unit along with unreacted metal part from the plant. Find the flow rate M_6 & metal fraction by wt w_6 . The liquid part flow rate is 7500 kg/hr then find and the composition is 0.1 by wt. _{metal}
 Also find M_5 & w_5



metal feed to MRU = 500

$$\text{Metal recovery } M_4 = 500 \times 90\% = 450$$

metal fraction selection
acc. to given condition. $\leftarrow M_4 w_4 = 0.9 (M_2 w_2)$

$$M_2 = M_4 + m_5$$

$$5000 = 450 + m_5$$

$$m_5 = 4550$$

$$500 = 450 + 4550 w_5$$

$$50 = 450 + 4550 w_5$$

$$M_1 = m_3 + M_2$$

$$m_3 = 2500$$

~~$$m_5 + m_3 + m_6$$~~

~~$$4550 = 2500 + m_6$$~~

$$m_6 = 2050$$

$$m_5 + m_3 = m_6$$

$$4550 + 2500 = m_6$$

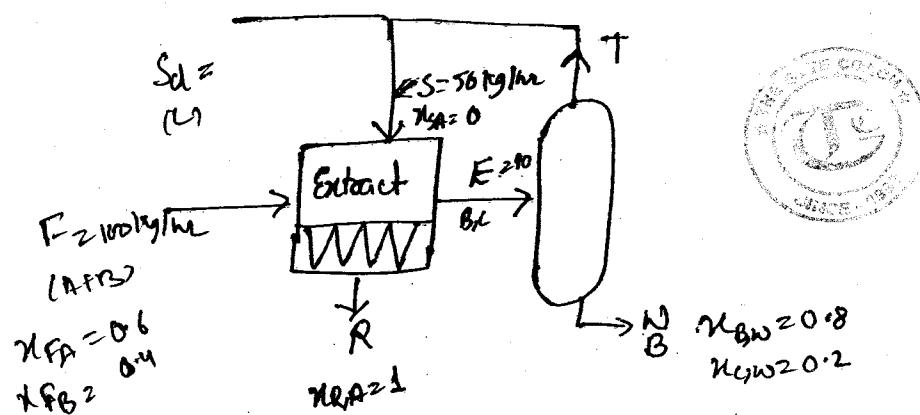
$$m_6 = 7050$$

$$m_5 w_5 + m_3 w_3 = m_6 w_6$$

$$4550 \times 0.01 + 2500 \times 0.1 = 7050 w_6$$

$$w_6 = 0.04$$

Q Solvent C is used to extract the soluble B with selectivity from 100 kg/hr feed. from the mixture of A & B at a steady state continuous process as shown in fig. The solubility of B & C in the raffinate and solubility of A in the extract phase are negligible. The extract E is feed to distillation column to recover bottom product B. The overhead product coming out from the distillation column is fed to the extractor and mixed with solvent C (dosing). To compensate the amount of C. The total flow rate of solvent stream is 50 kg/hr and the mass fractions are shown in fig. Find w , s_d , E , T .



MB for A to find R

$$F + S = R + E$$

$$100 + 50 = R + 10$$

$$0.6 \times 100 = R \times 1$$

$$R = 60$$

$$E = 90$$

$$R = 60$$

$$E = 90$$

$$W = 40$$

MB for B to find W

~~$$F + S + W$$~~
~~$$100 + 50 + W$$~~

~~$$F + S = R + W$$~~
~~$$100 = 60 + W$$~~

~~$$W = 40$$~~

~~$$E = T + W$$~~

$$100 \times 0.4 = 0.8 W$$

$$W = 50$$

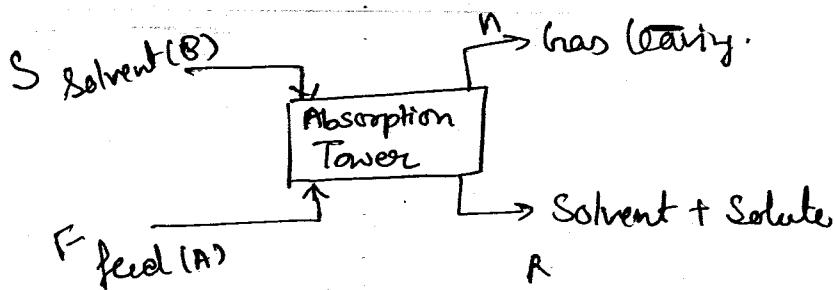
$$T = 40$$

$$S_d = 10$$

Q.) A binary hydrocarbon (q. mixture A & B ($K=1.5$) containing 60 mole% A. If 40% of feed is flash vapourised. Find the mole fraction of A in liquid pdt.

July 15, 14

Absorption Tower:-



Please apply mass balance

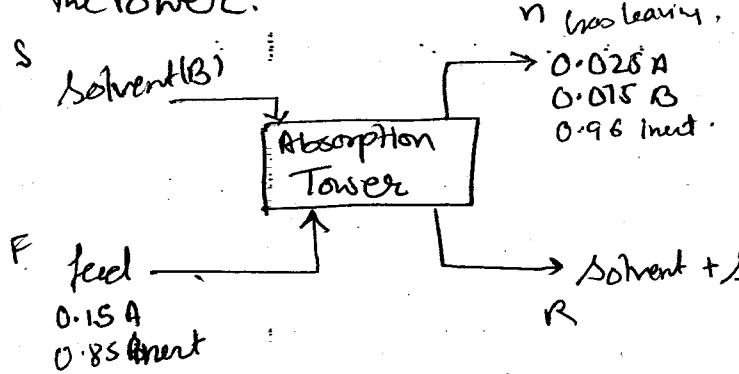
Overall M-B

$$F+S = n+R$$

Balance for A component.

$$F x n_{PA} + S x S_{PA} =$$

- Q. A gas mixture containing 15 mole% A and 85 mole% inert. This gas mixture is fed to an absorption tower and contacted with liquid solvent B. The ratio of solvent B to feed entering the tower is 2:1. The gas leaving the absorber contains 2.5% A, 1.5% B and rest inert.
- Final. i. %age recovery of solute A.
- ii. Fraction of solvent B fed to the column lost in gas in leaving the tower.

Basis: 100 mole $F = 1$

$$\left\{ \begin{array}{l} \text{overall M-B } S+F = n+R \\ 3F = n+R \end{array} \right.$$

$$\left\{ \begin{array}{l} 3F = n+R \\ 300 = n+R \end{array} \right.$$

$$\frac{S}{F} = \frac{2}{1}$$

$$S = 2F$$

i) Inert M-B

$$100 \times 0.85 = 0.96 \times n$$

$$85 = 0.96 \times n$$

$$n = 88.54$$

$$R = 211.46$$

Material Balance over A.

$$0.15 \times 100 = 88.54 \times 0.025 + R_A$$

$$R_A = 12.78$$

$$\frac{S}{F} = \frac{n}{1}$$

$$S = 2F$$

$$S+F = n+R$$

$$0.15 \times 100 = 0.025A$$

$$F = 12$$

$$3F = n+R$$

$$300 = n+R$$

$$100 \times 0.85 = 0.96 \times n$$

$$85 = n$$

$$n = 88.54$$

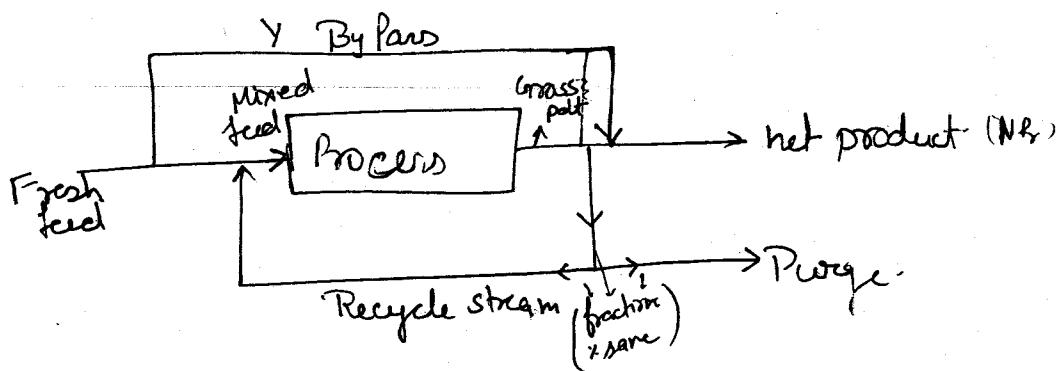
$$2.21$$

$$15 = 88.54 \times 0.025$$

$$+ 211.46 \times R_A$$

11.) amount of solute leaving = 0.015×8854
 $= 1.3281$

frac = $1.3281 / 200$
 $= 0.0066$



→ Recycle Ratio R/F

→ Purge Ratio P/R

→ % Recovery (Recovered amount) $\frac{Np}{feed} \times 100$

→ % Conversion $\frac{A \text{ in fresh feed} - A \text{ in net pdt}}{A \text{ in fresh feed}} \times 100$

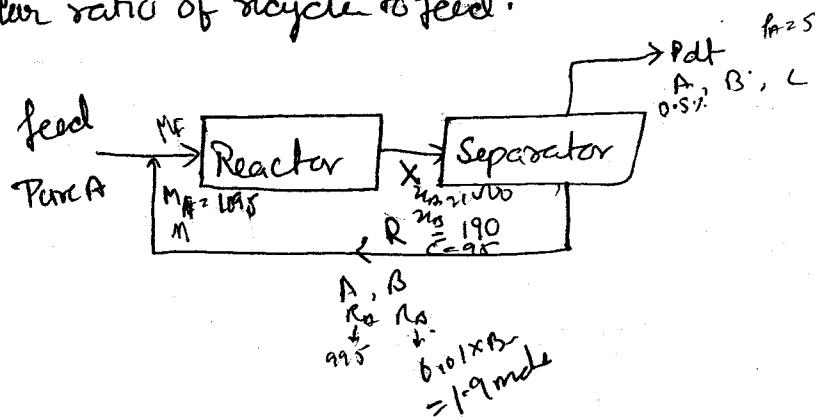
→ By Pass Ratio Y/F $\frac{P \text{ for pass conversion}}{S \text{ in pass}} \times 100$

$\frac{A \text{ in mixed feed} + A \text{ in gross pdt}}{A \text{ in mixed feed}} \times 100$

2.) The reaction $A \rightarrow B \rightarrow C$ takes place in a catalytic reactor. The reactor effluent is sent to separator. The overall conversion of A is 95%. The pdt streams from separator consist of B, C & 0.5% A. Entering the separator while the recycle stream consist of remaining unreacted A and 1% of B entering the separator.

i.) Single pass conversion of A in the reactor.

ii.) Molar ratio of recycle to feed.



Basis = 100 mole.

$$\text{Overall conversion of A} \Rightarrow \frac{100 - P_A}{100} = 0.95$$

$$\frac{100 - 0.05 \times 100}{100} = 0.95$$

$$P_A = 1000 \text{ moles}$$

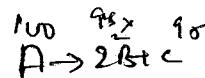
$$M_A = 1000$$

i) A in mixed feed = 100 + 0.95

$$= 1095$$

$$\text{Single conversion} = \frac{1095 - 1000}{1095} \\ = 8.67\%$$

ii) Recycle ratio = $\frac{R}{F} = \frac{995 + 1.0}{100} = 9.95$

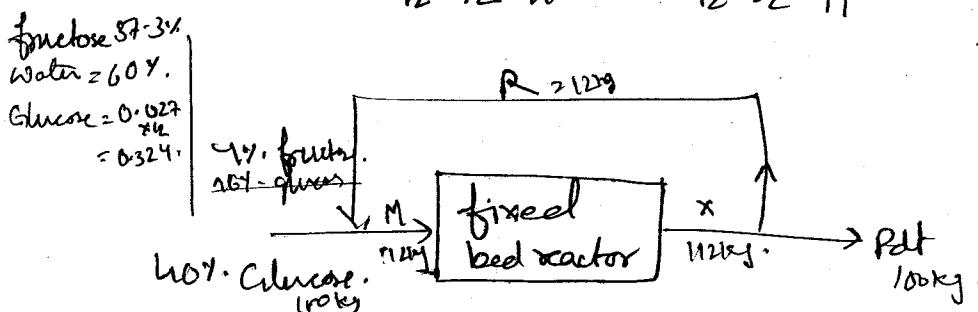


Q) Immobilised glucose isomerized is used as a catalyst for producing fructose for producing glucose in fixed bed reactor. Water is what % glucose will result on the product - goes through the reactor. The ratio of exit stream to recycle in mass unit is 8.33.



Since the rkn is same as reactant & prod. that's why: $F = P \Rightarrow P = 100 \text{ kg}$

$$\frac{P}{R} = 8.33$$



Basis 1 - Prod 100

overall balance.

$$F = P$$

$$100 = P$$

$$P/R = 8.33$$

$$R = 12.00 \text{ kg}$$

$$\begin{array}{|c|} \hline 100 = R + P \\ 40 = 0.4R + P \\ 40 = 0.8R + 100 - R \\ 0.96R = 60 \\ R = 100 \text{ kg} \\ P = 37.5 \\ \hline \end{array}$$

$$\begin{array}{|c|} \hline 100 + R = P \\ 100 + 0.96R = 100 + R \\ \hline \end{array}$$

$$x_F = \frac{112 \times 0.04}{12} = 0.373$$

= 37.3 fraction.

$$x_G = 1 - 0.6 - 0.373 = 0.027$$

$$x_{\text{benzene}} = 112 \times 0.027 = 3.024$$

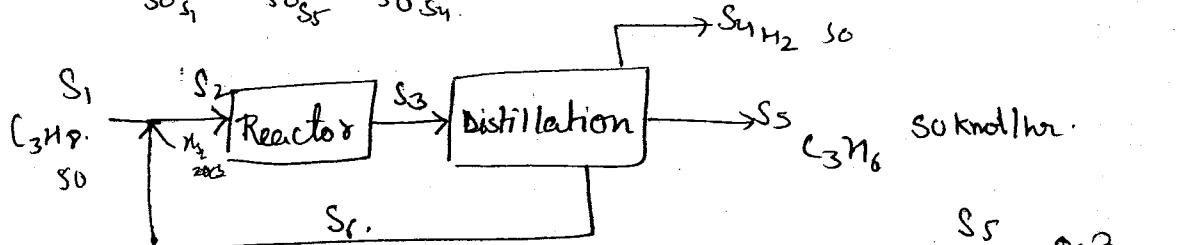
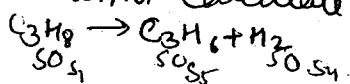
$$M = 40 + (R)(0.324)$$

$$= 40.324$$

$$\text{Conversion} \% = \frac{40.324 - 3.024}{40.324} \times 100$$

$$= 92.5\%$$

Q.) The process of propane dehydrogenation is shown in fig. It is desire to set a simplified version of M&S for this plant for material balance. Assume that yield of propylene per pass is 30%. i.e. 30% of the propane entering the reactor is converted to propylene and the inlet flow rate is 50 kmol/hr. Calculate the flow rate of stream S_2 & S_3 .



$$\frac{S_5}{S_3} = 0.3$$

$$S_2 = 166.66$$

$$S_1 = S_4 + S_5$$

$$S_1 - S_4 = 60$$

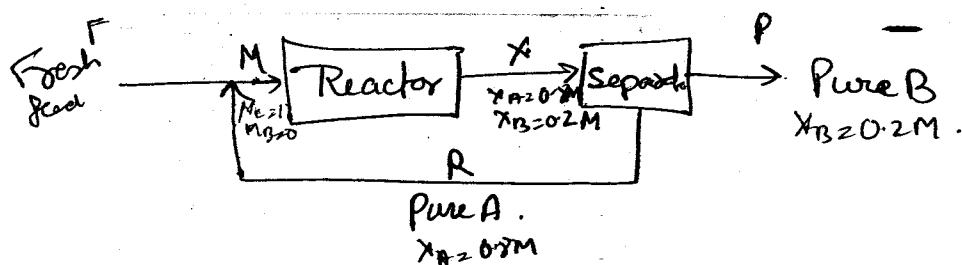
$$S_6 = S_2 - S_1$$

$$= 116.67$$

$$S_3 = S_4 + S_5 + S_6$$

$$= 216.67$$

Q.) If single pass conversion of $A \rightarrow B$ is 20%. Then find recycle ratio.



Feed :-

100 kg

$$F+R=M \quad \text{overall balance}$$

$$100+R=M$$

$$100+0.8M=M \quad \text{Material Balance}$$

$$M=800$$

$$R=400$$

$$\frac{R}{F} = \frac{400}{100} = 4$$

$$\begin{aligned} \frac{M-X}{X} &= 20 \\ M-X &= 20X \\ M &= 19X \\ X &= P+R \\ F+R &= M \\ F+X-P &= M \\ 100+X-P &= 19X \\ 100-P &= 18X \end{aligned}$$

Ans :-

July 16, 14

Q.) Limestone mixed with coke is being burnt in kiln. And an avg. analysis of limestone is CaCO_3 (calcium carbonate) is 84.5%, MgCO_3 is 11.5% and rest inert. The coke contains 76% C, 2% ash, 3% moisture. The calculation of CaCO_3 is 95% complete for calcination reaction. And that of MgCO_3 is 90%. The carbon in coke is burnt completely in CO_2 . The kiln is fed with 1 kg of coke per 5 kg of limestone. Calculate the wt.% CaO (calcium oxide) in the pct leaving the kiln.

Assume
100 kg limestone
 $\text{CaCO}_3 = 84.5\text{ kg}$
 $\text{MgCO}_3 = 11.5\text{ kg}$
inert = 4 kg.

Kiln

as it is given
in 1:5 ratio
20 kg Coke
 $C = 15.2\text{ kg}$
ash = 4.2 kg.
moisture = 0.6 kg.

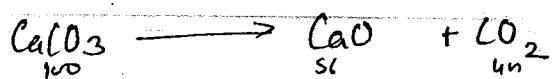
$\text{CO}_2 = 33.324\text{ kg} (\text{CaCO}_3)$
 $\text{CO}_2 = 5.402\text{ kg} (\text{MgCO}_3)$
moisture = 0.6 kg.

$\frac{100}{5} \xrightarrow{\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2}$
5 kg limestone
11 kg coke.

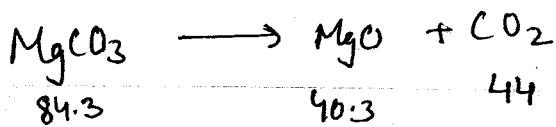
$\text{CaO} = 44.954\text{ kg}$
 $\text{MgO} = 1.15\text{ kg}$
 $\text{CaO}_3 = 6.225\text{ kg}$
inert = 4.1 kg.
ash = 4.2 kg.

63.476

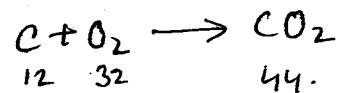
$$\text{Calcined} = \frac{84.5 \times 0.95}{100} = 80.275$$



$$\begin{aligned} \text{Calcined} &= 84.5 \times 0.95 \\ &= 80.275 \\ \text{remaining} &= \frac{84.5 - 80.275}{100} \\ &= 4.225 \end{aligned}$$



$$\begin{aligned} &\rightarrow 11.5 \times 0.95 \\ \text{Calcined} &= 10.35 \\ \text{remaining} &= 11.5 - 10.35 \\ \text{MgCO}_3 &= 1.15 \end{aligned}$$



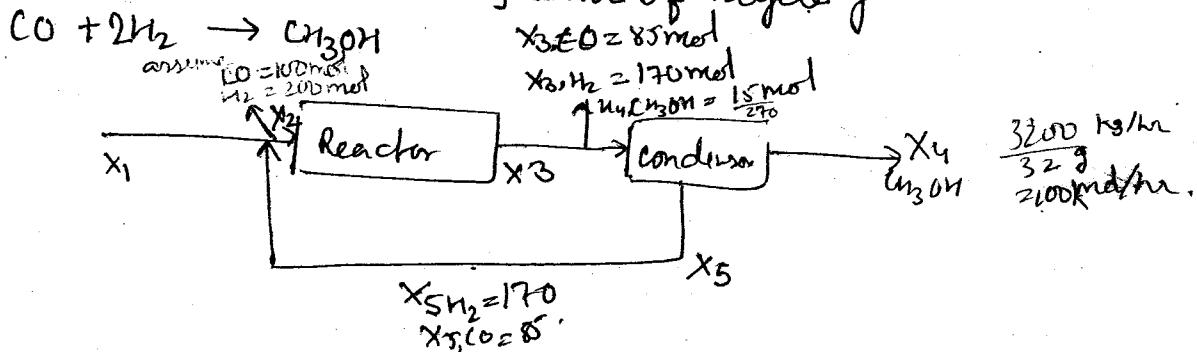
$$\frac{44}{12} \times 15.2 = 55.73$$

$$= \frac{35.32 + 5.402 + 55.73}{100} = 96.452$$

$$= \frac{44.45}{160.5} \times 100 = 28\%$$

Q2) Methanol is produced by the rxn of CO with hydrogen. The CO conversion per pass is 15% and the methanol formed is condensed & recovered completely. The unreacted CaO & H₂ is recycled back to the reactor. The feed ratio will contain H₂ & CO in ratio 2:1. For 3200 kg/hr pdt methanol. Calculate i) kg mole/hr of fresh feed.

ii) kg mole/hr of recycle gas



$$\text{scale up factor} = \frac{100}{15}$$

15 mol CH_3OH Produced by = 30 mol $\times x_{\text{H}_2}$

100 mol

$$= \frac{30}{15} \times 100$$

$$= 200$$

Recycle:

$$x_{\text{H}_2} = \frac{170 \times 100}{15} = 1133.3$$

fresh feed

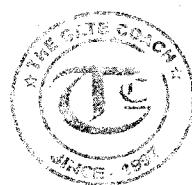
$$x_{\text{H}_2} = \frac{30}{15} \times 100 = 200$$

$$x_{\text{CO}_2} = \frac{85 \times 100}{15} = 566.6$$

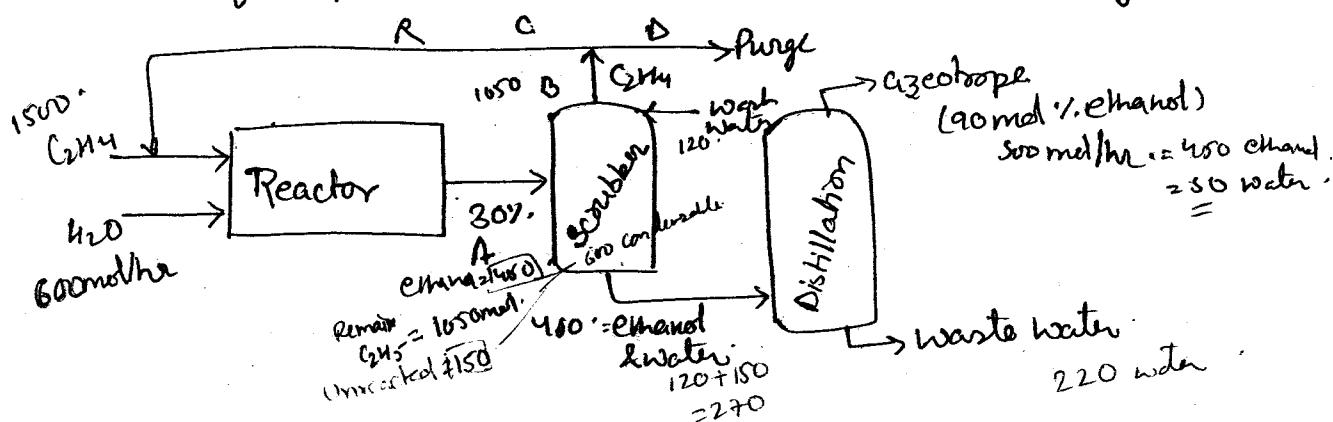
$$x_{\text{CO}_2} = \frac{15}{15} \times 100 = 100$$

$$= 1699.99 \text{ kmol/hr.}$$

$$30 \text{ kmol/hr}$$



Q) conversion For the production of ethanol from ethylene, the conversion of ethylene is 30% and the scrubber completely separates ethylene as the top product stream and ethanol and water as bottom. The last column (distillation) gives ethanol water azeotrope (90 mole% EtOH) as the final product & water as waste. The recycle to purge ratio is 34.

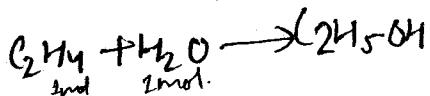


i) For an azeotrope pdt rate 500 mol/hr. find the recycle rate in mol/hr.

$$1020 \text{ mol}$$

ii) For the same process, if fresh water feed in the reactor is 600 mol/hr and wash water in scrubber is 20% coolable coming out of reactor. Find the water flow rate from the waste stream of distillation column. 220.

77



$$\frac{C}{D} = 34$$

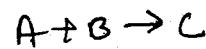
$$C + D = 1050$$

$$34D + D = 1050$$

$$D = 30$$

$$R = 1020 \text{ mol/hr}$$

Required Amount \rightarrow stoichiometrically



Supplied amount \rightarrow $\text{kg/moles} = \text{kg/moles}$

limiting Reactant \rightarrow which is available in lesser quantity.

Excess Reactant:— Available in excess of theoretically or stoichiometric required.

$$\% \text{ excess} = \frac{\text{amount B supplied} - \text{required B}}{\text{required B}} \times 100$$

Q) Pure propane is burnt with excess of air to give following analysis of combustion products in volume %.

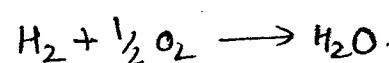
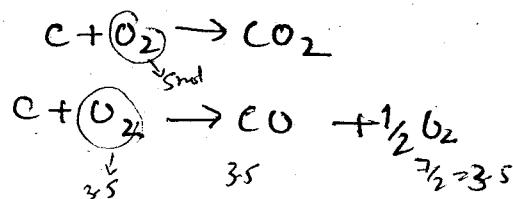
$$\text{CO}_2 = 5, \text{ CO} = 3.5, \text{ H}_2\text{O} = 11.4, \text{ N}_2 = 73.1, \text{ O}_2 = 7$$

Calculate %age excess air used.



$$\text{O}_2 \text{ used, react} = 5 + 3.5 + 5.7 = 14.2 \text{ mol}$$

$$\text{excess} = \frac{\text{Supplied} - \text{required}}{\text{required}} \times 100$$

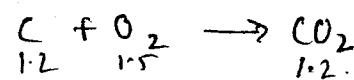


$$11.4 \quad 5.7 \quad 11.4$$

$$\text{O}_2 \text{ Supplied} = \frac{73.1 \times 0.21}{0.78} = 19.68 \text{ mol} \quad \text{Nitrogen and the O}_2 \text{ left out.}$$

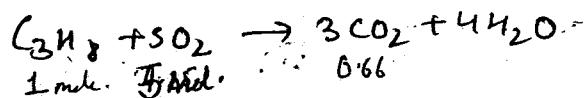
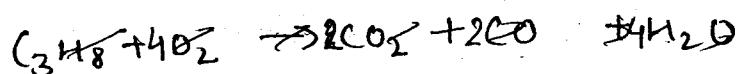
$$\% \text{ excess} = \frac{19.68 - 14.2}{14.2} \times 100 = 38.39.$$

Q) 1.2 g atom of Carbon and 1.5 gm moles of oxygen are reacted to give 1.2 mole of CO_2 . Find limiting reacted, %age excess reacted supply.



$$\frac{1.5 - 1.2}{1.2} \times 100 = 25\%$$

Q) 84 kg of C_3H_8 is burnt with 1160 kg of air ($28.84 \approx 29$ kg/mole) to produce 88 kg of CO_2 & 14 kg CO . i) What is % excess air used. ii) What is % of C burnt. (30g/mol)



1) Moles of air supplied = $\frac{1160}{29} = 40$ mole

$$O_2 \text{ required} = 5 \text{ mole}$$

$$\text{Air required} = \frac{5}{0.21} = 23.80 \text{ mole}$$

$$\% \text{ excess air used} = \frac{40 - 23.80}{23.80} \times 100$$

$$= 68.06\%$$

ii)

$$1 \text{ mole } C_3H_8 \text{ given in feed} = 36 \text{ g wt. C}$$

12x3

$$2 CO_2 \rightarrow 44 \text{ g} \rightarrow 88 \text{ kg of } CO_2$$

$$\text{moles of } CO_2 \text{ produced} = \frac{88}{44} = 2 \text{ moles}$$

$$CO \text{ burnt} = \frac{281}{28} = 0.5 \text{ mole}$$

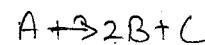
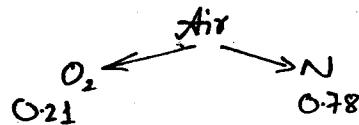
$$= 2 + 0.5 \text{ mole} = 2.5 \text{ mole}$$

$$= 30 \text{ g}$$

$$C \text{ burnt \%} = \frac{30}{36} \times 100$$

$$= 83.33\%$$

July 18, 14



$$F_B = 2F_A$$

$$F_C = 2F_A$$

Q)

$$* \% \text{ excess } O_2 = \% \text{ excess air}$$

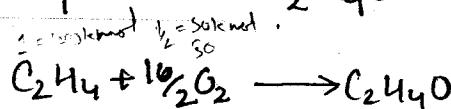
N never take part in rxn.

$$O_2 \text{ supplied} = x$$

$$x \quad N_2 \text{ in pdt} = \frac{x}{0.21} \times 0.78 = x \times 3.76$$

on hot basis

20

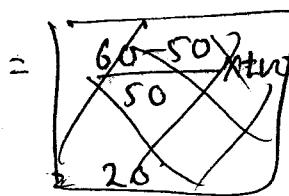
Q) Oxidation of C_2H_4 to produce C_2H_4O 

If air is 20% excess of theoretically required. Calculate the quantity of air supplied for 100 kmol of ethylene feed.

$$\begin{array}{l} 1) O_2 \text{ required} \\ 2) O_2 \text{ supplied} \text{ corresponds to } 1.2 \times 21 = 60 \end{array}$$

$$O_2 \text{ required} = 50$$

$$20\% \text{ excess } O_2 \text{ supplied} = 1.2 \times 21 = 60$$



$$\begin{aligned} \text{amt of air supplied} &= \frac{60}{0.21} \times 100 \text{ kmol} \\ &= 285.71 \end{aligned}$$

$$\begin{array}{l} 1) O_2 \text{ required} \\ 2) O_2 \text{ supplied} \end{array}$$

$$= 1.2 \times 21$$

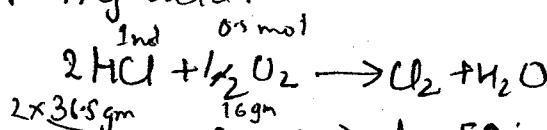
$$\begin{array}{l} 1) O_2 \text{ supplied (90\% excess)} \\ 2) O_2 \text{ supplied (100\% excess)} \end{array}$$

$$= 1.9 \times 21$$

$$= 4 \times 21$$

$$\begin{aligned} \text{air supplied in kg} &= \frac{60}{0.21} \times 28.84 \text{ kg} \\ &= 8240 \text{ kg} \end{aligned}$$

Q) In manufacture of Cl_2 , a dry mixture of HCl gas and air is passed over a heated catalyst which promotes oxidation of HCl . Air is in 30% excess of theoretically required. Calculate the wt. of air supplied per/kg acid.



$$O_2 \text{ required} = 50$$

$$30\% \text{ excess supplied} = 50 + 3 = 65$$

$$2 \times 36.5 \text{ gm} \quad 0.5 \times 32 \text{ gm}$$

$$O_2 \text{ required} = 16 \text{ gm}$$

0.5 mol O_2 required \rightarrow 2 mol of HCl

0.25 mol O_2 " \rightarrow 1 mol " HCl

$$\text{air required} = \frac{0.25}{0.21} = 1.190 \text{ mol}$$

$$\text{air supplied} = \frac{0.25}{0.21} \times 1.3 = 1.5476 \text{ mol}$$

$$\text{kg air supplied} = \frac{0.25}{0.21} \times 1.3 \times 28.84 = 44.63 \text{ kg/g}_{1 \text{ mol HCl}}$$

$$36.5 \text{ g HCl} = \frac{0.25}{0.21} \times 1.3 \times 28.84$$

$$1 \text{ g HCl} = \frac{0.25}{0.21} \times \frac{1.3 \times 28.84}{36.5} = 1.2228 \text{ g/g mol HCl}$$

1.222 kg/kg mol HCl

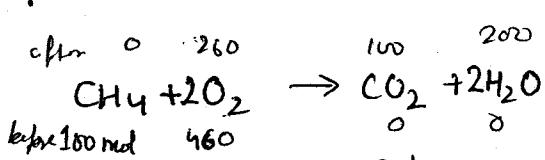
Q) A factory owner burn Natural gas containing 100% methane CH_4 and air supplied is adjusted to provide 130% excess air. What is the % of CO_2 found in the pdt.

$$1 \rightarrow O_2 \text{ required} = 200 \text{ mol.}$$

$$2 \rightarrow O_2 \text{ supplied} = 200 \times 1.3 = 460 \text{ mol}$$

$$N_2 \text{ pdt} = 460 \times 3.76 = 1729.6 = 1730$$

$$\text{total pdt} = 100 + 200 + 1730 + 260 = 2290$$



$$\begin{aligned} & \text{Pdt} \\ & \text{CO}_2 = 100 \\ & H_2O = 200 \\ & N_2 = 1730 \\ & O_2 = 260 \end{aligned}$$

$$\% \text{ of } CO_2 \text{ found} = \frac{100}{2290} \times 100 = 4.3\%$$

Q) The Orsat analysis of flue gas is $[O_2, CO, N_2, O_2]$ gives $CO_2 = 12.7\%$, $O_2 = 7.1\%$.

$N_2 = 80.2\%$ ^{by volume} Determine % excess air used in combustion. N_2 present in flue gas is contributed by air only.

$$\% \text{ excess air} = ?$$

$$\% \text{ excess } O_2 = ?$$

$$O_2 \text{ supplied} \times 3.76 = N_2 \text{ pdt}$$

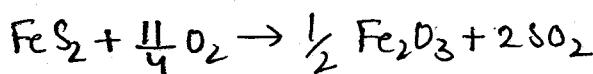
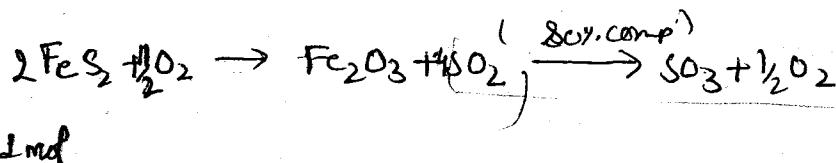
$$O_2 \text{ supplied} = \frac{80.2}{3.76} = 21.32 \text{ mol.}$$

$$\text{remaining } O_2 = 7.1 \text{ mol.}$$

$$O_2 \text{ used} = 21.32 - 7.1 = 14.22 \text{ mol.}$$

$$\% \text{ excess } O_2 = \frac{21.32 - 14.22}{14.22} \times 100 \\ = 49.92\%.$$

Q) FeS_2 is burn with air in 100% excess of required to oxidize all iron into Fe_2O_3 and all sulphur into SO_2 . Calculate the composition of exist gases. If 80% of SO_2 is further oxidised to SO_3 . and rest is SO_2 in pdt.



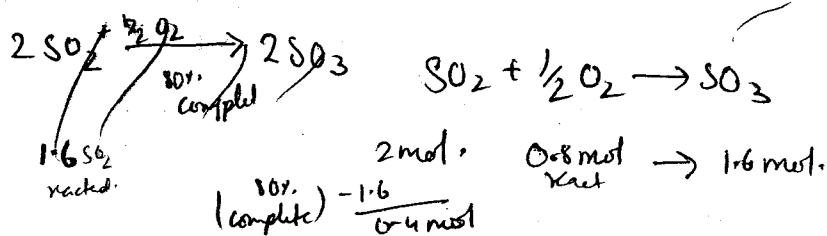
$$O_2 \text{ required} = 1\frac{1}{4} \text{ mol.} \quad \text{Pdt}$$

$$O_2 \text{ supplied} = \frac{11}{4} \times 2 = 5.5 \quad \text{1 mol}$$

$$N_2 \text{ supplied} = \frac{11}{4} \times 2 \times 3.76 = 20.68$$

$$\begin{array}{l} \text{Fe}_2\text{O}_3 = 0.8 \\ SO_2 = 2 \text{ mol} - 1.6 \text{ mol} = 0.4 \\ SO_3 = 1.6 \text{ mol.} \\ N_2 = 20.68 \\ O_2 = 1.95 \end{array}$$

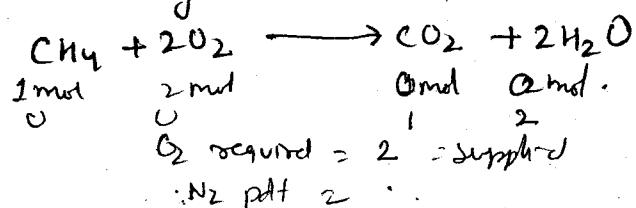
24.53



$$\begin{aligned} O_2 \text{ remaining} &= O_2 \text{ supplied} - O_2 \text{ used} \\ &= 5.5 - (0.8 - 2.75) \\ &= 1.95 \end{aligned}$$

$$Fe_2O_3 = \frac{0.8}{24.53} \times 100 = 1.98\%.$$

Q) CH_4 is completely burn with air. Find volume % of CO_2 in the flue gases on wet basis as well as dry basis.



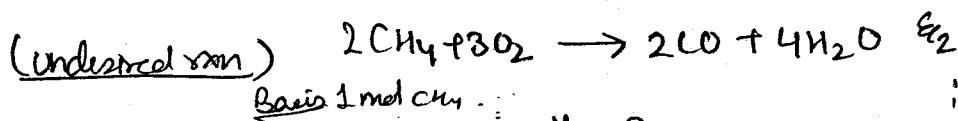
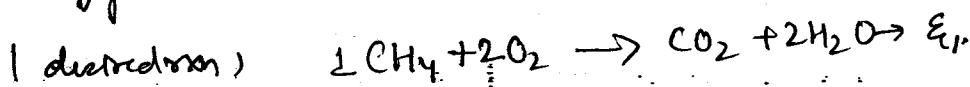
$$\begin{aligned} O_2 \text{ Supplied} &= 2 \text{ mol} \\ N_2 \text{ Supplied} &= 7.52 \end{aligned}$$

$$\begin{array}{ll} \text{Pdt wet), Pdt combust} \\ \text{CO}_2 = 1 \text{ mol} & \text{CO}_2 = 1 \text{ mol} \\ N_2 = 7.52 \text{ mol} & N_2 = 7.52 \text{ mol} \\ H_2O = 2 \text{ mol} & \end{array}$$

$$\text{CO}_2 \text{ % in dry basis} = \frac{1}{8.52} \times 100 \\ = 11.73\%$$

$$\text{CO}_2 \text{ % in wet basis} = \frac{1}{10.52} \times 100 \\ = 9.5\%$$

Q.) In the combustion of CH_4 , 20% of excess air is supplied to combust. The conversion of CH_4 is 80% and the molar ratio of CO/CO_2 is $\boxed{1/3}$ in flue gas. Assume air to have 80 mol% N_2 and rest oxygen. Find the amount of O_2 consumed / per unit oxygen supplied in the combustor.



ϵ = extent of rxn

$$O_2 \text{ required} = 2 \quad (1+\epsilon_2)$$

$$O_2 \text{ Supplied} = 2 \times 1.2 = 2.4.$$

In request we also take supplied oxygen from desired rxn.

$$\text{CH}_4 \text{ consumed} = 1 \times \epsilon_1 + 2 \epsilon_2 = 0.8 \Rightarrow 6\epsilon_2 + 2\epsilon_2 = 0.8$$

$$\boxed{\epsilon_2 = 0.1}$$

$$\text{Relation for CO} = \frac{2\epsilon_2 \epsilon_1}{\epsilon_1} = \frac{1}{3}$$

$$\epsilon_1 = 6\epsilon_2$$

$$\boxed{\epsilon_1 = 0.6}$$

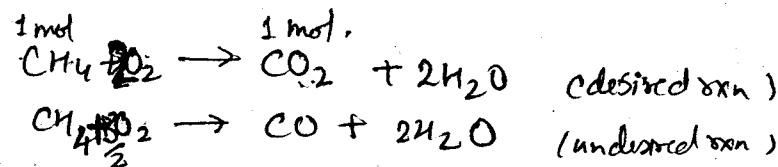
$$O_2 \text{ %} = \frac{O_2 \text{ Consumed}}{O_2 \text{ Supplied}} \times 100$$

$$= \frac{0.6 \times 1.5}{2.4} \times 100 \\ = 62.5\%$$

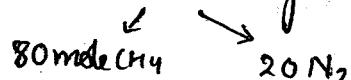
Species	Reactant	Pdt
O_2	2.4 mol	$2.4 - 6\epsilon_1 - 3\epsilon_2 = 0.9$

July 21/14

Q.) A sample of Natural gas containing 80% CH_4 and 20% N_2 is burnt with 80% of combustible 20% excess air with 80% of the combustible producing CO_2 and the remainder going to CO . Find the overall analysis in volume %.

Set

Basis: 100 mole natural gas



O_2 reqd for 80 mole CH_4 Combustion = 160 mole

$$\text{O}_2 \text{ Supplied} = 160 \times 1.2 = 192 \text{ mole}$$

$$\text{CO}_2 \text{ formed} = 80 \times 0.8 \text{ mole } \text{CH}_4 \text{ reacted} = 64 \text{ mole}$$

$$\text{CO formed} = 80 - 64 = 16 \text{ mole}$$

$$\text{N}_2 \text{ Product} = \text{O}_2 \text{ Supplied} \times \frac{0.79}{0.21} + 20 \quad \text{(present in natural gas)}$$

$$= 192 \times 3.76 + 20$$

$$= 742.28 \text{ mole}$$

Product

$$\text{CH}_4 = 0$$

$$\text{CO} = 16 = \frac{16}{742.28}$$

$$\text{CO}_2 = 64$$

$$\text{N}_2 = 742.28$$

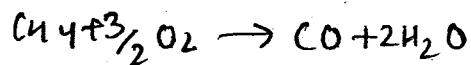
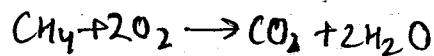
$$\text{O}_2 =$$

$$\begin{aligned} & \text{O}_2 \text{ mole} \quad 64 \times 2 + 16 \times \frac{3}{2} \\ & \text{consumed} \quad = \frac{40}{742.28} \\ & \text{to form} \end{aligned}$$

6 mole CH_4 need to form
 64 mole CO_2
 16 mole N_2 need to form 16
 mole CO

Q7 The pelt of combustion of CH_4 in atm air. has the following composition
 air $[\text{CO}_2 = 10\text{ mole} \text{ (per cent)} \text{, } \text{O}_2 = 2.37 \text{, } \text{N}_2 = 87.1 \text{, } \text{CO} = 0.53]$. Find the
 ratio of moles of CH_4 to moles of O_2 in feedstream.

Basis :- 100 moles pelt.



$$\begin{aligned} \text{Moles of } \text{CH}_4 \text{ consumed} &= \text{Moles of } \text{O}_2 \text{ formed} + \text{Moles of CO} \\ &= 10(\text{CH}_4 \text{ consumed} + 0.53 \text{ mole } \text{CH}_4 \text{ reacted.}) \\ &\quad \text{in grol.} \end{aligned}$$

$$= 10.53 \text{ mole } (\text{CH}_4 \text{ in feed.})$$

$$\text{O}_2 \text{ Supplied (feed)} = \frac{87.1}{0.79} \times 0.21 = 23.153$$

↓
ATR
↓
O₂ supplied

O_2 Consumed + O_2 remaining

$$\frac{\text{CH}_4 \text{ in feed}}{\text{O}_2 \text{ in feed}} = \frac{10.53}{23.153} = 0.454$$

Q8 % conversion / fractional conversion / % burnt reacted.

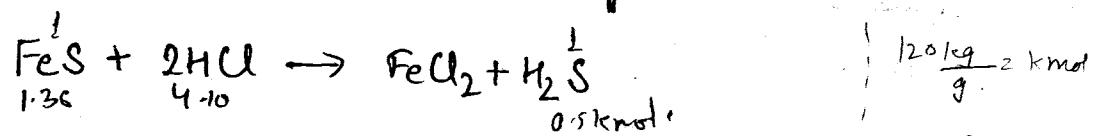


$$= \frac{\text{Amount of A reacted to form desired pelt}}{\text{Amount of A fed or charged}} \times 100$$

Degree of completion :- (A) (Limiting Reagent)

$$= \frac{\text{amount of A reacted}}{\text{amount of A fed}}$$

Q) H_2S is produced from the rxn $FeS + 2HCl \rightarrow H_2S + FeCl_2 + 120 \text{ kg } FeS$ react with 150 kg of HCl and, to produce 0.5 kg of H_2S . Find the degree of completion of rxn & the limiting reagent.



$$FeS = 55.85 + 32.07 = 87.92$$

$$HCl = 1 + 36.5 = 37.5$$

$$Fe = 55.85$$

$$S = 32.07$$

$$HCl = 37.5$$

$$\text{No. of moles of } FeS = \frac{120 \text{ kg}}{87.92 \text{ g}} = 1.364 \text{ kmol}$$

$$\text{No. of moles of } HCl = \frac{150}{37.5} = 4.09 \text{ kmol}$$

$$\text{So, } FeS \text{ reacted} = 0.5 \text{ kmol}$$

$$0.5 \text{ kmol } H_2S \rightarrow 0.5 \text{ kmol } FeS \text{ reacted}$$

$$\% \text{ degree of completion} = \frac{0.5}{1.36} \times 100$$

$$= 36.76\%$$

Q) In manufacture of CH_3COOH by the oxidation of acetaldehyde. 100 kmol of acetaldehyde is fed from the ^{to the plant} reactor / hr. The pct leaving the reactor contains acetaldehyde 14.8%, Acetoc acid 59.2% and rest O_2 . Find the conversion of acetaldehyde.

$$\text{Acetaldehyde feed} = 100 \text{ kmol/hr}$$

$$\text{Acetaldehyde reacted} = 59.2$$

$$0.14812x + 0.5921x = 100$$

$$x = 135.09$$

~~$$\frac{59.2}{135.09} \times 100 = 43.81\%$$~~

$$= \frac{59.21 \times 135}{100 \times 100} \times 100$$

Q) Analysis of gas entering the secondary converter in contact process

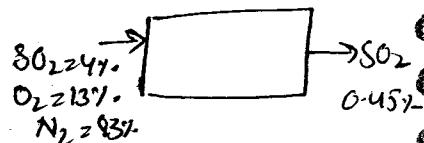
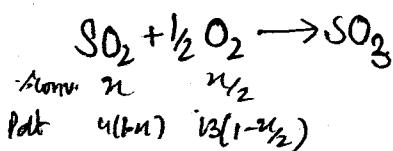
Ans. $\text{SO}_2 = 4\%$, $\text{O}_2 = 13\%$, $\text{N}_2 = 83\%$ mol % in converter SO_2 is

oxidized to SO_3 . The gas leaving the converter 0.45% contains SO_2 .

Calculate the % conversion of SO_2 .

Basis: 100 mol feed.

$x = \%$ conversion.



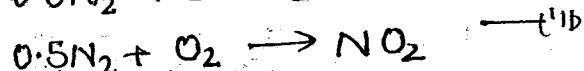
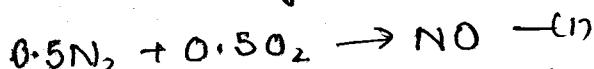
$\text{SO}_2\%$ in Product = ~~$\frac{4(1-x) + 13(1-\frac{x}{2})}{100}$~~

$$\Rightarrow \frac{4(1-x)}{100 - 13\frac{x}{2}} = 0.0045$$

$$x = 88.10$$

	Actual	Product amount
SO_3	0	4x
SO_2	4	$4(1-x)$
O_2	13	$13(1-\frac{x}{2})$
N_2	83	83

Q) Air (79% N_2 , $\text{O}_2 = 21\%$) is passed over a catalyst at high temp; O_2 completely reacts with N_2 with following rxn.



The molar ratio of NO_2 in pdt stream is 2:1. Find the fractional conversion of N_2 .

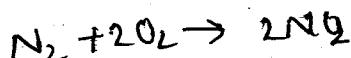
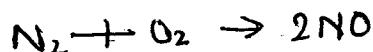
Ans:

$$\frac{\text{NO}}{\text{NO}_2} = \frac{2}{1}$$

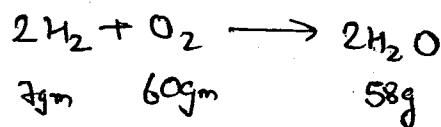
Fractional Conversion = $\frac{\text{Amt of N}_2 \text{ Converted to form pdt}}{\text{Amt of N}_2 \text{ fed}}$

Suppose we have x moles of O_2 reacted in rxn (1),
 $y \quad n \quad n \quad n \quad n \quad \text{in rxn (1')},$

$$x+y = 21$$



Q. $2H_2 + O_2 \rightarrow 2H_2O$. What is % yield of water if 58g of H_2O produced by combining 60gm of O. and 7gm of H_2 .



LR $\rightarrow H_2O$ in lesser quantity.

H_2 is limiting.

$$\% \text{ yield} = \frac{58}{63} \times \frac{\text{actual}}{\text{theoretical}} \\ = 92.06\%$$

Oxygen

$$1 \text{ mole } O_2 \rightarrow 2 \text{ mole } H_2O \\ 32g O_2 \rightarrow 2 \times 18g H_2O \\ 60g O_2 \rightarrow \frac{2 \times 18}{32} \times 60 \\ = 67.5g H_2O$$

Hydrogen

$$2 \text{ mole } H_2 \rightarrow 2H_2O \\ 1 \text{ mole } H_2 \rightarrow 1H_2O \\ 2g \rightarrow 18g \\ 7g \rightarrow \frac{18}{2} \times 7 \\ \rightarrow 63.9g H_2O$$

Selectivity:-

$$= \frac{\text{moles of desired pdt}}{\text{moles of undesired pdt}} \times 100$$

Q. CH_4 & steam are fed to a reactor in molar ratio 1:2. The following reaction takes place



CO (Undesired), CO_2 (desired), H_2 (byproduct).

$$CH_4 = 4.35$$

$$CO_2 = 15.21$$

$$H_2 = 10.88$$

$$CO = 2.17$$

$$H_2 = 67.3$$

Find i) selectivity ?, ii) yield of CO_2 iii) fractional conversion of CH_4 .

$$\text{Selectivity} = \frac{\text{moles of desired pdt}}{\text{moles of undesired pdt}} = \frac{15.21}{2.17} = 7$$

$$\text{yield of } \text{CO}_2 = \frac{\text{actual yield}}{\text{theoretical yield}}$$

$$\text{Theoretical yield} = \text{CO}_2 + \text{O}_2 + \text{CH}_4 = 21.73$$

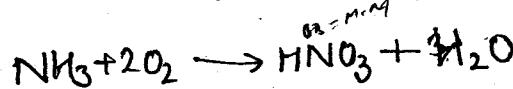
$$= \frac{15.21}{21.73} \times 100$$

$$= 69.99\%$$

$$\text{fractional conversion of } \text{CH}_4 = \frac{15.21}{21.73} = 0.699$$

Q) Estimate the consumption of NH_3 & Air for production of 5000 kg of HNO_3

The yield of NO is 97% & the yield of HNO_3 is 92%. and the content of NH_3 in NH_3 -air mixture is 7% by wt. & Air - 93% by wt.

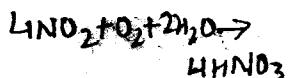
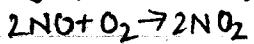
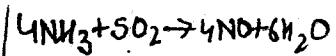


Ans

$$5000 \text{ kg/hr} = \text{HNO}_3$$

$$\text{NO} = 97\%$$

$$\text{HNO}_3 = 92\%$$



$$17 \text{ gm}$$

$$63 \text{ gm}$$

17 gm NH_3 reqd for 63 gm HNO_3 produced

63 gm HNO_3 needs = 17 gm NH_3

$$5000 \text{ kg} = \frac{17}{63} \times 5000$$

$$= 1349.206 \text{ kg } \text{NH}_3$$

$$\text{NH}_3 \text{ in feed} \times 0.97 \times 0.92 = 1349.21 \text{ kg}$$

$$\text{NH}_3 \text{ in feed} = 1511.88 \text{ kg}$$

$$\text{NH}_3\text{-Air mixture supplied} = \frac{1511.88}{0.07}$$

$$\text{Air supplied} = 21598.28 \times 0.95$$

$$= 20,086.40571$$

Energy Balance

Heat capacity :- c

$$\text{Specific heat} = c = \frac{d\theta}{dT}$$

$$C_p - C_v = R$$

$$c = f(T) = a + bT + cT^2 + dT^3$$

$$Q = \int_{T_1}^{T_2} c dT$$

$$C = A \text{ J/k/kg}$$

$$Q = nC(T_2 - T_1)$$

Mean Molal Sp. heat

$$C_m = \frac{\int_{T_1}^{T_2} c dT}{(T_2 - T_1)}$$

Q: Calculate the heat that must be added to 3 kmol of air to heat it from 298 K to 473 K. using mean molal sp. heat of air

$$C_m = 29.3985 \text{ kJ/kmol.K}$$

$$Q = nC_p(\Delta T)$$

$$= 15432.63 \text{ kJ}$$

Q: Calculate the heat required to raise the temp of 1 mol of solid from 100°C to 1000°C. Spheat $C_p = 20 + 0.005T \text{ J in K}$ (J/kmol.K)

$$\begin{aligned} Q &= nC_p(\Delta T) \int_{T_1}^{T_2} c dT \\ &= \left[20T + \frac{0.005T^2}{2} \right]_{100-373}^{1000-1273} \\ &\approx 20 \times 900 + \\ &= 21703.5 \end{aligned}$$

July 23, 14

Q7 Bituminous coal with calorific value 20000 KJ/kg is used for generating steam in a boiler. How much coal has to be burnt to produce 1MW of energy. Efficiency of combustion is 0.75. How much air is supplied if 50% excess air is used. Assume Coal contains 67% C, 33% ash

Soln

$$\text{Calorific Value} = 20000 \text{ KJ/kg}$$

$$[\text{Coal required} = 0.0666 \text{ kg/s}]$$

$$[\text{Air Supplied} = 0.0266 \text{ kmol/s}]$$

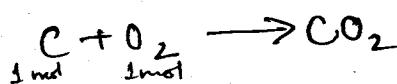
$$1 \text{ MW} = 10^6 \text{ W} = 10^6 \text{ J/s} = 10^3 \text{ KJ/s}$$

$$\text{Amount of coal} = \frac{10^3}{20000} \frac{\text{KJ/kg}}{\text{KJ.s}} = 0.05 \text{ kg/s}$$

$$\begin{aligned} \text{Amt of coal for producing} &= 0.05 \text{ kg/s} \\ 10^3 \text{ kg energy} \end{aligned}$$

$$\text{amt coal used} \times 0.75 = 0.05 \text{ kg/s}$$

$$\text{amt coal} = \frac{0.05}{0.75} = 0.066 \text{ kg/s}$$



$$\text{Amt of C in coal} = \frac{0.066 \times 67}{100} = 0.04422 \text{ kg/s}$$

$$\text{mole of C} = \frac{0.04422}{12} = 0.0036 \text{ kmol/s}$$

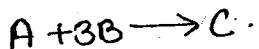
$$\text{Amt of O}_2 \text{ in mole/s} = 0.0036 \text{ kmol/s} \quad (\text{same as C})$$

$$\text{air} = \frac{0.00372}{0.21} = 0.0175 \text{ kmol/s}$$

$$\text{air supplied} = 0.0175 \times 1.5 = 0.0263 \text{ kmol/s}$$

Q.) The heat of a rxn. at 300K and 1 atm pressure. ΔH are?

$$\Delta H_{\text{rxn}} \text{ (300K, 1 atm press)} = -50,000 \text{ cal/mol of A reacted.}$$



Value of sp. heat C_p for all the species. C_p (cal/mol/K)

$$C_{pA} = -0.4 + 80 \times 10^{-3} T$$

$$C_{pB} = 7$$

$$C_{pC} = 26$$

Calculate the heat of the rxn at 500K

$$\text{Ans: } \Delta H_{\text{rxn}} \text{ (500K)} = \Delta H_{\text{rxn}} \text{ (300K)} + \int_{300K}^{500K} \Delta C_p^{\circ} dT$$

	A	B	C		$\Delta C_p^{\circ} = 0.4 - 80 \times 10^{-3} T - 21 + 26$
ν_i	-1	-3	1	1	$= 5.4 - 80 \times 10^{-3} T$
C_p°	$-0.4 + 80 \times 10^{-3} T$	7	26		$= 5.4 - 80 \times 10^{-3} T$

$$\Delta C_p = \sum \nu_i C_p^{\circ}$$

ν = reactant = -ve

prod = +ve.

ν = stoichiometric coeff.

$$\begin{aligned} &= -50000 + \int_{300}^{500} (5.4 - 80 \times 10^{-3} T) dT \\ &= -50000 + (-320) \\ &= -55320 \text{ cal/mol} \end{aligned}$$

Q.) A stream containing 10% CH_4 & 90% air by volume is to be heated from 373 - 573K at a rate of 0.05 m^3 at (NTP)/s. Calculate the heat required.

	$C_p(373-298)$	$C_p(573-298)$
CH_4	37.5974	43.0821
Air	29.2908	29.612

$$Q = n \Delta C_p \Delta T$$

$$\Delta C_p(\text{mix}) = \sum n_i C_p$$

↓
mole fraction.

in case of by volume
we take as by mole-
but in case of by wt.
to find mole we have to
divide by M.W.

$$\begin{aligned}\Delta Q &= \Delta Q_{\text{gas}} - \Delta Q_{\text{sol}} \\ &= n C_p \Delta T - n \Delta C_p \Delta T \\ &= n \Delta C_p_{\text{mix}} (373 - 298) - n \Delta C_p_{\text{mix}} (373 - 298) \\ &= \end{aligned}$$

1 mole = 22.4 litre

$$\text{rate} = 0.05 \text{ m}^3 \text{ (NTP/s)} = 0.05 \times 10^3 \text{ L/s}$$

$$1 \text{ litre} = \frac{1}{22.4} \text{ mole}$$

$$0.05 \times 10^3 \text{ L} = \frac{1}{22.4} \times 0.05 \times 10^3 \text{ mole}$$

$$n = 2.232 \text{ mol/s} = 2.232 \times 10^{-3} \text{ mol/s.}$$

$$\begin{aligned}\Delta C_p_{\text{mix}} &= 43.082 \times 0.1 + 29.612 \times 0.9 \\ &\approx 30.959\end{aligned}$$

$$\begin{aligned}\Delta C_p_{\text{mix}} &= 37.5974 \times 0.1 + 29.2908 \times 0.9 \\ &\approx 30.12146\end{aligned}$$

$$\begin{aligned}\Delta Q &= n \Delta C_p_{\text{mix}} (373 - 298) - n \Delta C_p_{\text{mix}} (373 - 298) \\ &\approx 13.96 \text{ kJ/s} = 13.96 \text{ kW}\end{aligned}$$

Q) Dry CH_4 is burnt with dry air, both are at 25°C initially and finally at 1300°C. If complete combustion is assumed. Find how much excess air is required. $\Delta H_{\text{rxn}}^\circ = -8.028 \times 10^5 \text{ J/mol}$ and the specific heat of every substance.

$$C_p = (1300 - 25^\circ \text{C}) \text{ J/gmol/K} \quad O_2 = 34.01$$

$$CO_2 = 51.88$$

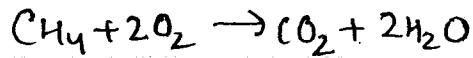
$$H_2O = 40.45$$

$$N_2 = 32.21$$

Solⁿ

	CH ₄	O ₂	N ₂	CO ₂	H ₂ O
feed	1	χ	3.76 χ	0	0
Pdt	0	$\chi-2$	3.76 χ	1	2
C _p	-	34.01	32.21	51.88	40.45
	0	34.01($\chi-2$)	32.21 \times 3.76	51.88	80.9

$$\Delta H_{mixn} = \Delta C_p \Delta T$$



$$\Delta C_p = 34.01\chi - 68.02 + 121.10\chi + 51.88 + 80.9$$

$$= 155.119\chi + 64.76$$

$$+ 8.028 \times 10^5 = + (155.12\chi + 64.76) \frac{1300-25}{1275}$$

$$= 19277.8\chi +$$

amt Supplied. $\chi = 3.641$ mol

$$\% \text{ excess} = \frac{\text{Supplied} - \text{required}}{\text{required}} \times 100$$

$$= 82\%$$

Q2) Pure CO is mixed with 100% excess air and only 80% of CO burns. The reactants are 100°C & pdt are at 300°C. Calculate the amount of heat added per kg mol CO feed. $C_p = (1 \text{ kJ/kg mol K})$

C_p Gas	T = 100-25°C	T = 300-25°C	Reactant kg mol	$\Delta C_{pr.}$	Pdt	ΔC_{pp}
CO	20.22	30.61	1	20.22	0.2	6.122
CO ₂		43.77	0		0.8	35.016
O ₂	29.64	30.99	1	29.64	0.6	18.594
N ₂	29.17	29.66	3.76	109.67	3.76	111.5216

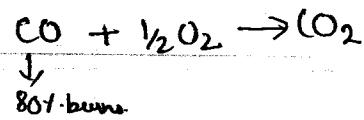
$$\Delta C_p = 159.53$$

$$\Delta C_{pp} = 171.249$$

$$\Delta H_{CO}(25^\circ C) = -1105.24 \text{ kJ/kg mol}^\circ C$$

$$\Delta H_{CO_2}(25^\circ C) = -393.514$$

Assume CO feed = 1 mole.



$$\text{Supplied O}_2 = \text{req'd} \times 2$$

(100% excess)

$$= 0.5 \times 2$$

$$= 1$$

$\Delta H_{\text{O}_2} = 0$



$$\Delta H_{\text{rxn}} = \Delta H_{\text{formation of CO}_2 \text{ from CO}} + \Delta H_{\text{raising the temp.}}$$

$$\Delta H_{\text{raising the temp.}}^{(300-100)} = \Delta H_{\text{pd}} - \Delta H_{\text{react}}$$

$$= \sum \Delta C_p (300-25) - \sum \Delta C_p (100-25)$$

$$= 35128.725$$

74222

$$\Delta H_{\text{formation}} = \Delta H_{\text{pd}} - \Delta H_{\text{reactant}}$$

$$= -393.514 - (-1105.24)$$

$$= 711.72$$

$$\Delta H_{\text{rxn}} = 35840.44 \text{ kJ/kg mol}$$