Process Calculation BE-207

Fundamental quantities
→ Length
→ Mass
→ Time
→ Temp
→ Mole

Systems →	SI	AES
Volume (Q) flowrate	$m^3 s^{-1}$	ft^3/s

Physical quantities
→ Scalar 0 dimensions
→ Vector 1
→ Tensor 2

notation
a (magnitude)
$\bar{a}$ (mag + dirxn)
$\bar{\bar{a}}$

To find dimension of product → dot product $\cdot \rightarrow -2$ dimensions
$\times \rightarrow -1$ dimensions
Vector Product

examples

$1+(-2)+1 = 0$
$\bar{a} \cdot \bar{b} = c$

$\bar{a} \times \vec{b} = c$

$\bar{\bar{a}} \cdot \bar{b} = \bar{\bar{c}}$
$2+(-2)+2 = 2$

$\bar{\bar{a}} : \bar{\bar{b}} = c$
$2 + (-4) + 2 = 0$

$\bar{a} + \vec{b} \Rightarrow$ eg $\bar{5} + \bar{3} =$ (lies between 2 to 8)

Rectangular components :-

$a = 3^0$
$\bar{a} = 3^1$ (components)
$\bar{\bar{a}} = 3^2 = 9$ (components

$\bar{a} = \hat{i} a_x + \hat{j} a_y + \hat{k} a_z$

$\bar{\bar{a}} = \hat{i}\hat{i}\, a_{xx} + \hat{i}\hat{j}\, a_{xy} + \hat{i}\hat{k}\, a_{xz} + \underbrace{\hat{j}\hat{i}}_{\text{Tensor}}\, a_{yx} + \hat{j}\hat{j}\, a_{yy} + \hat{j}\hat{k}\, a_{yz} + \hat{k}\hat{i}\, a_{zx} + \hat{k}\hat{j}\, a_{zy} + \hat{k}\hat{k}\, a_{zz}$

Diadic Product $\bar{a}\bar{b} = \bar{\bar{c}}$
$1+1$

Tensor Product

2^{nd} Law ⇒ Rate of change of momentum is proportional to force applied

$$F \propto ma$$
$$F = cma$$

for SI $c = \frac{1\ N}{kg \frac{m}{s^2}}$

for AES $c = \frac{1}{32.174} \frac{lbs\ s^2}{lbm\ ft}$

$$g_c = 32.174 \frac{lbm\ ft}{lbs\ s^2}$$

⇒ Newton = SI unit of force in absolute system
kgf = SI unit of force in gravitational system

	SI	AS
SI	N	kgf
CGS	dyne	gf (~~grand~~ gram force)
FPS	Pound~~alg~~	Lbf

1 kgf = 9.8N
↳ force with which body of 1kg attracted ~~with~~ to centre Of earth

Q) 1 lbf = ? N

$1 lb_m = 0.4536$ kg
1ft = 0.3048 m
$g = 9.81 m/s^2 = 32.2 ft/s^2$

$1N = 1kg * 1 m/s^2$

1 Poundal = 1 lbm * 1ft/s^2
= 0.4536 kg × 0.3048 m/s^2

1 lbf = 1 lbm * 32.2 ft/s^2 = 1 lbm * 1g
= 32.2 Poundal

Work

absolute
→ Nm Joule
→ dyne cm erg
→ Poundal ft ft poundal

gravitational
→ kgf m = kgm

⇒ 550 foot Pound force per second = 1 Horse Power (HP)
Grade ki chakki

$1\,hp = 550\ ft\ lbf/s$

$1\,hp = 550 \times 0.3048\,m \times 0.4536\,kg \times 9.8\,m/s^{-2}/s$

$1\,hp = 745.2\ W$

Mole : Amount of substance that contains as many elementary units (atoms / molecules/ions / Particles) as there are ~~in~~ atoms in 0.012kg of carbon 12

$1\,gmole = 6.023 \times 10^{23}$ no. of atoms/molecules/ions/particles

$1\,kg\,mole = 6.023 \times 10^{26}$

$1\,lb\,mole = 453.6 \times 6.023 \times 10^{23}$

Density : $\frac{Mass}{Volume} \Rightarrow g\,cm^{-3},\ kg\,m^{-3},\ lbm/ft^3$ Property of substance

Concentration : $\frac{Mass}{Volume} \Rightarrow$ " " " " " mixture

dictionary

Specific gravity = $\frac{\text{density of substance}}{\text{density of reference substance}}$ (water at 4°c)

$ppm = 10^6$
$ppb = 10^9$

$$10\,ppm = \frac{10\,mole\ of\ HCN}{\underset{\swarrow\ \downarrow}{10^6\,mol\,of\,air} + \underbrace{10\,mole\ HCN}_{negligible}} = \frac{10 \times 27 \times 10^{3}\,mg}{10^6 \times 29 \times 10^{-3}\,kg}$$

79% N_2 21% O_2
≈ 29

$= 9.32\ mg/kg$
↓
Not Lethal

Temperature

Kelvin scale
Rankine scale } Absolute scale

$$\frac{T_1 - MP_1}{BP_1 - MP_1} = \frac{T_2 - MP_2}{BP_2 - MP_2}$$

	K	°C	°F	Rankine scale
BP	373	100	212	672
MP	273	0	32	492
Absolute zero	0	-273.15	-460	0

$$\Rightarrow \frac{C}{100} = \frac{F-32}{180} = \frac{T-273}{100} = \frac{R-492}{180} \Rightarrow 1\Delta °C = 1.8 \Delta °F$$

(Q) denominator

$\Rightarrow$ At 32°F $\quad$ 117 Btu/hr ft^2 (°F/ft)

? Btu / hr ft^2 (K/ft) $\Rightarrow$ 1.8 × 117 BTU / hr ft^2 (K/ft)

~~$\frac{K-273}{100} = \frac{5}{9}\frac{F-32}{180}$~~

~~$\frac{9}{5}(K-273) + 32 = F \rightarrow \frac{1}{117} = 32$~~

~~$K = 255.226$~~

~~117~~ ~~$= \frac{117}{K}$~~

~~$\frac{117}{\frac{9}{5}(K-273)+}$~~ ~~$= \frac{117}{1}$~~

Heavy Knowledge gained

1) Limiting Reagent (Reactant)
2) Excess Reactant / Percent excess
3) % conversion
4) Selectivity
5) yield

1) $\textcircled{A} + 3B + 2C \rightarrow \textcircled{P} + Q$ $\quad \frac{B}{A} = 3 \quad \frac{C}{A} = 2$

1.1 mole of A
3.2 mole of B
2.4 mole of B

$\frac{3.2}{1.1} = 2.9$ Less than 3, B limiting b/w B & A

$\frac{2.4}{1.1} = 2.18$ A limiting b/w C & A $\Rightarrow$ B Limiting

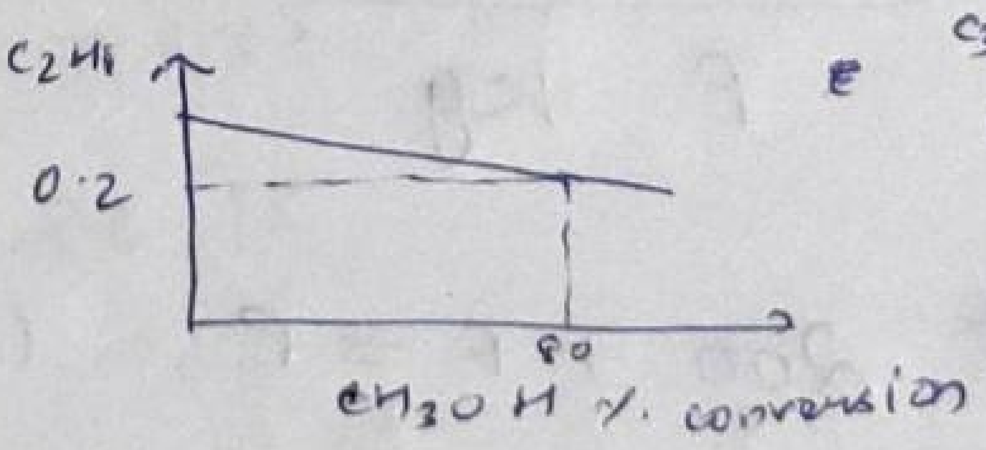
$\Rightarrow \frac{1}{3} \times 3.2 = 1.066$ of A required to complete use B

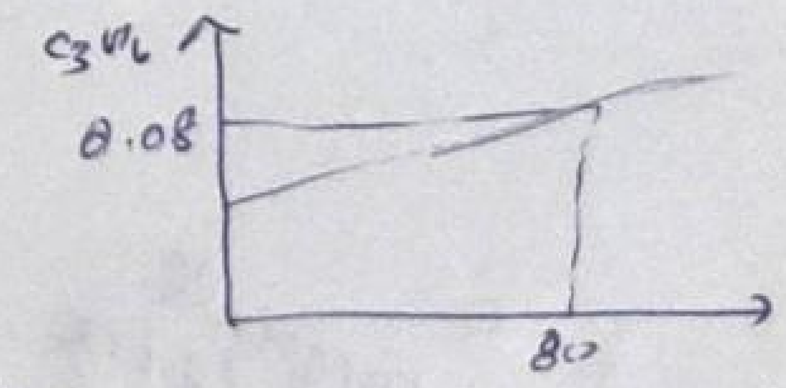
2) % excess of A $= \frac{1.1 - 1.066}{1.066} \times 100$

3) main objective of rxn A to P (key Reactant, key Product)
max P that can be formed is 1.066 $\Rightarrow$ 100% conversion
suppose 0.9 mole of A to P
% conversion $= \frac{0.9}{1.1} \times 100$
or 1.066 depending on ques

4) What is the selectivity of C_2H_4 over C_3H_6 for 80% conversion of CH_3OH

$CH_3OH \rightarrow C_2H_4$
$CH_3OH \rightarrow C_3H_6$





selectivity $= \frac{0.2}{0.08} = 2.5$
↳ 2.5 times C_2H_4 made over C_3H_6

5) Yield $= \frac{\text{kg(mole) of key product formed}}{\text{kg (mole) of key reactant used}}$

(Q)
1.27)

Excess A, Limiting B

$Sb_2S_3 + 3Fe \rightarrow 2Sb + 3FeS$ $\quad \frac{B}{A}$ should be $= 3$

600g $\quad$ 250g $\quad$ 200g

$Sb_2S_3 = \frac{600}{240} = 1.76$

$Fe = \frac{240}{56} = 4.46$

$2Sb = \frac{200}{122} = 1.64$

$\frac{B}{A} = 2.53 = \left(\frac{4.46}{1.76}\right)$

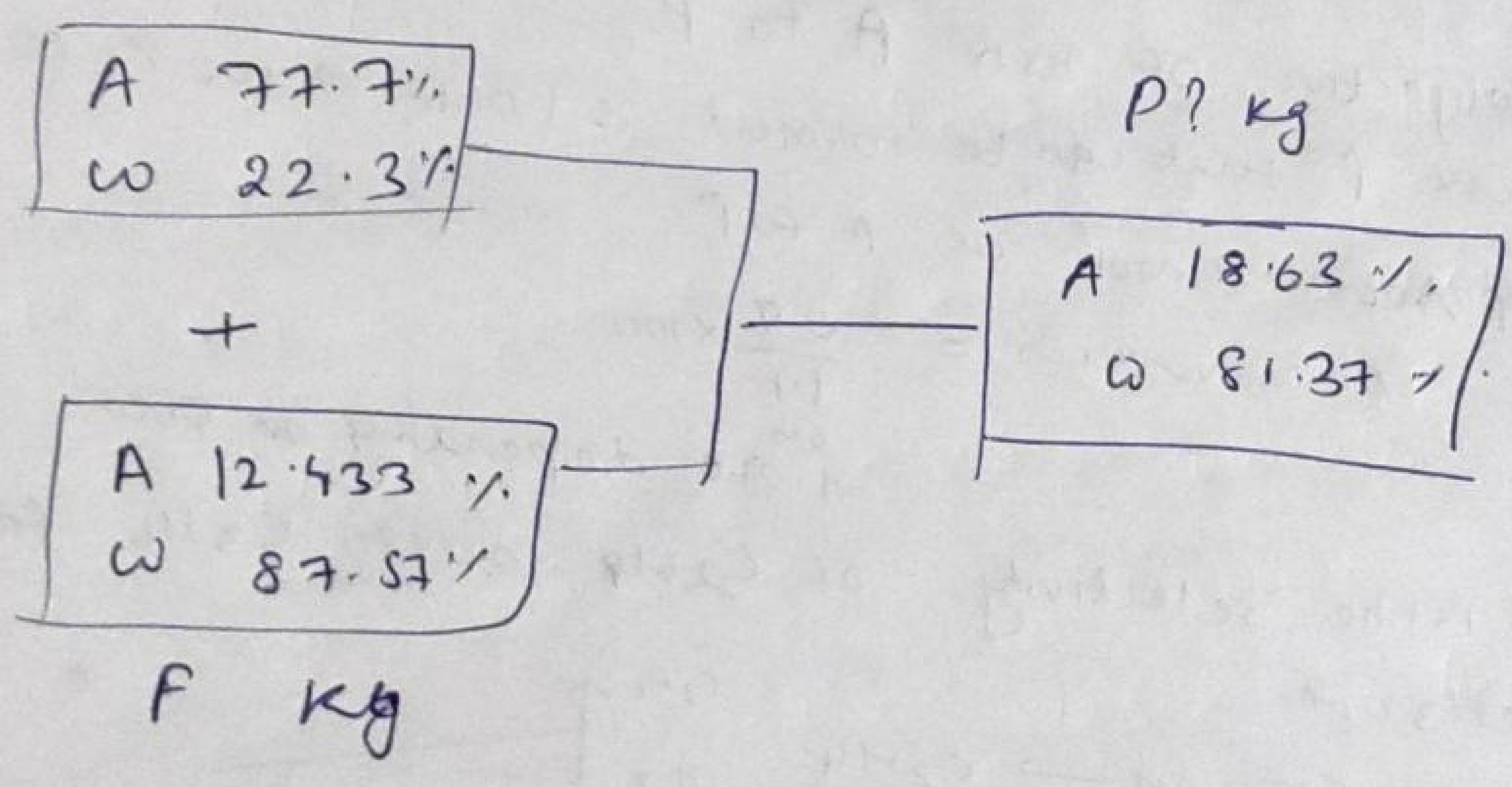
$B = \underline{\text{limiting}}$

$\frac{1}{3} \times 4.46$ mole A required $= 1.486$

% excess $= \frac{1.76 - 1.48}{1.48} \times 100 = 18.46\ \%$

Q)
3.7

$A = 200\,kg$



Overall Balance $\quad 200 + F = P \quad$ (wgt) ①

Acid balance $\quad 0.777 \times 200 + 0.12433F = 0.1863P$ — ②

water balance $\quad 0.2231 \times 200 + 0.8757F = 0.8137P$ — ③
used to verify

Q3.9)

T	Saturation
0	7
10	12.5
20	21.5
30	38.8 → $\frac{38.8 g}{100 g\ H_2O}$

Mass fraction $Na_2CO_3 = \frac{38.8}{138.8} = 0.28$ (A)

3000 kg crystal $\underbrace{Na_2CO_3}_{106} \cdot \underbrace{10H_2O}_{180}$ (B)

$106 + 180 = 286 g$

Mass fraction of Na_2CO_3 in crystal $= \frac{106}{286} = 0.37$

7000 kg (C)

Na_2CO_3 conserved

$10000 \times 0.28 = 3000 \times 0.37 + 7000 \times x$

$x = 0.2414$

~~solubility 24.14%~~

10	12.5	0.111
20	21.5	0.176
30	38.8	0.28

$\therefore T \in (20, 30)$

$T - 20 = \frac{30-20}{0.28-0.176}(0.24 - 0.176)$

$T - 20 = 6.15$

$T = 26.15$

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Q3.10)

20 kg C_3H_8 $\frac{20}{44}$ kg mole

400 kg air $\frac{400}{29}$ mole air $= \frac{400}{29} \times 0.21$ Kmole O_2

$= 2.89$ kg mole O_2

44 kg CO_2 $\frac{44}{44}$ kg mole

$C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O$

2.27 kg mole $= \frac{5\times 20}{44}$ kg mole O_2 required for complete compustion

excess air $= \frac{2.89 - 2.27}{2.27} \times 100$

Q3.11)

$\frac{8,330000 \text{ lbm of water}}{18} = 462,777.77$ lb mole water

$\cancel{2}\, Na_2SO_3 + \frac{1}{2}O_2 \rightarrow Na_2SO_4$

10 PPm $= \frac{10 \text{ mole } O_2}{10^6 \text{ mole water}}$

O_2 present $\frac{10}{10^6} \times 462,777.77$

O_2 present $= 4.627777$ lbM mole

Na_2SO_3 required $= 2 \times O_2 = 9.26$ lbM mole

Na_2SO_3 excess required $=$ 1.35 X 9.26 lb mole

$= 1.35 \times 126 \times 9.26$ lbm

3.13

Fg

CO_2 13.4
O_2 3.6
N_2 83
} mole %

86% C } mass
12% H_2

→ Liquid solid %. If not stated = mass %.

→ gas % = mole %.