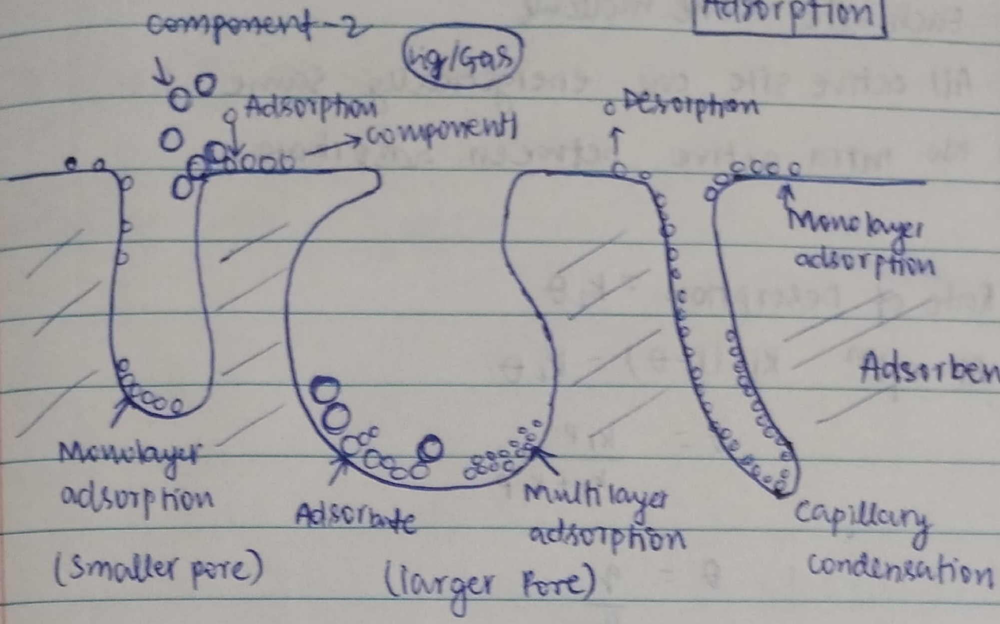
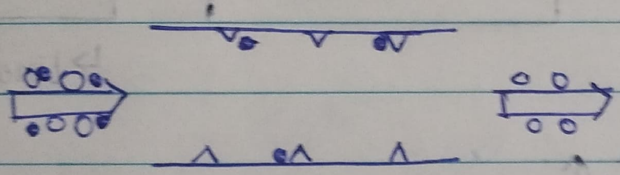
Mass Transfer-II

$\boxed{\text{Adsorption}}$



Model Selection

- ~~Molecular~~ Separation of components (Liq/Gas)



P = partial pressure of two adsorbate

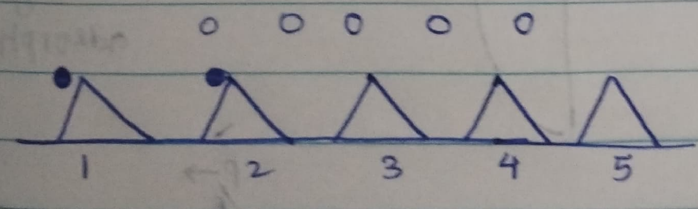
θ = Fraction of covered area

q = amt of gas/liq adsorbed at equil^m per gram of adsorbate

q_m = max qty of gas/liq adsorbed per gram of adsorbate

Rate of Adsorption = $k_1 P(1-\theta)$

1.



$\theta = 2/5$

1) Molecules adsorption on discrete active site
2) Each site → one molecule
3) All active site are energetically same
4) No intra active between adsorbate

Rate of Desorption $= k_2\theta$

At eq^{1m} $k_1P(1-\theta) = k_2\theta$

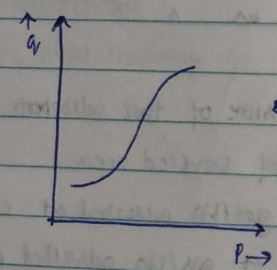
$$\theta = \frac{k_1P}{k_2 + k_1P}$$

$$\theta = \frac{q}{q_m}$$

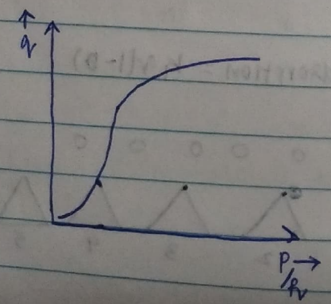
$$\theta = \frac{k_1P}{k_2+k_1P} = \frac{q}{q_m}$$

Langmuir Isotherm $\boxed{q = \dfrac{q_m k_1 P}{k_2 + k_1 P}}$ $\Rightarrow$ $\boxed{\dfrac{P}{q} = \dfrac{1}{q_m k} + \dfrac{P}{q_m}}$

↳ Linear Regression



← depends on adsorbent



Multilayered adsorption

freundlich Isotherm

$$q = \frac{q_m KP}{1 + KP}$$

$q = K'P^{1/n}$ (emperical)

$\log q = \log K' + \frac{1}{n}\log P$

$m = \frac{1}{q_m}$

$c = \frac{1}{q_m K}$

$K = \frac{1}{q_m} \times C$

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$$q = \frac{q_m c' X}{(1-X)[1+(c'-1)X]}$$

q = quantity adsorbed

$X = P/P_v$

P_v = vapour pressure

c' = const

q_m = quantity of gas to be adsorbed to form monolayer in surface gram / gram adsorbed

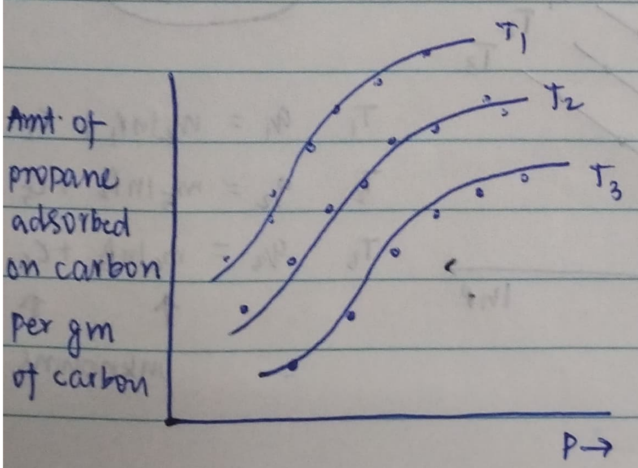
$$(1-P/P_v)[1+(c'-1)P/P_v] = \frac{q_m c' P/P_v}{q}$$

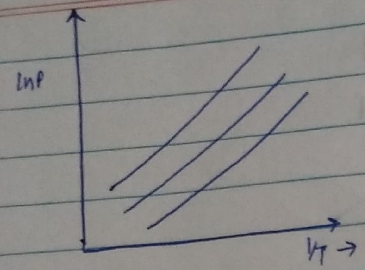
$$\frac{P_v - P}{P} + \frac{P_v - P}{P_v}(c'-1)\frac{P}{P_v} = \frac{q_m c' P/P_v}{q}$$

$$\frac{1}{c' q_m} + \frac{(c'-1)P}{P_v q_m c'} = \frac{P}{q(P_v - P)}$$

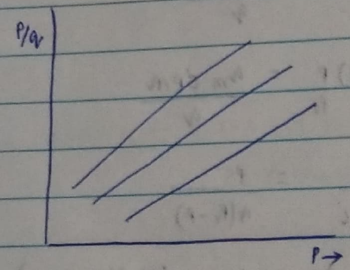
$$\frac{P}{q(P_v-P)} = \left(\frac{c'-1}{P_v q_m c'}\right)P + \frac{1}{c' q_m} \quad \text{(st line form)}$$

Heat of Adsorption $(\Delta H)_{ads}\big|_{iso}$





$$(\Delta H)_{iso} = \frac{P\,d\ln(P)}{d(1/T)}$$

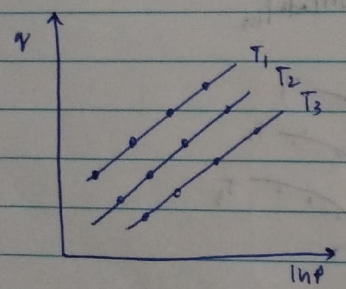


$$q = \frac{q_m KP}{1+KP} \quad — (1)$$

			P	q_m	lnP
T_1	$Y_1 = m_1 x_1 + c_1$	→	-	-	-
T_2	$Y_2 = m_2 x_2 + c_2$	→	-	-	-
T_3	$Y_3 = m_3 x_3 + c_3$	→	-	-	-

↑ ↑ unknowns

Use m_i, c_i to calculate q as a func of P at each temp



Use eq (1)

T_1 $q_1 = m_4 \ln P_1 + c_4$

T_2 $q_2 = m_5 \ln P_2 + c_5$

T_3 $q_3 = m_6 \ln P_3 + c_6$

↑ ↑ unknowns

	(m_4, c_4)	(m_5, c_5)	(m_6, c_6)
q=1.5	$\ln P_1$	$\ln P_1$	$\ln P_1$
q=2.5	$\ln P_2$	$\ln P_2$	$\ln P_2$
q=3.5	$\ln P_3$	$\ln P_3$	$\ln P_3$

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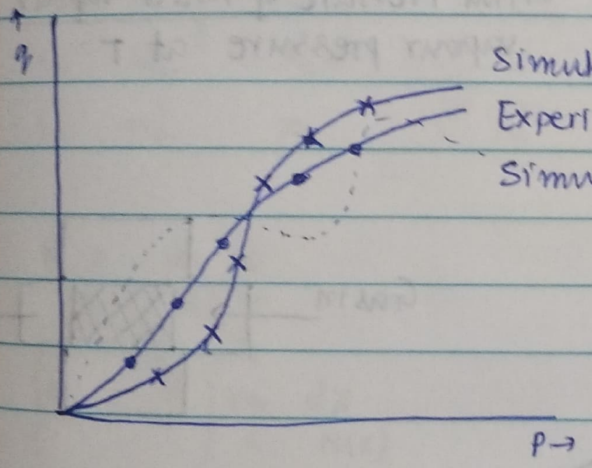
Model Comparision

1. $q = \dfrac{q_m K P}{1 + K P}$ (Langmuir Isotherm)

2. $q = K P^{1/n}$ (Freundlich's Isotherm)

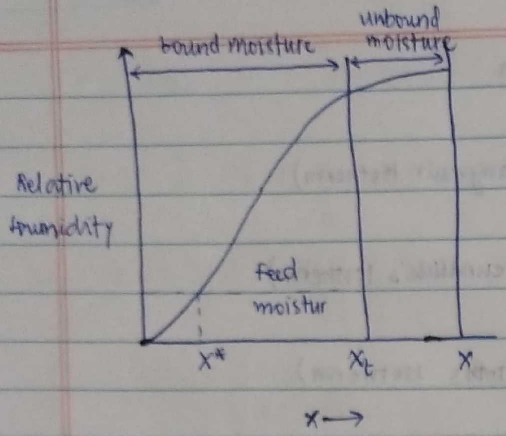
3. $q = \dfrac{q_m P}{(b + P^n)^{1/n}}$ (Toth's Isotherm)

4. $q = \dfrac{q_m (K'' P)^{1/n}}{1 + (K'' P)^{1/n}}$ (Sip's Isotherm)



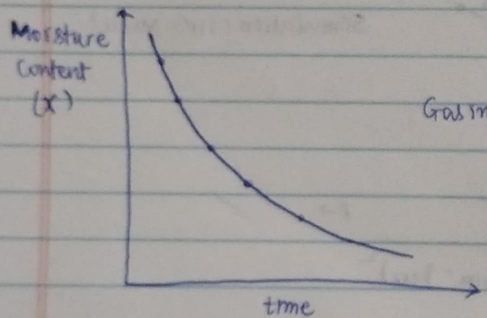
$$RMSE = \sqrt{\sum_{i=1}^{n} (q_{sim} - q_{exp})^2}$$

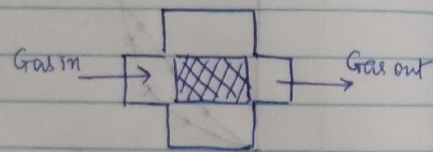
$$\text{Correlation coeff} = \frac{\sum_{i=1}^{n} (X - X_i)(Y - Y_i)}{\sum_{i=1}^{n} (X - X_i)^2 \sum_{i=1}^{n} (Y - Y_i)^2}$$



kg moisture / kg dry solid

Relative Humidy : $\dfrac{\text{Partial Pressure of water vapour}}{\text{vapour pressure at } T}$



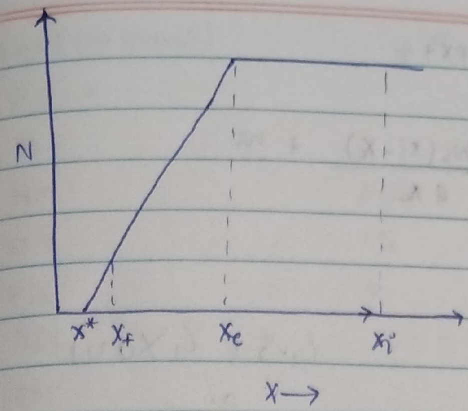


W_s = mass of solid

a = drying ~~rate~~ area

X = moistue content at time t

Drying Rate: $N = -\dfrac{W_s}{a}\dfrac{dX}{dt}$



Time	W	$X = W - W_s$	$X' = X_{i+1} - X_i / t_{i+1} - t_i$	$N_i = -\frac{W_s}{a} X_i'$
t_1	W_1	X_1	X_1'	
t_2	W_2	X_2	X_2'	
t_3	W_3	X_3	X_3'	

$$N = -\frac{W_s}{a}\frac{dX}{dt}$$

$$\int_0^t dt = -\int_{X_i}^{X_f} \frac{W_s}{a}\frac{dX}{N(X)}$$

$$t = -\frac{W_s}{a}\int_{X_f}^{X_c}\frac{dX}{N(X)} - \frac{W_s}{a}\int_{X_c}^{X_i}\frac{dX}{N(X)}$$

$$t = \underbrace{\frac{W_s}{a}\int_{X_c}^{X_f}\frac{dX}{N(X)}}_{\text{falling rate}} + \underbrace{\frac{W_s}{a}\int_{X_i}^{X_c}\frac{dX}{N(X)}}_{\text{const rate}}$$

$\frac{1}{N}$ vs X

*Trapizoidal Rule

2.6+

Suppose, $N = px + q$

$$t = \frac{w_s(x_i - x_c)}{a\, x_c} + w_s$$

$4.5 + 4 \times 00)$

$0.$

$2.5+$

23

weight (in grams)

81.5

88.0

56.0 0.5

62.5 1.5

87.5 3

86.5

87.5

90.0

62.0

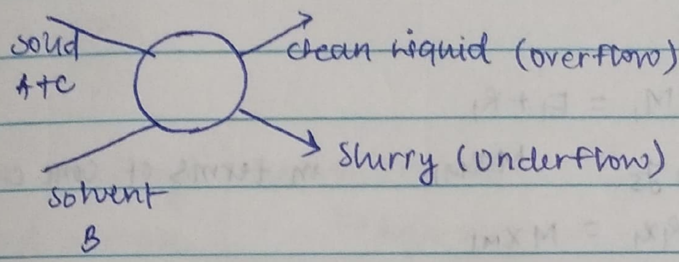
65.5

63.5

Solid Liquid Equilibrium Data

Overflow			Underflow		
W_A	W_B	W_C	W_A'	W_B'	W_C'
0.3	99.7	0.0	67.2	32.8	0.0
0.45	90.6	8.95	67.1	29.94	2.96

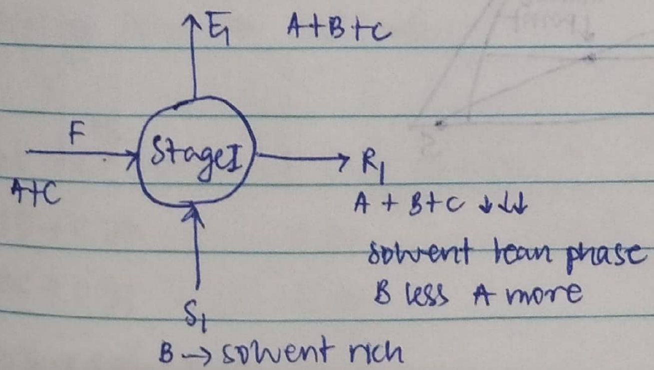
A → Solid
B → Solvent
C → Solute

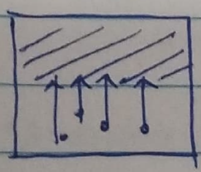


Liquid-Liquid Equilibrium Data

% Acetic Acid	% water	Isopropyl ethane

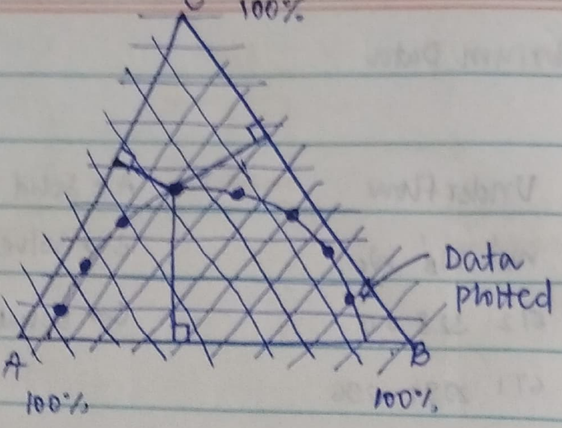
A → pure component (Liq)
B → pure component (solvent liq)
C → distributed solid





x = wt fraction of C in solvent lean (A rich) or raffinate liq

y = wt fraction of C in the solved rich (B rich) or extract liq



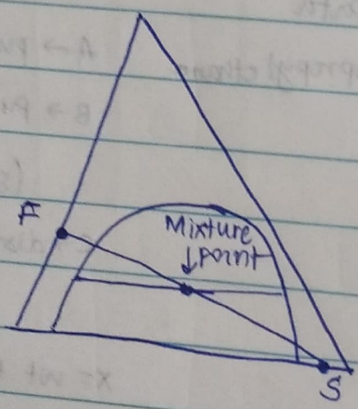
$F + S_1 = M_1 = E_1 + R_1$

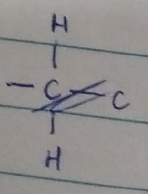
$F x_F + S_1 y_S = M x_{M1}$ in terms of conc c

$E_1 y_1 + R_1 x_1 = M x_{M1}$

$\uparrow\ \uparrow \quad \uparrow\ \uparrow$

4 unknowns

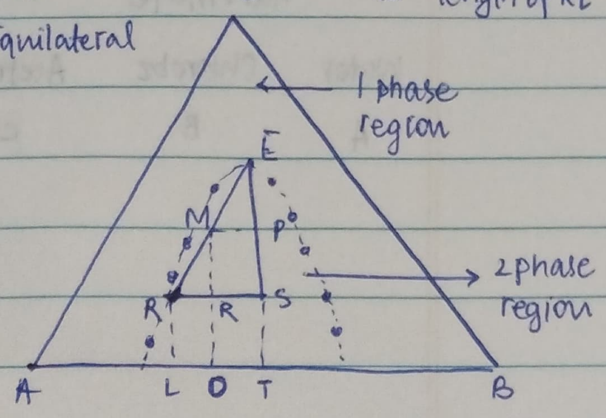




LLE

Equilateral

RL - length of RL



Component balance for solute

$F + S = M = R + E$

$\hookrightarrow$ $R x_{e,s} + E y_{e,E} = M x_{e,M}$

$R(RL) + E(ET) = M(MO)$

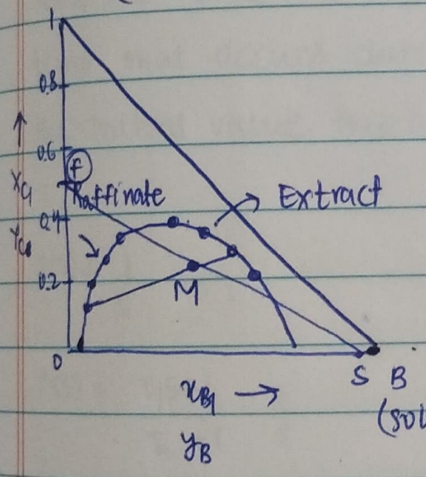
$\frac{R}{E}(RL) + (ET) = \frac{M}{E}(MO)$

$\frac{R}{E}(RL) + (ET) = \frac{R+E}{E}(MO)$

$\frac{R}{E}(RL - MO) = MO - ET$

$\frac{R}{E} = \frac{ET - MO}{MO - RL} = \frac{EP}{PS} = \frac{EM}{RM}$

Right Angle coordinate sys

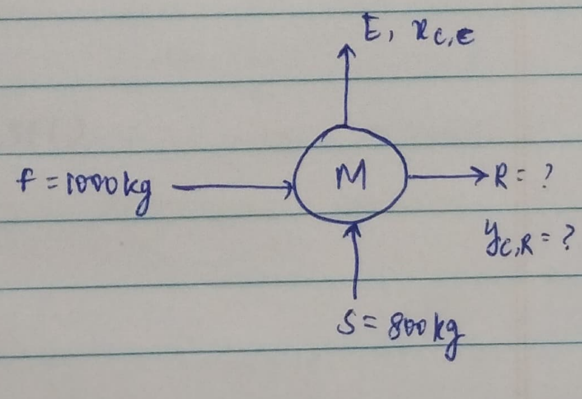


$F = 1000 kg$, $x_F = 0.5$

$S = 800 kg$

$y_{c,s} = 0.005$

$x_B = 1 - 0.005$



$E + R = F + S = M$

$E y_{c,E} + R x_{c,R} =$

$F x_{c,A} + S x_{c,s}$

$F + S = M$

$F x_F + S x_{c,s} = M x_{c,M}$

$x_{cM} = \frac{F x_F + S x_{c,s}}{F + S}$

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Raffinate			Extract		
Water	Chlorobz	Acetone	Water	Chlorobz	Acetone
A	B	C	A	B	C

$y(t) = A[t - \tau + \tau e^{-t/\tau}]$

$y(t) - y(0) = A[t - \tau + \tau e^{-t/\tau}]$

$y(0.1) = 1[0.1 - 0.2 + 0.2e^{-0.1/0.2}]$

$= 0.0213$

$x(t) - y(t) = 0.1 - 0.0213$

② $\dfrac{Y(s)}{X(s)} = \dfrac{\tau_1 s+1}{\tau_2 s+1}$

$x(t) = u(t)$

$\dfrac{\tau_1}{\tau_2} = 5$

Show the numerical values of the min, max & ultimate temp. that occurs during the transfer. Check it using the initial value theorem and final value theorem.

$X(s) = \dfrac{1}{s}$

$Y(s) = \dfrac{\tau_1 s+1}{\tau_2 s+1} \cdot \dfrac{1}{s}$

$\dfrac{\tau_1 s+1}{(\tau_2 s+1)s} = \dfrac{A}{\tau_2 s+1} + \dfrac{B}{s}$

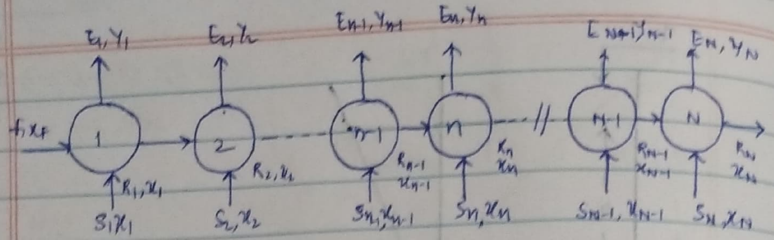
$\tau_1 s+1 = As + B(\tau_2 s+1)$

$s=0$ $\quad 1 = B$

$s = \dfrac{-1}{\tau_2}$ $\quad -\dfrac{\tau_1}{\tau_2} + 1 = -\dfrac{A}{\tau_2}$

$A = -\tau_2\left(1 - \dfrac{\tau_1}{\tau_2}\right)$

$A = -\tau_2 + \tau_1 = \tau_1 - \tau_2$



System of Eqn:

1) $R_{i-1} + S_i = M_i$ $\Rightarrow$ 2) $E_i + R_i = M_i$

3) $R_{i-1} x_{cR(i-1)} + S_i Y_{cS(i-1)} = M_i x_{Mi}$

4) $R_i x_{cRi-1} + E_i Y_{cEi} = M_i x_{Mi}$

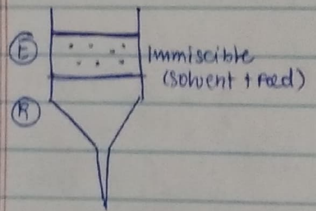
5) $x_{cRi} = a x_{Ri}^3 + b x_{Ri}^2 + \dots + c$

6) x_{cEi} = - - - - - - -

7) $x_{cRi} = M x_{BRi} + c''$

8) Y_{cEi} = - - - -

Insoluble liquids



A kg of substance - present in all raffinate

B kg of solvent - present in all Extract.

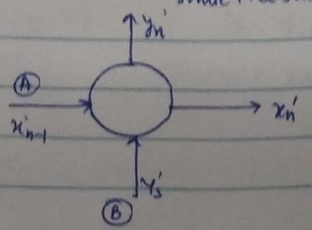
for stage n,

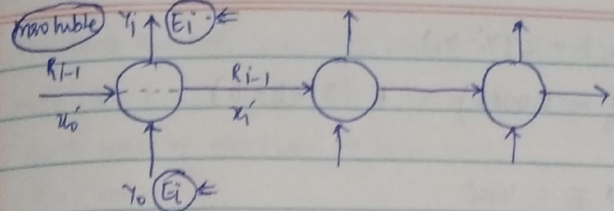
$A x'_{n-1} + B_n y'_n = B_n y'_n + A x'_n$

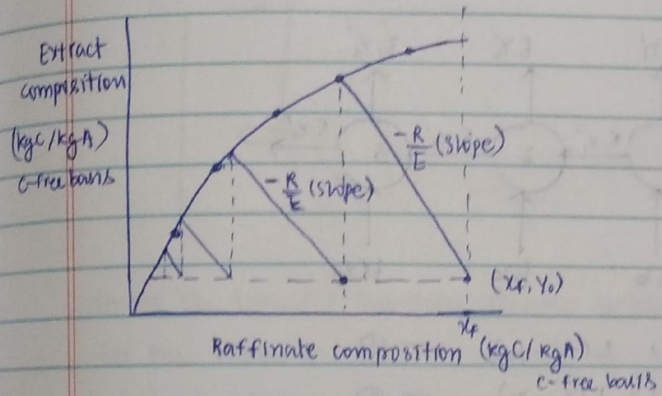
$\therefore \dfrac{A}{B_n} = \dfrac{Y_s - Y'_n}{x_{n'} - x_n}$

for this, $x' = \dfrac{x}{1-x}$ $y' = \dfrac{y}{1-y}$

solute/solute free basis





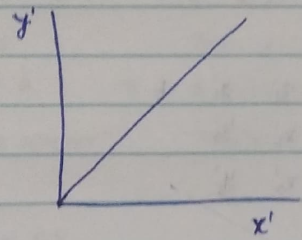


eg $Y' = 3.75 x'$

$\left(\dfrac{\text{Mass solute}}{\text{Mass of solute free solvent}}\right)$

x' = conc C/A

y' = conc C/B



15% solute / 1000 kg F = 1000×0.15 = 150 kg C

Amt of A = $1000 - 150$ = 850 kg

95% solute to be removed = $0.95 \times 150 = 142.5$

$\dfrac{150 \times 0.05}{850} = 0.0088 = x'_1$

$y'_1 = 3.75 x'$

$= 3.75 \times 0.0088 = 0.033$

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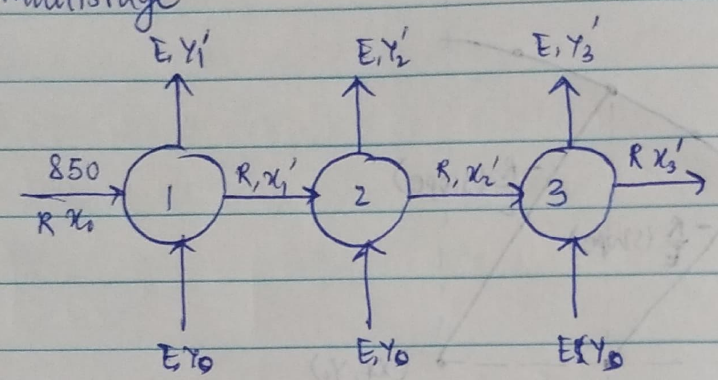
$R(x_0' - x_1') = E(Y_1' - Y_0)$

$$850\left(\frac{150}{850} - 0.0088\right) = E(0.033 - 0)$$

$\Rightarrow E = 4306$

Multistage



①: $R(x_0' - x_1') = E(Y_1' - Y_0)$ — ①

②: $R(x_1' - x_2') = E(Y_2' - Y_0)$ — ②

③: $R(x_2' - x_3') = E(Y_3' - Y_0)$ — ③

x_1' y_1 E

x_2' y_2'

x_3' y_3'

x

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