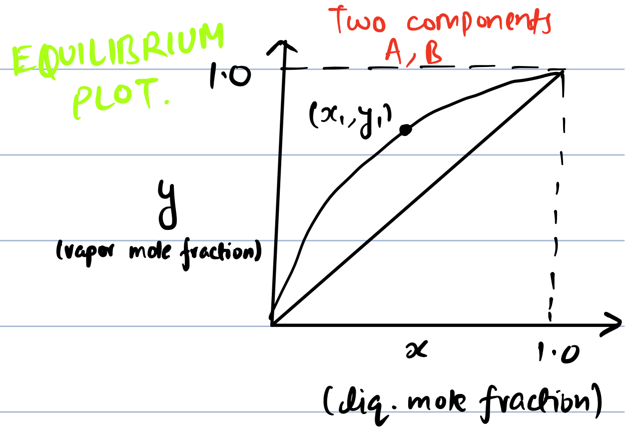
(1.) Extraction (Liquid-liquid extraction)

(2.) Leaching

(3.) Adsorption

Separation of 2 liquids → For liquids that can't be separated by distillation.



Relative volatility (α)

$$= \frac{\text{volatility of the lower boiling (more volatile) comp.}}{\text{volatility of the higher boiling (less volatile) comp.}}$$

$$= \frac{y/x}{(1-y)/(1-x)} = \frac{y}{(1-y)} \times \frac{(1-x)}{x}$$

volatility of a component $= P_A / x_A$

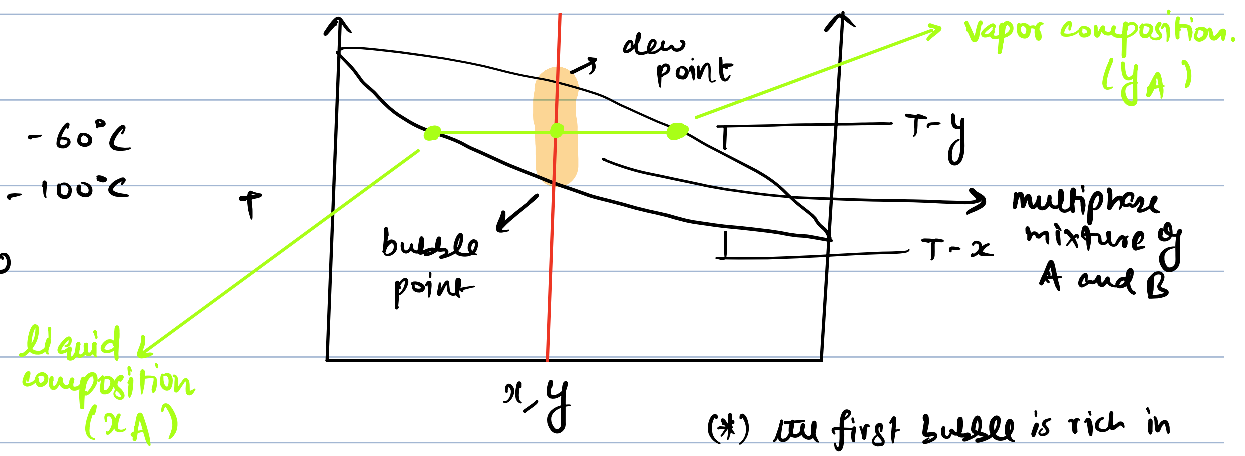
$$= \frac{P_1}{x_1} = \frac{y_1 P_T}{x_1}$$

(*) Eq'n curve is drawn w.r.t the more volatile component.

(*)

A] Liquids - 60°C
B] Miscible - 100°C

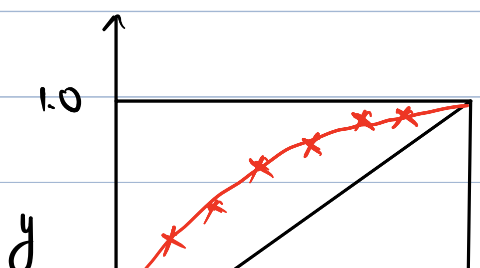
50 : 50



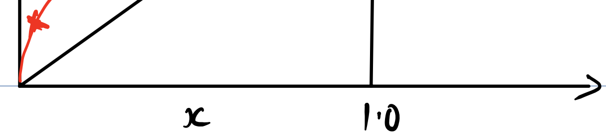
(*) the first bubble is rich in more volatile component, but it is a mixture.

(*) (x_A, y_A) gives us a datapoint on the equilibrium plot.

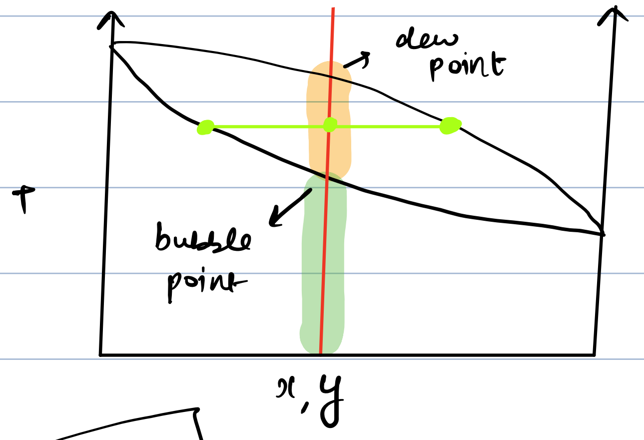
(*)



NOT AN ISOTHERMAL PLOT.



(*)



Liq. mix ⇒ P = 1, C = 2 (Phase Rule)

F = 3

(temp., pressure, composition)

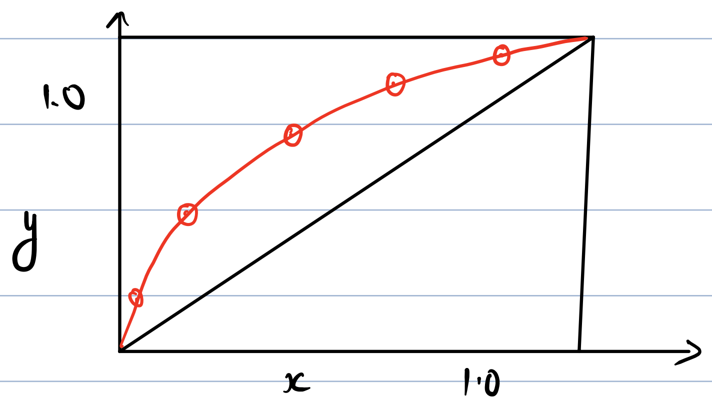
Multiphase mix ⇒ P = 2, C = 2

F = 2

(temp., composition)

Pressure constant.

(*) What is an OPERATING LINE ?



Extraction

Distillation fails when $\alpha \rightarrow 1.0$

Check:-

(ADU, VDU)

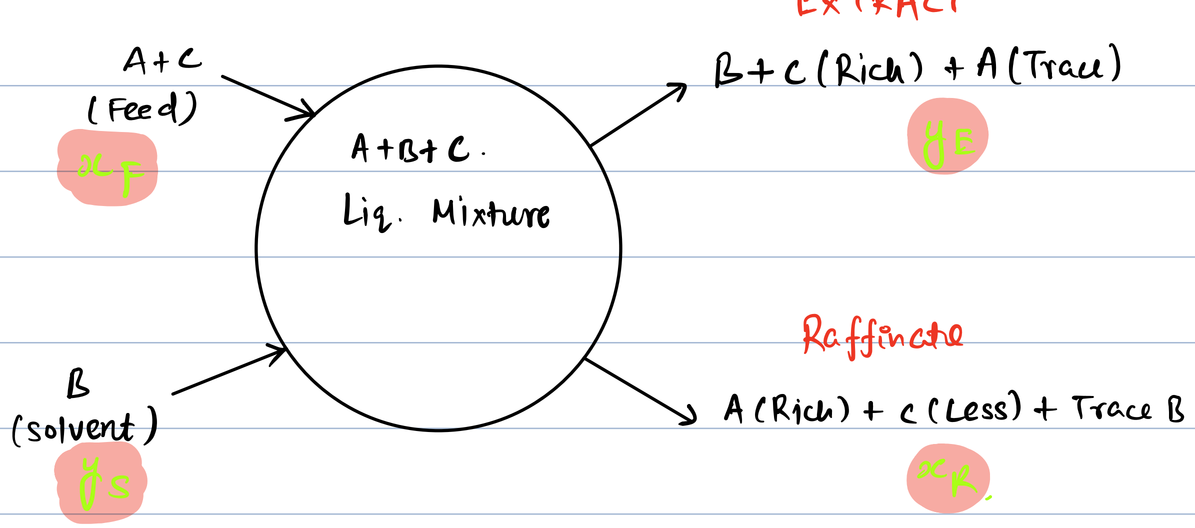
Atmospheric Distillation Unit

Vacuum Distillation Unit

Liq. mixture

A + C ; C = solute (* This is the component you want to separate)

A = carrier



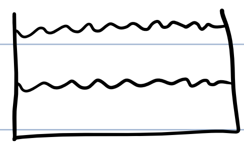
A,C → miscible (C↓)

B,C → miscible (C↑)

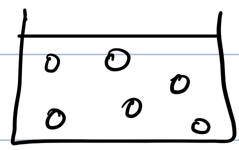
A,B → not miscible

Somehow B,C can be separated.

(*) Two immiscible liquids



A+B
(stratified layer)



A+B
(Emulsification)

Whether A and B form a stratified layer OR emulsification depends on 2 factors:-

(dispersed phase)

① difference in density.

② interfacial tension b/w 2 liquids.

favoured when interfacial tension is HIGH.

favoured when interfacial tension is LOW.

Nomenclature :-

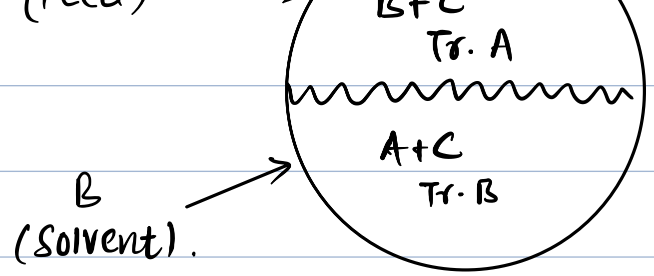
x → fraction of C in the Raffinate.

y → fraction of C in the Extract.

x, y → liquid in the context of extraction.

DOF = 4

(*) After C gets mixed with B the

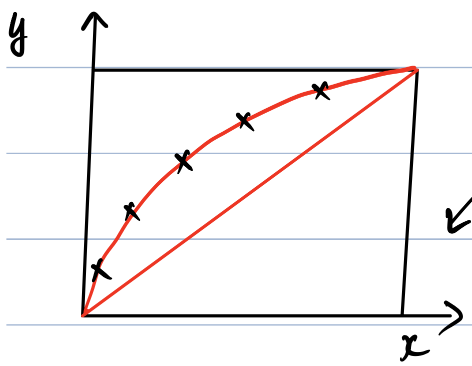


'B-C' mixture should also be immiscible with 'A-C' mixture.

(*) Relative density will decide which mixture is on top.

(*) we can separate using Decantation.

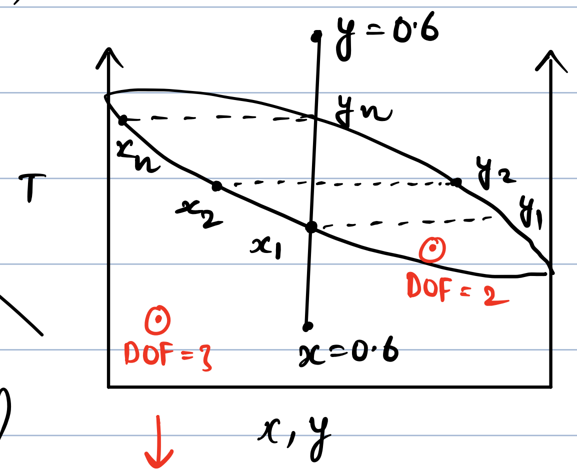
(#) $F = C - P + 2$ (GIBBS PHASE RULE).



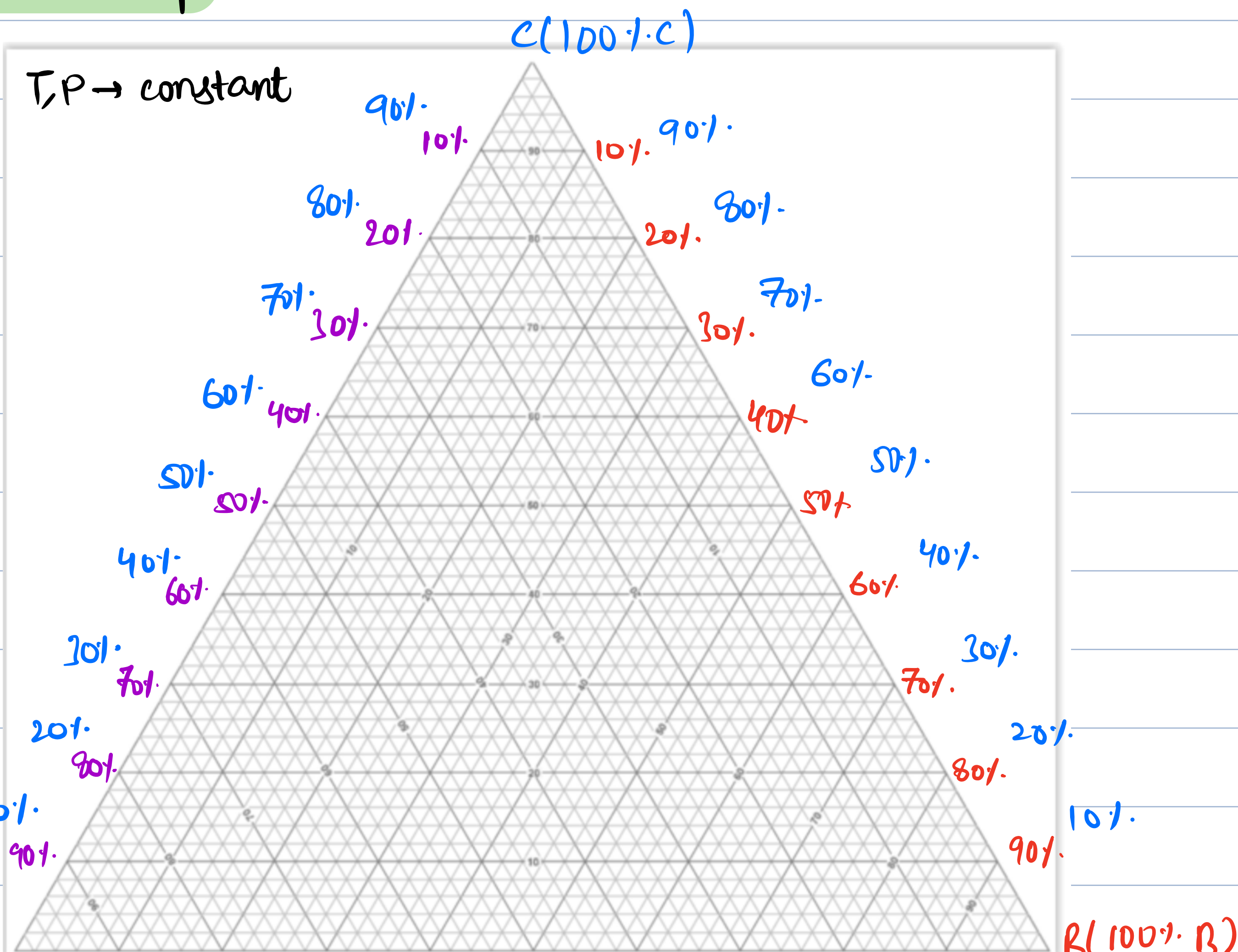
Every (x,y) is at a different temp.

The ends of a tie-line is translated as a single point on the x-y curve.

(All tie-lines are at a different temp.)



This graph is at a Constant Pressure.



A(100% A) 90% 80% 70% 60% 50% 40% 30% 20% 10%
10% 20% 30% 40% 50% 60% 70% 80% 90%

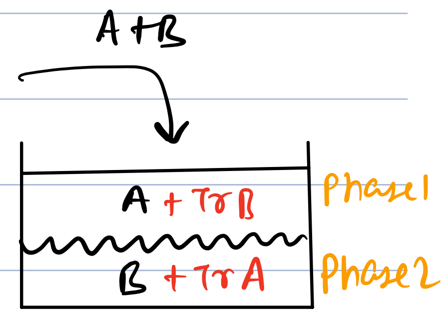
2 Immiscible Liquids :-

Assumption - (completely Immiscible)

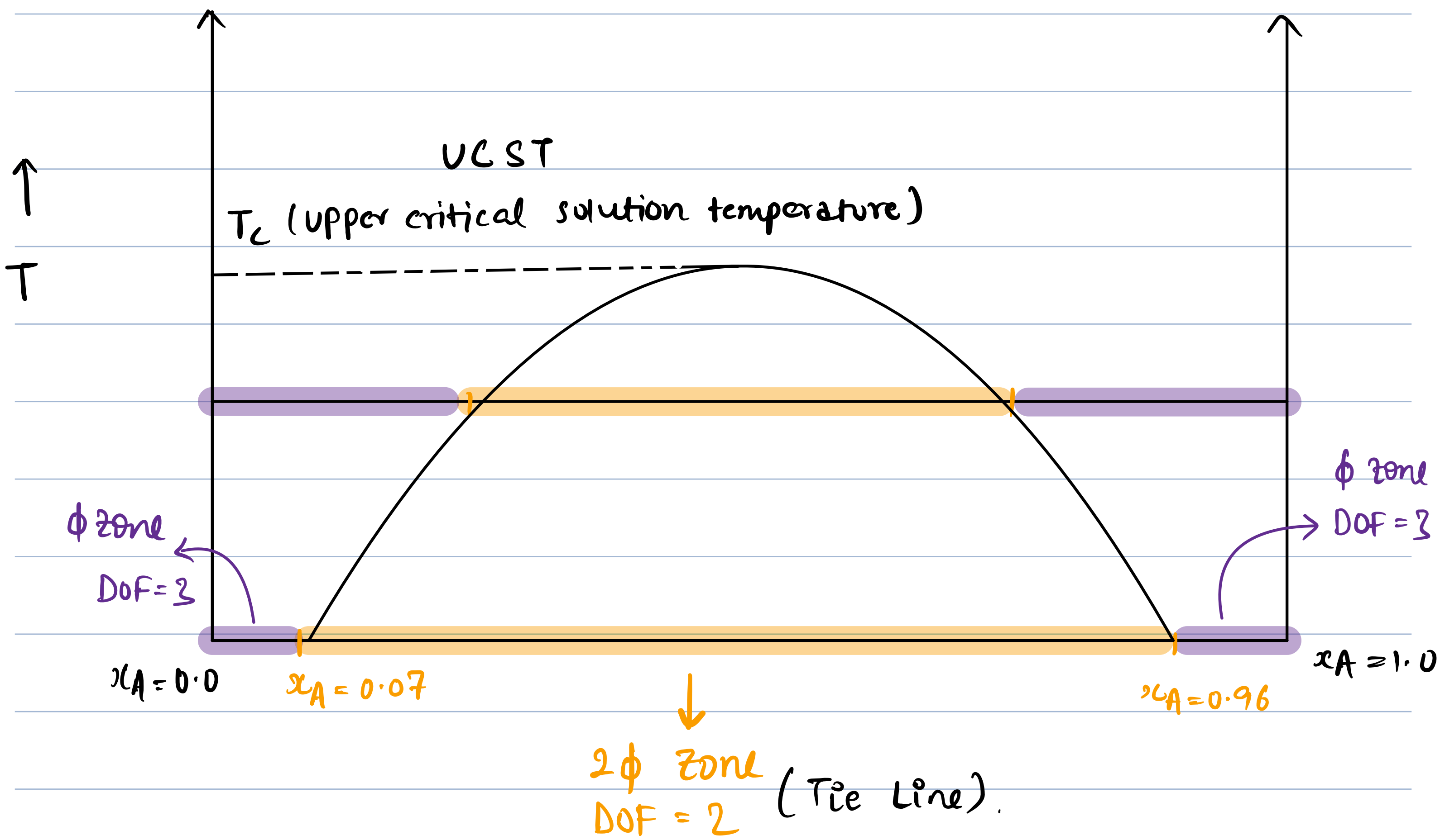
In reality 100% phase separation is impossible.

A x_A , $x_A + x_B = 1.0$

B x_B



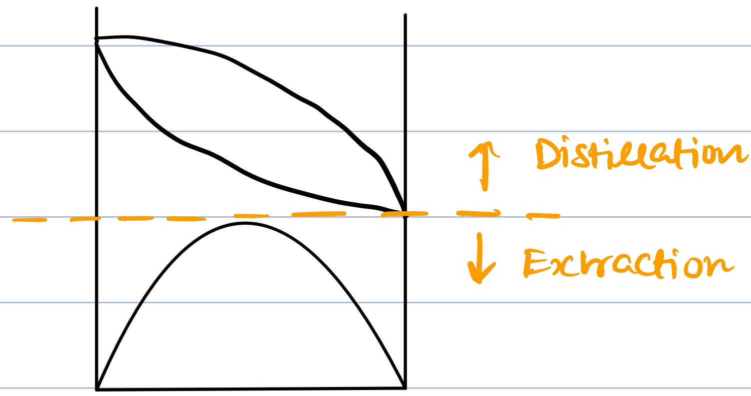
DOF = 2 + 2 - 2 = 2



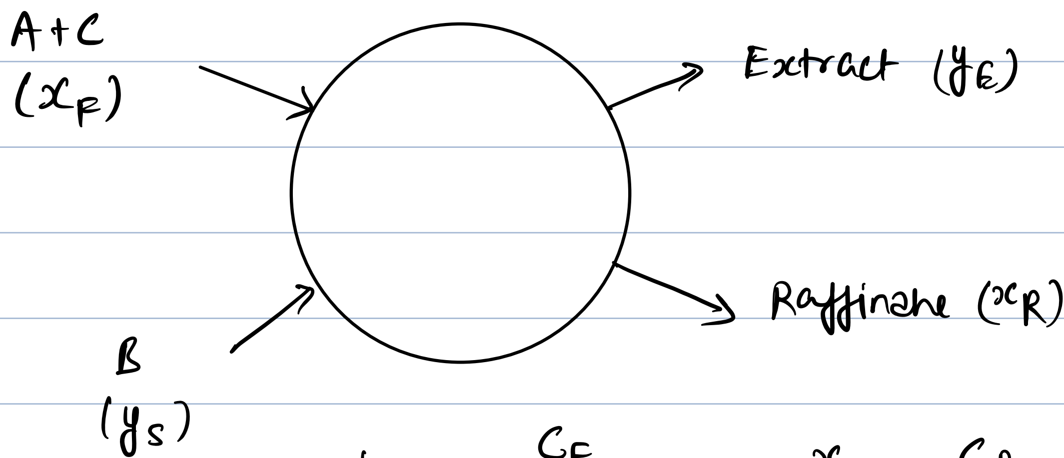
(*) with increase of temperature the region of insolubility decreases.

with T ↓ , relative immiscibility increases.

Complete picture



(*)

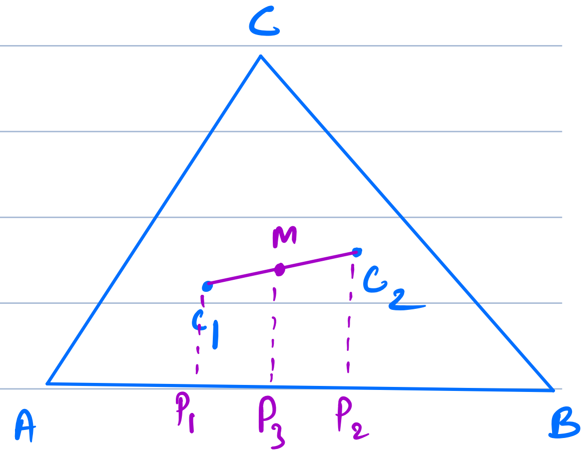


$$y_E = \frac{C_E}{A_E + B_E + C_E}, \quad x_R = \frac{C_R}{A_R + B_R + C_R}$$

y_E, x_R → both fractions of C in Liquid

(#) $C_1 = x_1$, L_1 kg

$C_2 = x_2$, L_2 kg



$$L_1 + L_2 = M$$

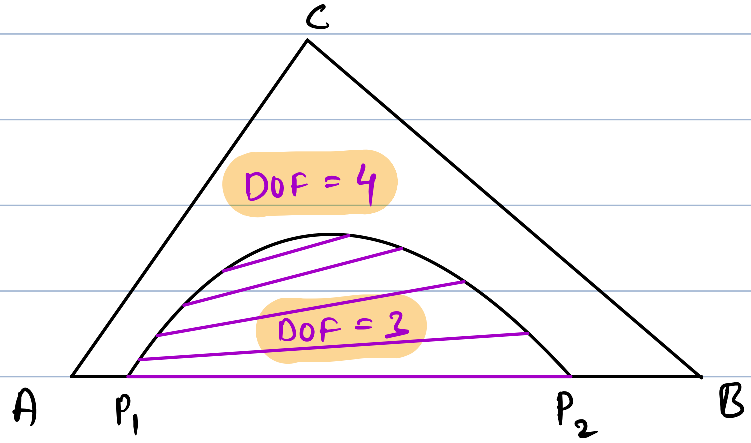
$$L_1 x_1 + L_2 x_2 = M x_M$$

$$\Rightarrow M \cdot \overline{MP_3} = L_1 \overline{C_1P_1} + L_2 \overline{C_2P_2}$$

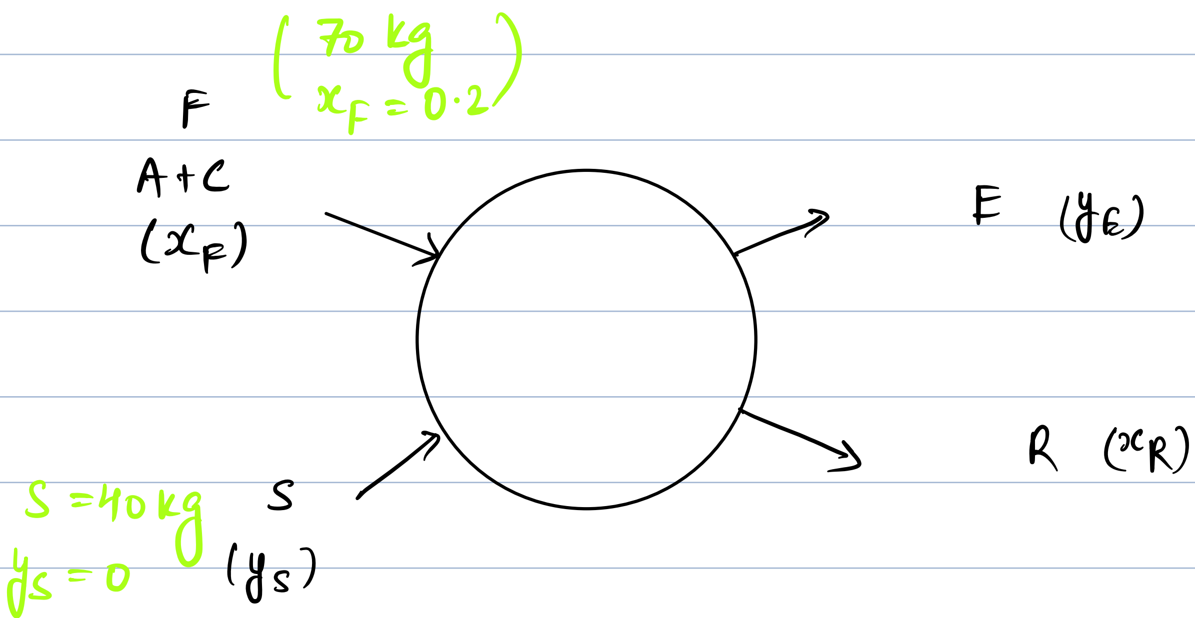
$$\Rightarrow (L_1 + L_2)\, \overline{MP_3} = L_1 \overline{C_1P_1} + L_2 \overline{C_2P_2}$$

$$\frac{L_1}{L_2} = \frac{\overline{MP_3} - \overline{C_2P_2}}{\overline{C_1P_1} - \overline{MP_3}} = \frac{x_2 - x_1}{x_M - x_1}$$

(#)



(#)



$y_E > x_F$ → desired.

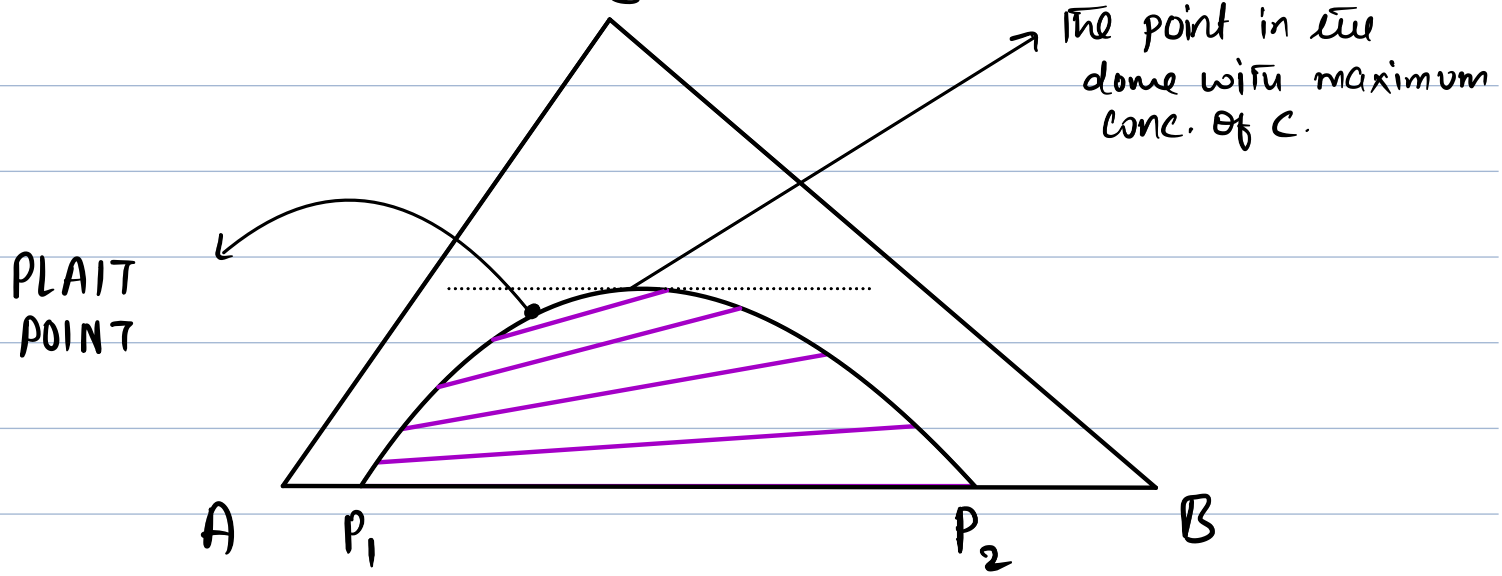
y_s should be ideally zero.

x_R should be ideally zero.

y_E, x_R are in equilibrium.

C

(#)



As $C \uparrow$, region of immiscibility decreases.

(#) $M = F + S = 110$ kg

C Balance:

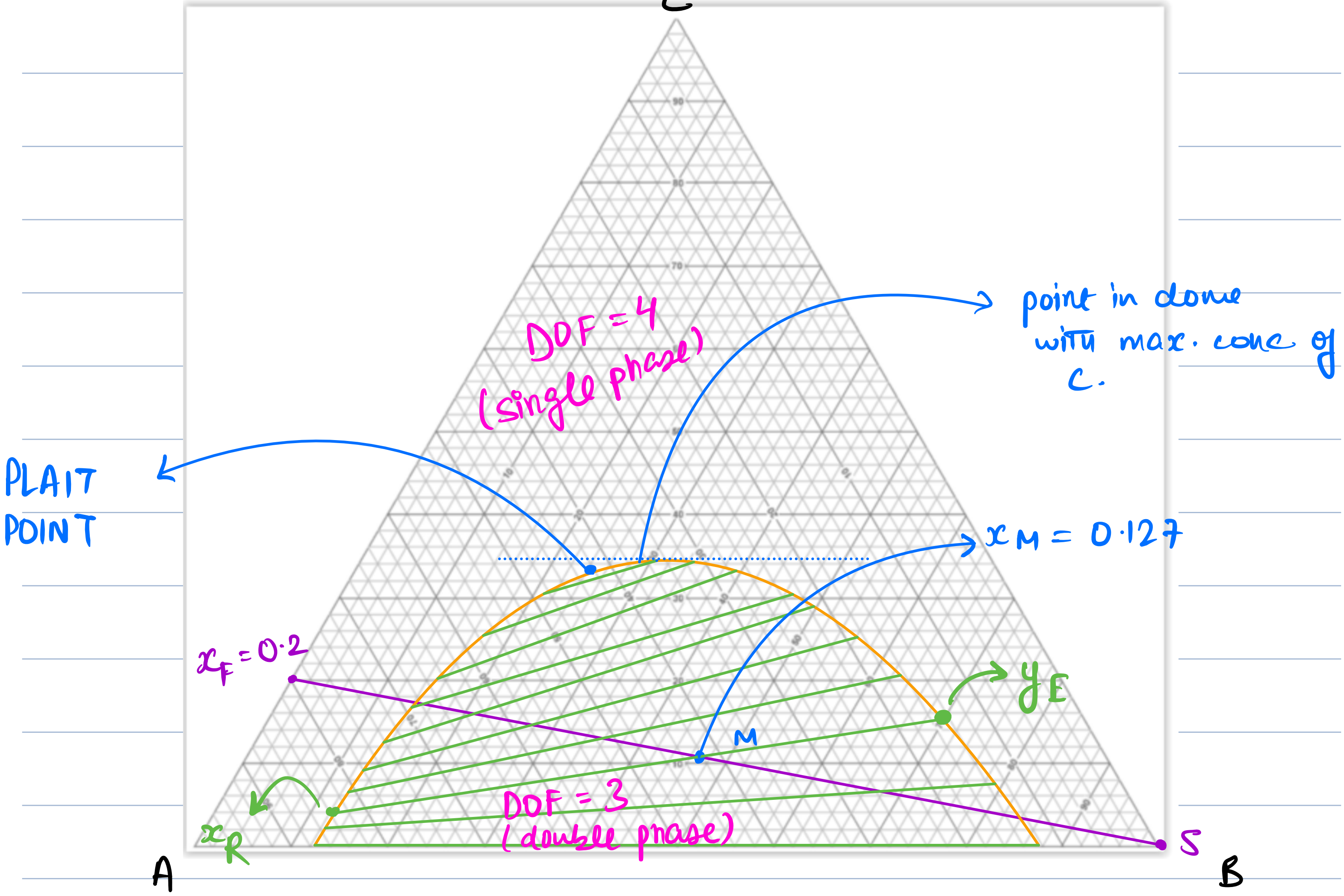
$M x_M = F x_F + S \cancel{y_s}^{\,0} \longrightarrow 70 \times 0.2 = 110\, x_M \Rightarrow x_M = \frac{14}{110}$

$\boxed{x_M = 0.127}$

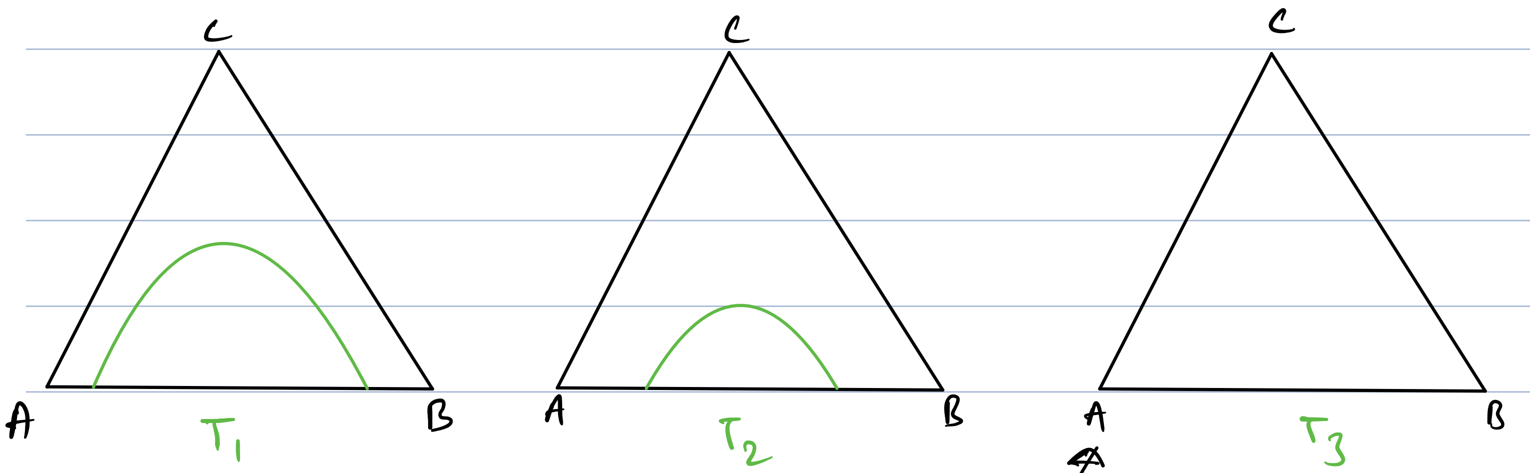
(#) → M is inside the 2 phase region (dome of insolubility).

→ The two ends of the M-containing tieline give the compositions of the two phases (A-rich) and (B-rich) in the 2-phase domain

→ Compositions INSIDE the dome are mathematical, the actual compositions of the two phases are given by the ends of the corresponding tieline.



If T is increased

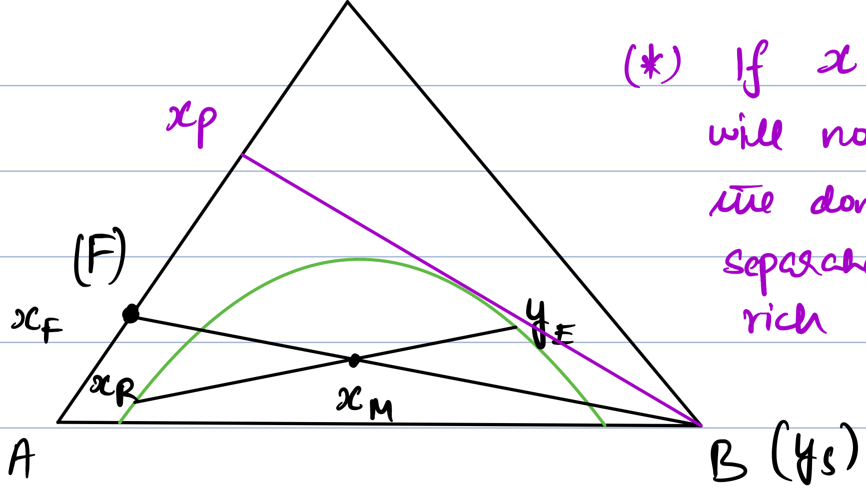


level of imiscibility decrease, A and B become completely miscible.

Conclusion ⇒ Extraction is preferred at lower temperature.

C

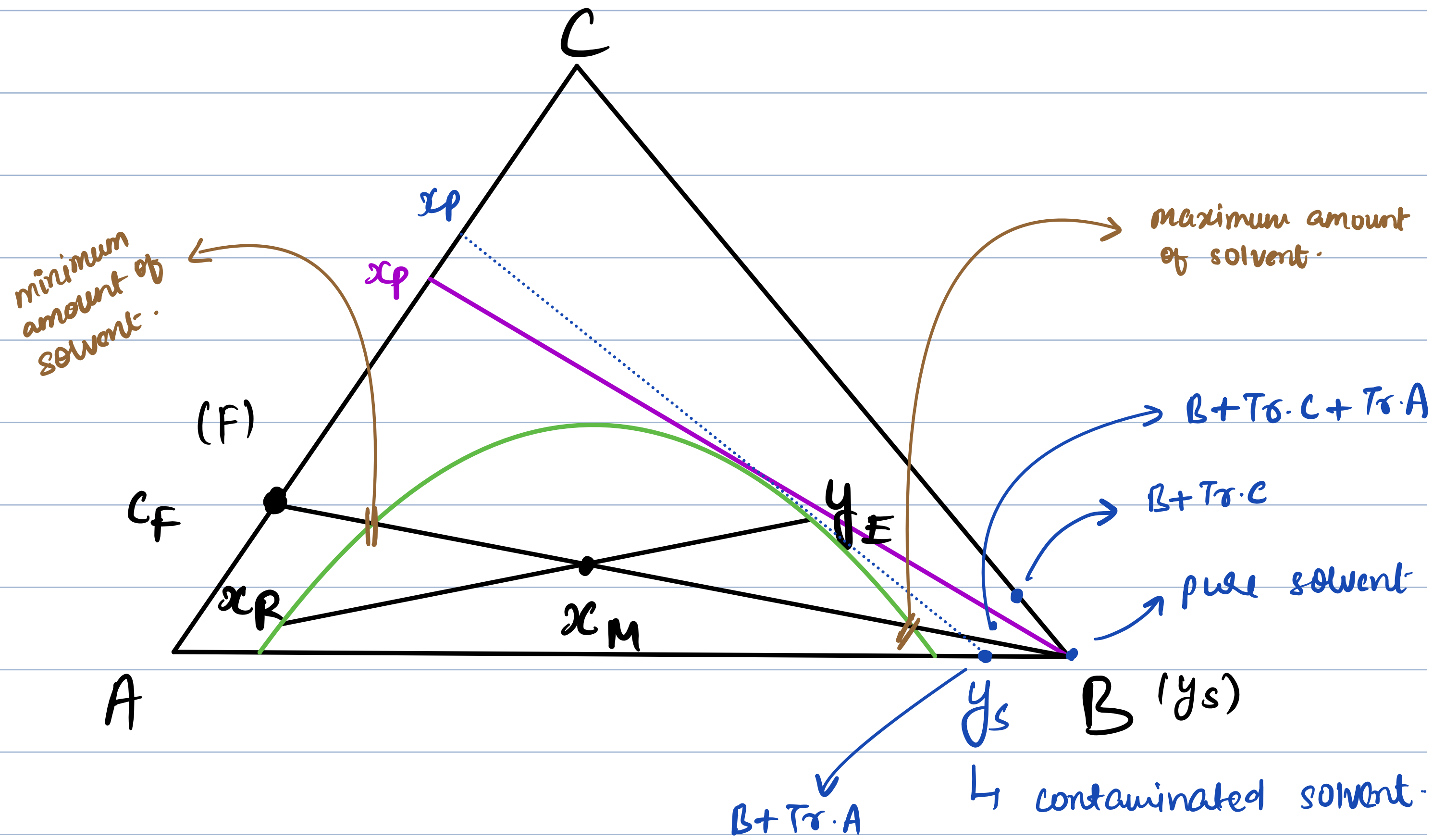
#



(*) If $x_F > x_p$ then x_M will not be obtained inside the dome, and will not separate into A rich and B rich phase.

Therefore $x_F < x_p$, for the mixture to separate into A-rich and B-rich phase.

If $y_s \neq 0$, then



The value of x_p is maximum for B+Tr.A.
The value of x_p is minimum for B+Tr.C.

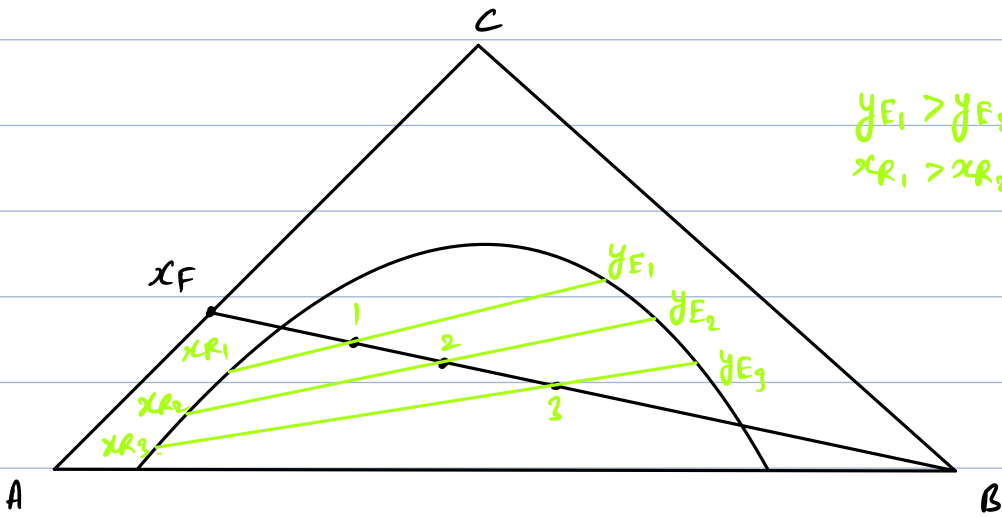
Even if $x_F < x_p$ it is possible that x_M lies outside the dome.

If we take F & S in extreme cases, then this may happen.

(*) By changing the amount (→ flow rate) of S and F x_M will translate along FB line.

(*) If solvent is low in amount then E will also drop. We will get a more pure product but in low quantities.

(#)



$y_{E_1} > y_{E_2} > y_{E_3}$
$x_{R_1} > x_{R_2} > x_{R_3}$

solve using equations.
↓
VERIFY

CHOICE OF SOLVENT

1.) Selectivity

$$\beta = \frac{(\text{wt. fraction of C in E})/(\text{wt. fraction of A in E})}{(\text{wt. fraction of C in R})/(\text{wt. fraction of A in R})}$$

partition coefficient.

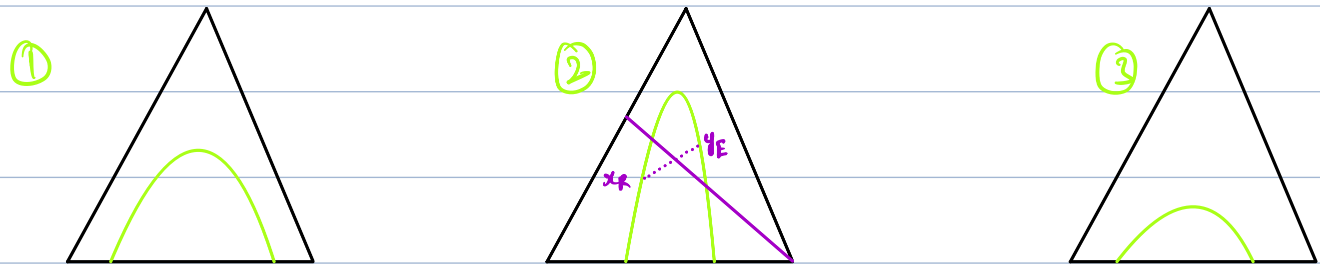
$$= \frac{y_E \times (\text{wt. fraction of A in R})}{x_R \times (\text{wt. fraction of A in E})}$$

Necessary condition for effective separation: $\beta > 1$

$\beta = 1 \rightarrow$ Tie line is horizontal. (x_R and y_E become equal, no separation possible.)

Azeotrope का ध्यान रख लेना !! ⟶ IMPORTANT

2.) Partition coefficient



region with more insolubility. | ↓ very little separation (x_R, y_E are very close) | region with less insolubility.

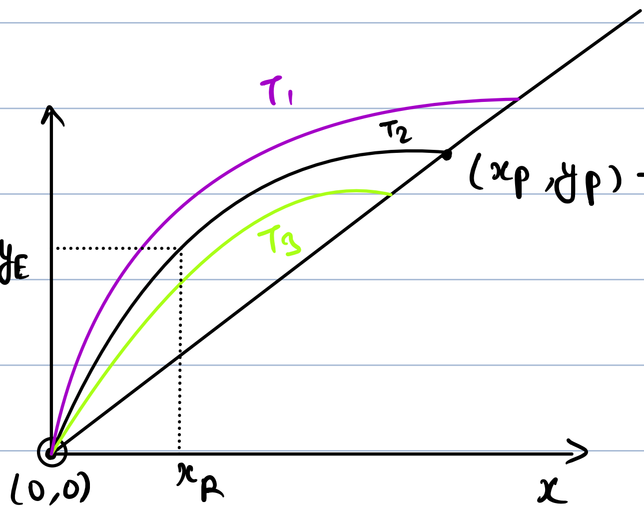
3.) Degree of Insolubility

4.) Recyclability of the solvent

5.) Surface Tension

6.) Density

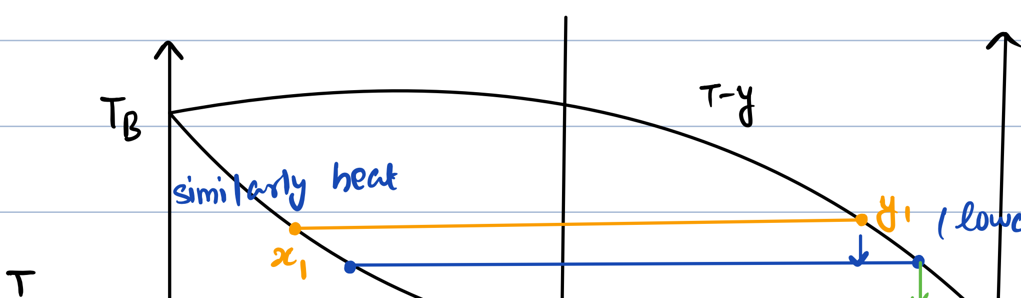
(#) EXTRACTION ISOTHERMAL PLOT



$(x_P, y_P) \rightarrow$ plait point. [Never go to (1.0, 1.0) Like distillation]

$$\boxed{T_3 > T_2 > T_1}$$

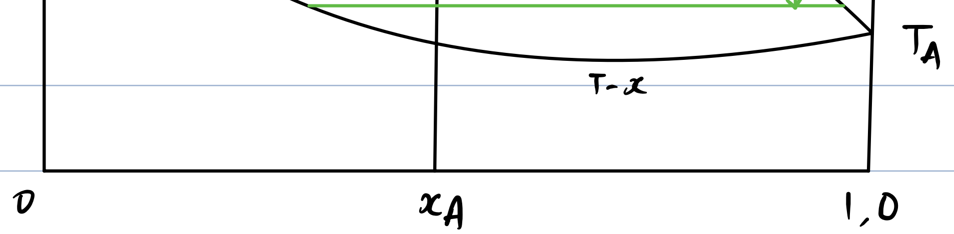
(*) why do we perform multistage in distillation?



(lowering down the temp.)

y will reach close

to pure A.



(*) McCabe - Thiele

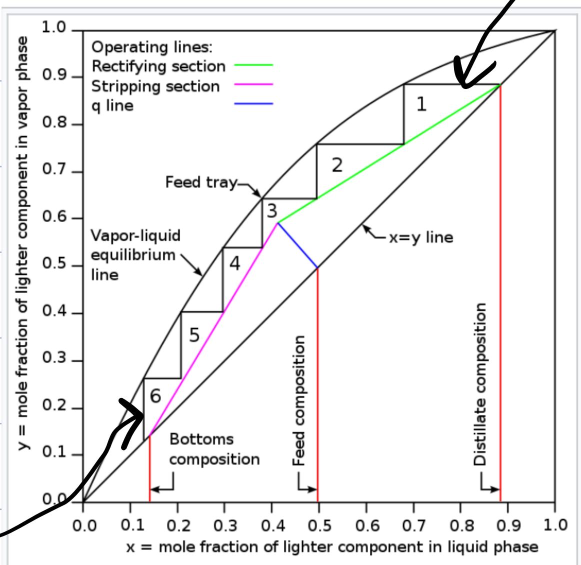
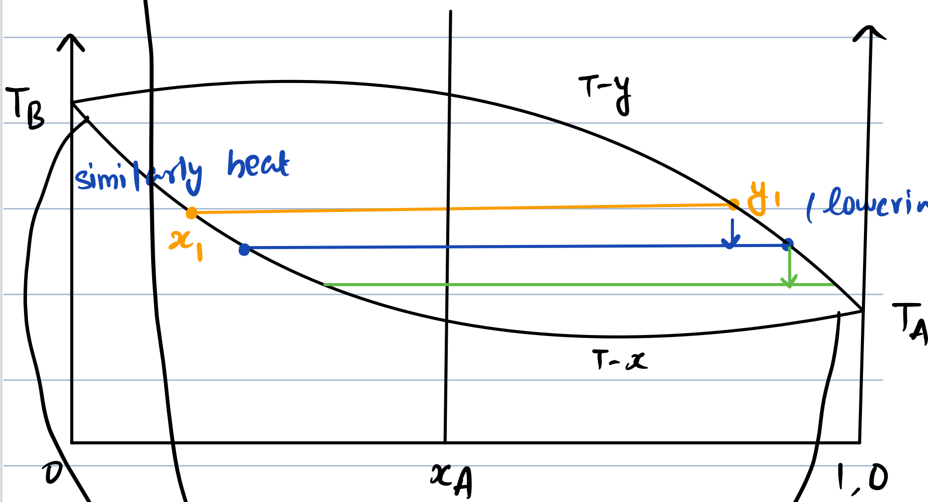


Figure 1: Typical McCabe–Thiele diagram for distillation of a binary feed

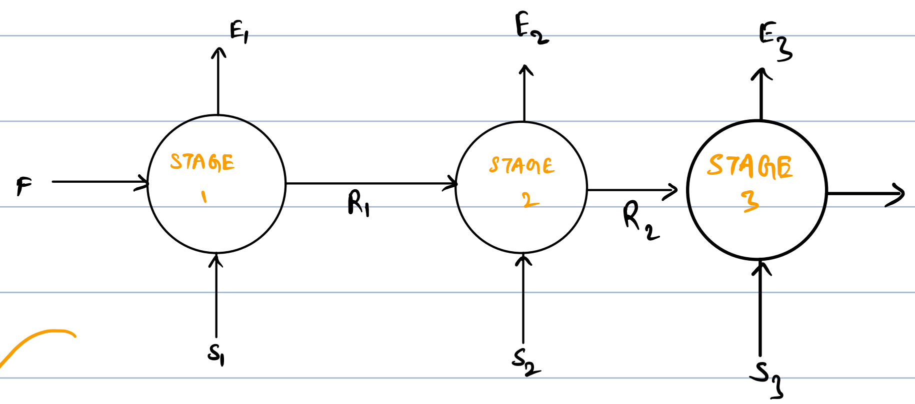


FIRST STAGE

operating line relates the liquid and vapor streams b/w 2 trays.

LAST STAGE

(*) Objective: To extract more c from the raffinate.



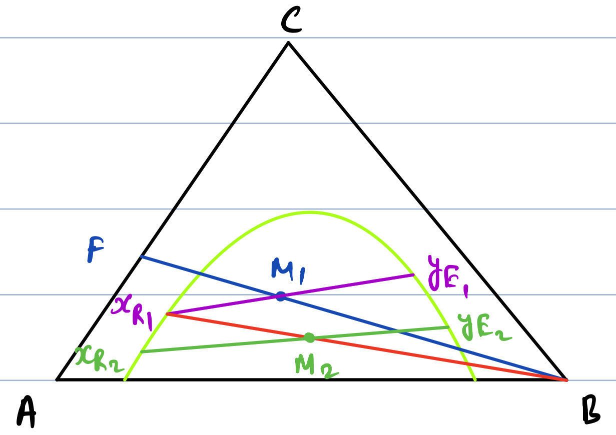
Balance for stage 2:

$$R_1 + S_2 = M_2$$

$$R_1 x_{R_1} + S_2 y_S = M_2 x_{M_2}$$

This is not similar to distillation column as this is CROSS FLOW.

Representing stage-2 on the graph:-



$M_1 \rightarrow$ first stage

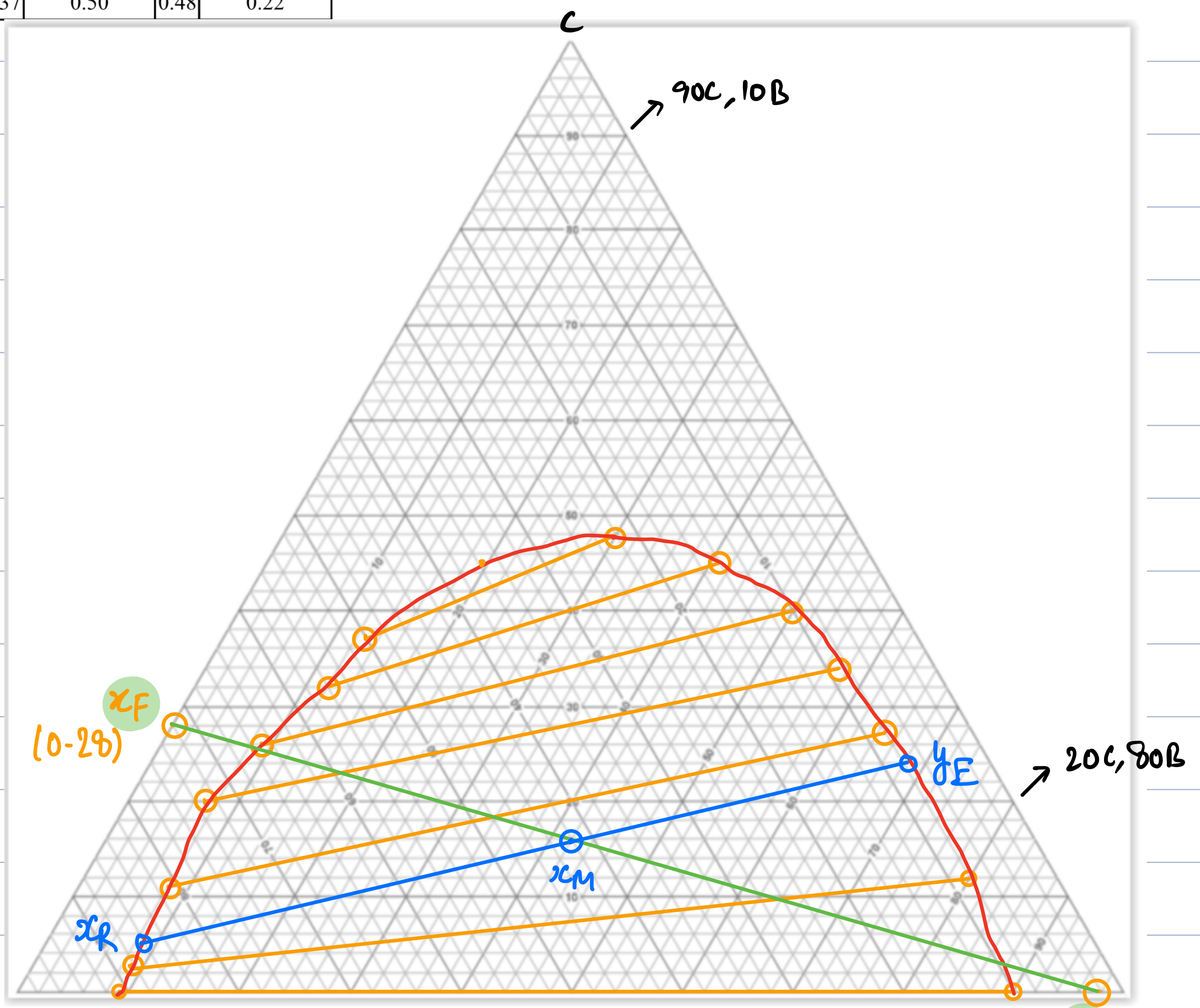
$M_2 \rightarrow$ second stage

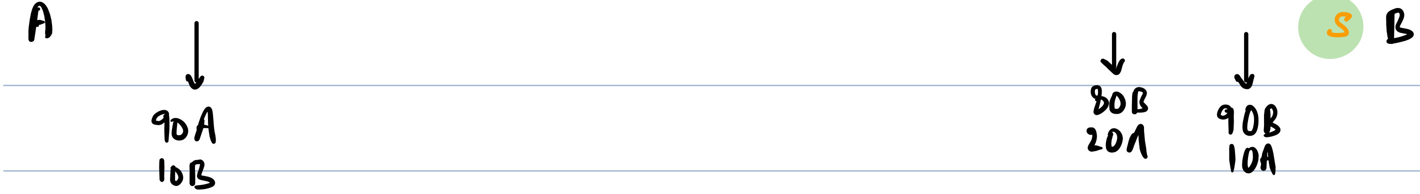
similarly join x_{R_2} & y_s for stage 3.

(12 Sept, 2022)

x	Fraction of A	y	Fraction of A
0	0.91	0	0.10
0.05	0.87	0.12	0.08
0.12	0.81	0.27	0.08
0.20	0.73	0.34	0.09
0.26	0.65	0.40	0.10
0.32	0.58	0.45	0.14
0.37	0.50	0.48	0.22

40 kg of feed with 28% solute is mixed with 30 kg of solvent that has 2 % carrier in it, in a single stage batch extractor. Find the amount and composition of the extract and raffinate.





S → solvent has 2% carrier in it. (B and S not coincident).

MASS BALANCE

$$S + F = M = 70$$

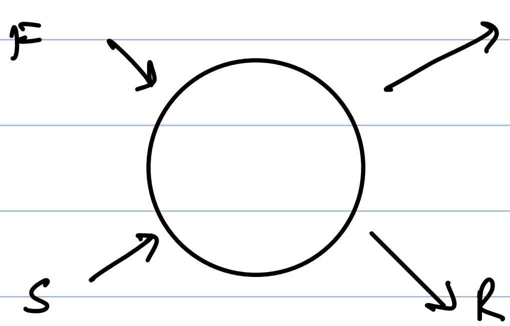
$$S y_s + F x_F = M x_M$$

$$40 \times 0.28 = 70 \times x_M$$

$$\Rightarrow \quad x_M = \frac{40 \times 0.28}{70} = 0.16$$

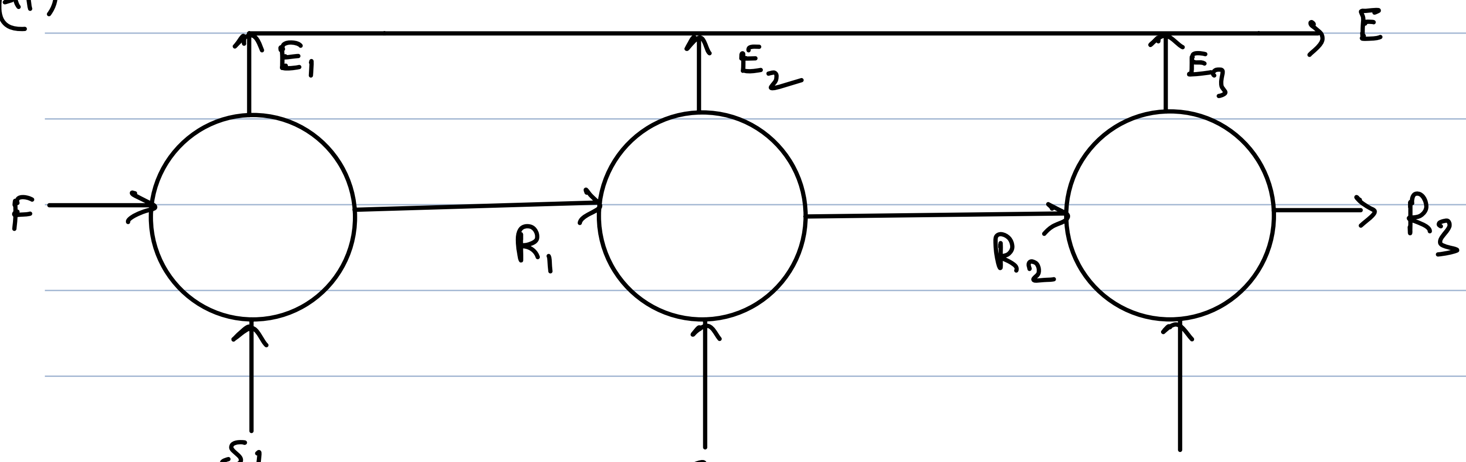
from graph $\Rightarrow$ $\underline{x_R = 0.06}$, $\underline{y_E = 0.23}$

(#)



SINGLE STAGE EXTRACTOR.

(#)

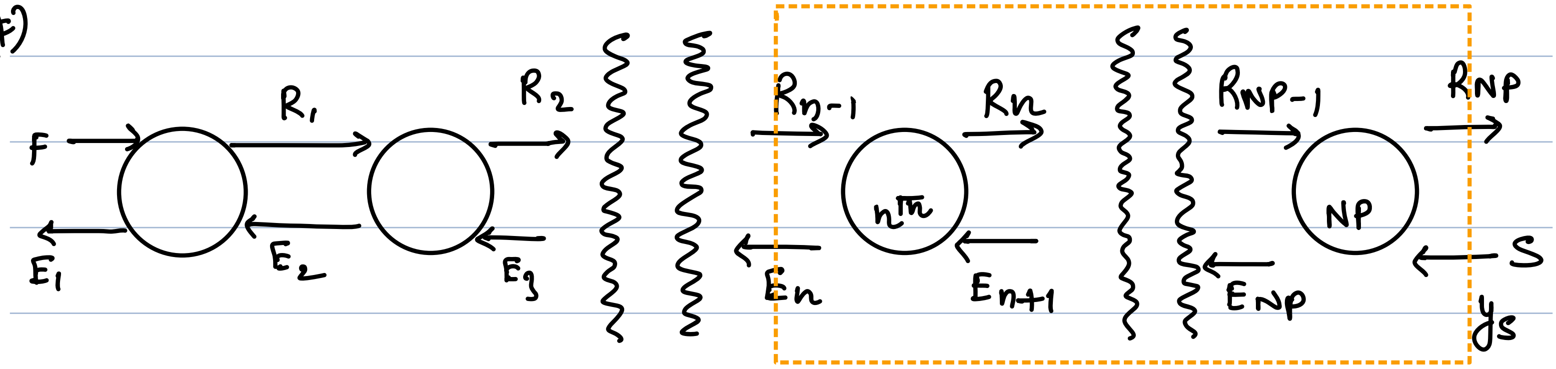


S_2 S_3

CROSS FLOW MULTISTAGE EXTRACTOR

COUNTER FLOW MULTISTAGE EXTRACTOR.

(#)



NP → number of plates.

(I)

Overall balance : $F + S = E_1 + R_{NP} = M$

$$F x_F + S y_S = E_1 y_1 + R_{NP} x_{NP} = M x_M$$

→ For this problem (E, y_{E_1}) or $(R_{NP}, x_{R_{NP}})$ must be specified.

→ Here M has no physical significance, but just a mathematical entity. F and S never come together OR E_1 & R_{NP}.

→ same for x_M.

$$\Rightarrow \quad \boxed{R_{NP} - S = F - E_1 = \Delta R.}$$

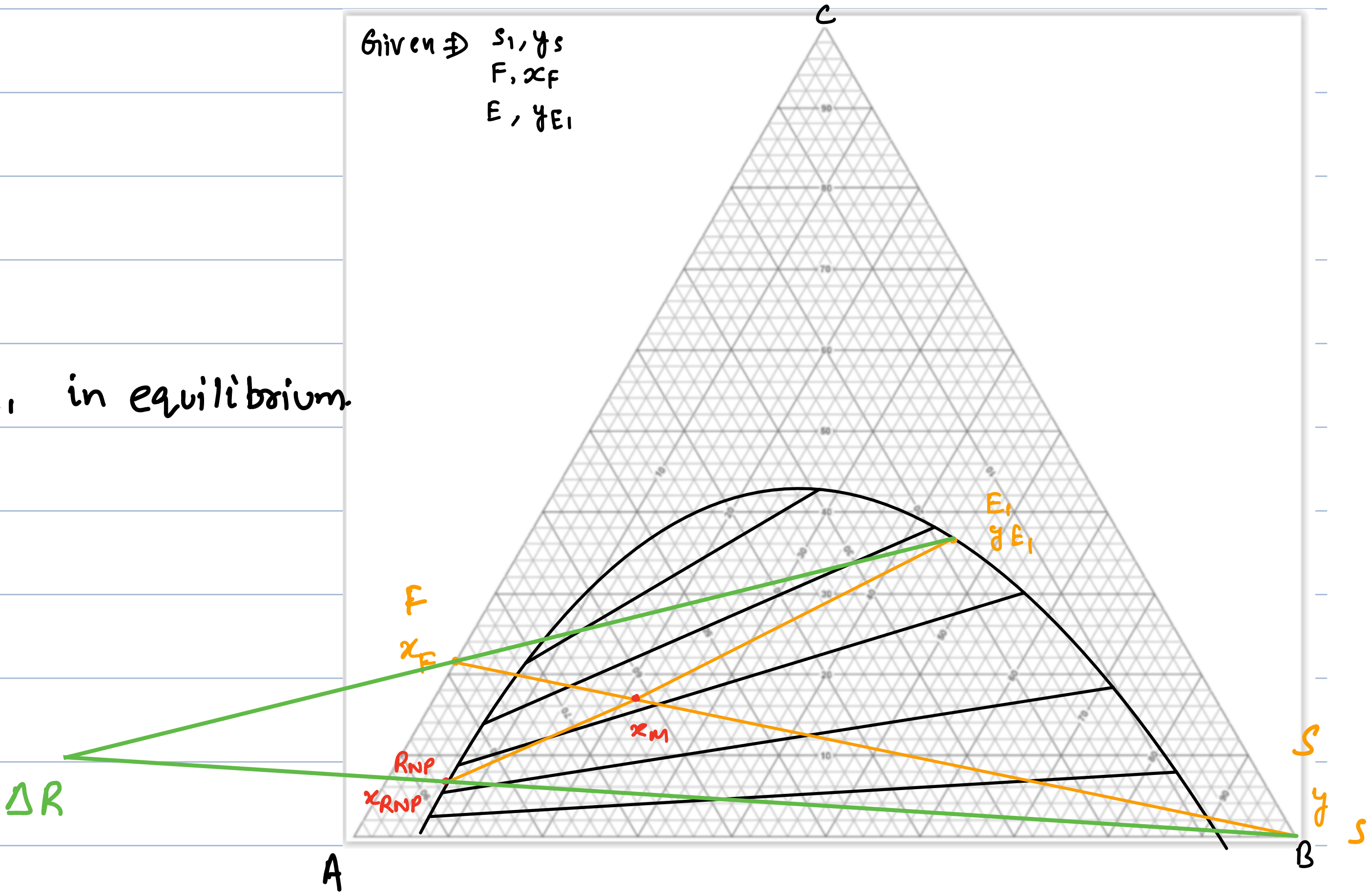
(II) Overall balance for stage n gives

$$R_{n-1} + E_{n+1} = R_n + E_n \Rightarrow \boxed{R_{n-1} - E_n = R_n - E_{n+1} = \Delta R.}$$

(III) Balance for whole plant from n^{th} to NP^{th} stage.

$$R_{n-1} + S = E_n + R_{NP} \Rightarrow \boxed{R_{NP} - S = R_{n-1} - E_n = \Delta R}$$

R_1, E_1 in equilibrium



15th Sept

(Q.) CROSS FLOW CONFIGURATION IN 3 STAGES

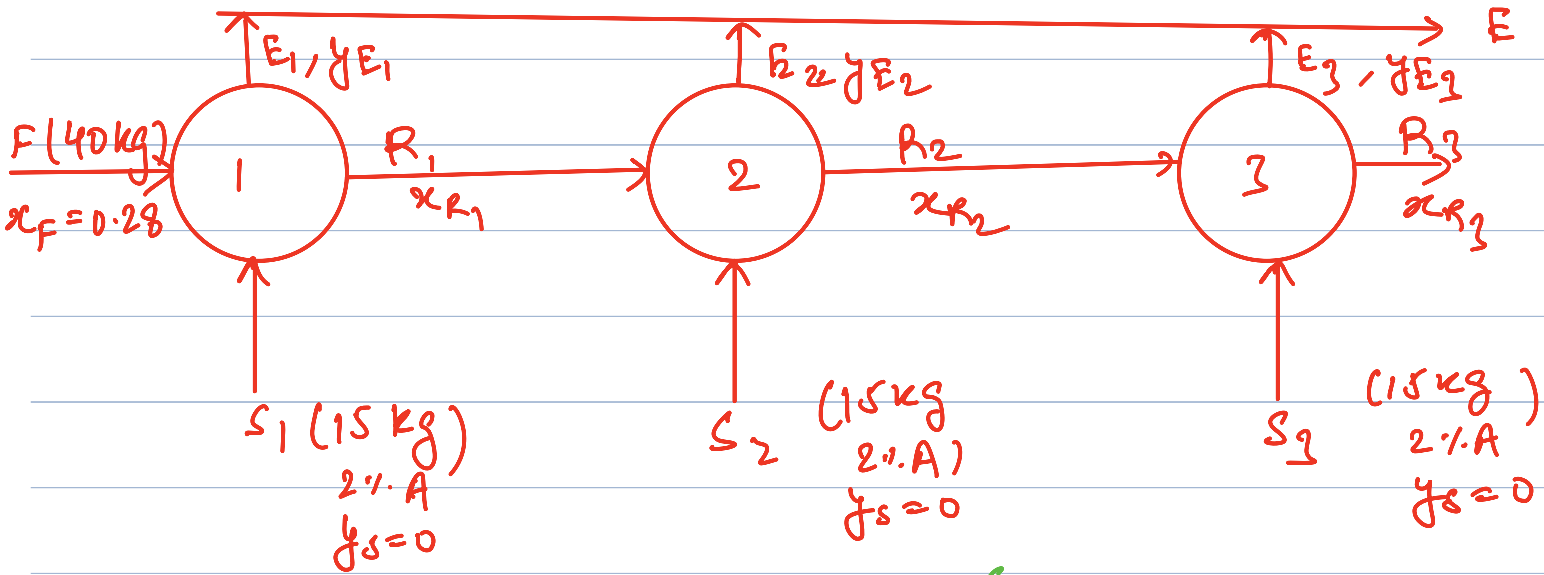
40 kg, 28% C → Feed

15 kg, 2% A → Solvent

x	Fraction of A	y	Fraction of A
0	0.91	0	0.10
0.05	0.87	0.12	0.08
0.12	0.81	0.27	0.08
0.20	0.73	0.34	0.09
0.26	0.65	0.40	0.10
0.32	0.58	0.45	0.14
0.37	0.50	0.48	0.22

To Find ⇒ Extract → Amount, → composition; Raffinate → Amount, → composition.

Sol'n (My attempt at the problem).



x	Fraction of A	y	Fraction of A
0	0.91	0	0.10
0.05	0.87	0.12	0.08
0.12	0.81	0.27	0.08
0.20	0.73	0.34	0.09
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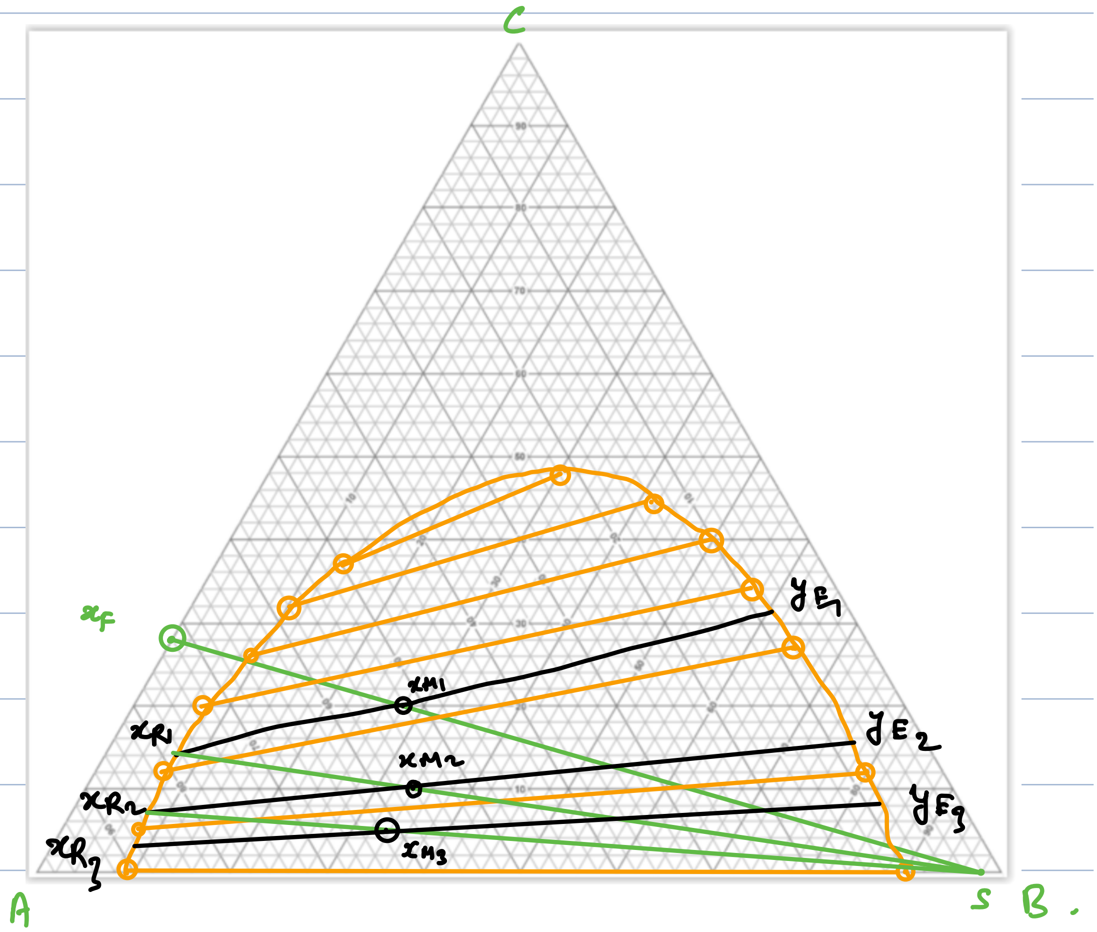
0.32	0.58	0.45	0.14
0.37	0.50	0.48	0.22



STAGE 1

$F + S_1 = E_1 + R_1$ → Total mass balance

$F x_F + S_1 y_{S_1} = E_1 y_{E_1} + R_1 x_{R_1}$ → c balance.

$F = 40kg$, $x_F = 0.28$, To find y_{E_1} and x_{R_1}

$S_1 = 15 kg$, $y_{S_1} = 0$, we need x_{M_1}.

From graph $x_{R_1} = 0.14$, $y_{E_1} = 0.31$

Mixture

$F + S_1 = M_1$

$E_1 + R_1 = 55$

$E_1(0.31) + R_1(0.14) = 11.2$ $\qquad$ $Fx_F + S_1 y_{S_1} = M_1 x_M$

$\Rightarrow E_1 = 20.6,\ R_1 = 34.4$ $\qquad$ $\Rightarrow M_1 = 55\ kg$

$\Rightarrow x_{M_1} = 0.2036$

$y_{E_1} = 0.31$	$x_{R_1} = 0.14$
$E_1 = 20.6$	$R_1 = 34.4$

STAGE 2

$R_1 + S_2 = M_2$

$R_1 x_{R_1} + S_2 y_{S_2} = M_2 x_{M_2}$

$34.4(0.14) + 15(0) = 49.4\, x_{M_2}$

$x_{M_2} = 0.1$

$E_2 + R_2 = M_2$

$R_2 y_{R_2} + E y_{E_2} = M_2 x_{M_2}$

From graph $x_{R_2} = 0.07$

$y_{E_2} = 0.15$

$E_2 + R_2 = 49.4$

$E_2(0.15) + (49.4 - E_2)(0.07) = 49.4 \times 0.1$

$0.08 E_2 + 3.458 = 4.94$

$E_2 = 18.525 \Rightarrow R_2 = 30.875$

$y_{E_2} = 0.15$	$x_{R_2} = 0.07$
$E_2 = 18.525$	$R_2 = 30.875$

STAGE 3

$R_2 + S_3 = M_3 \Rightarrow M_3 = 45.875$

$R_2 x_{R_2} + S_3 y_{S_3} = M_3 x_{M_3} \Rightarrow x_{M_3} = 0.05$

$y_{E_3} = 0.09$

$x_{R_3} = 0.03$

$E_3 + R_3 = M_3$

$E_3 y_{E_3} + R_3 x_{R_3} = M_3 x_{M_3}$

$E_3 + R_3 = 45.875$

$E_3(0.09) + (45.875 - E_3)0.03 = 45.875 \times 0.05$

$E_3(0.06) + 1.37625 = 2.29375$

$E_3 = 15.3 \Rightarrow R_3 = 30.6$

$y_{E_3} = 0.09$	$x_{R_3} = 0.03$
$E_3 = 15.3$	$R_3 = 30.6$

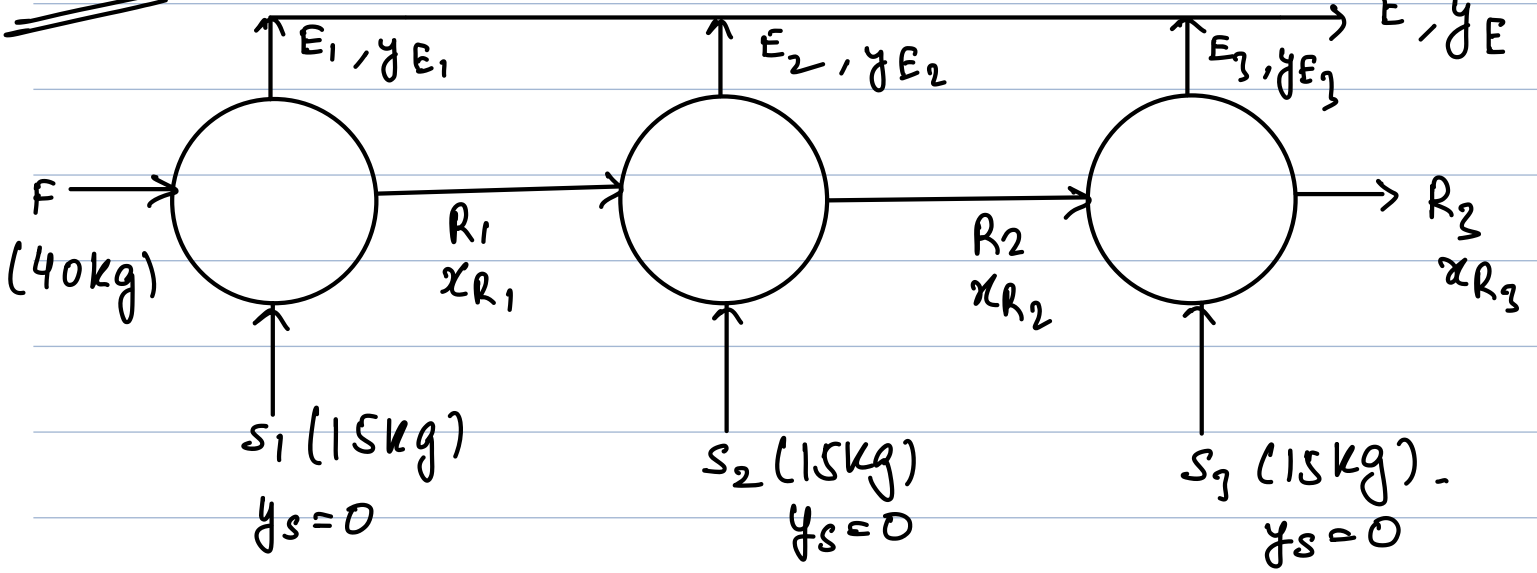
FINAL $\Rightarrow$

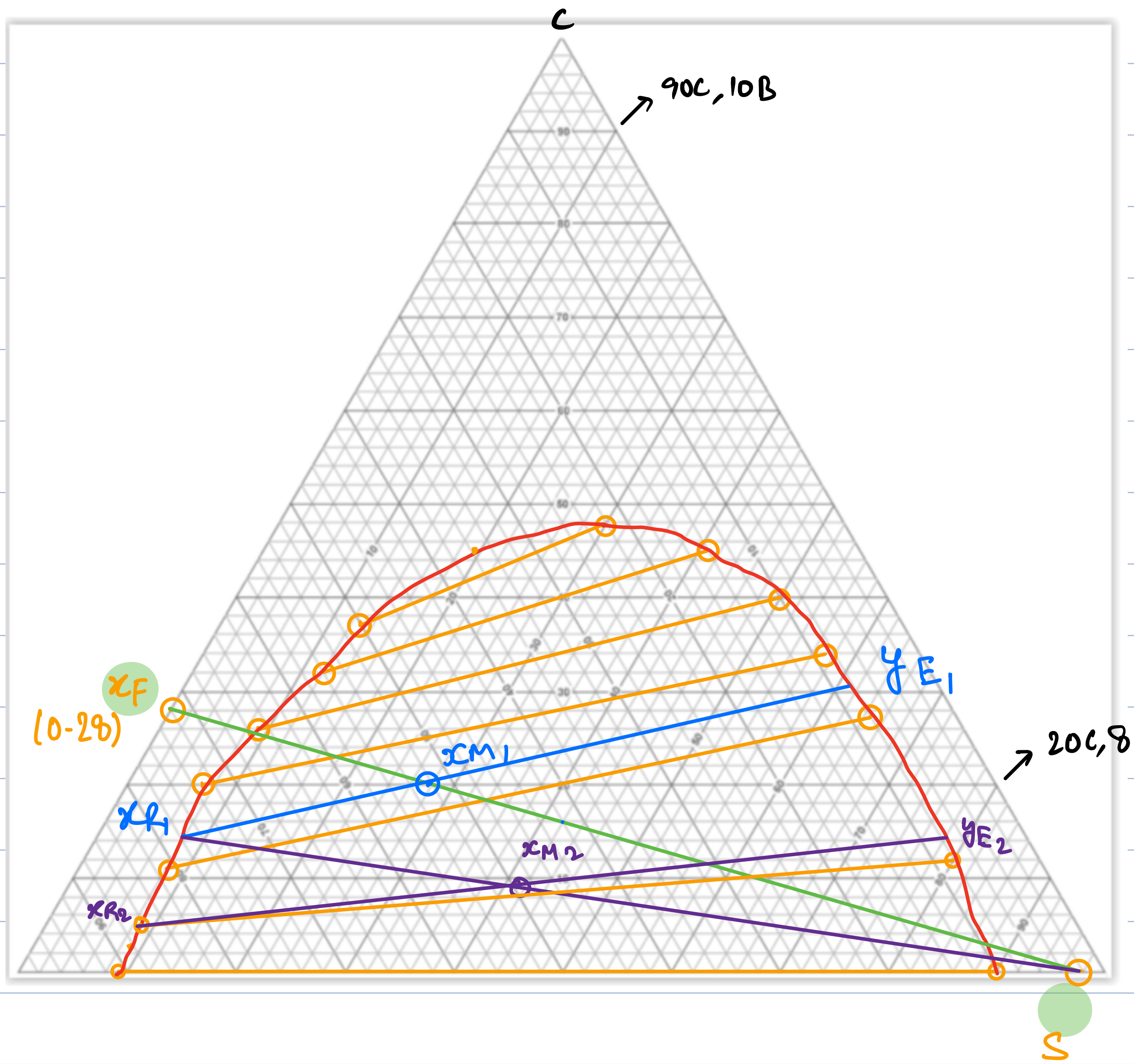
Raffinate = 30.6 kg, $x_{R_3} = 0.03$

Extract $\Rightarrow E, y_E$, $E = E_1 + E_2 + E_3 = 54.425$

$$y_E = \frac{\Sigma y_i E_i}{E} = 0.1936.$$

DIAGRAM





MASS BALANCE

$S + F = M_1 = 15 + 40 = 55$

$S y_s + F x_F = M x_M$

$40 \times 0.28 = 55\ x_M$

$x_{M_1} = 0.2036$

From graph $\Rightarrow$ $x_{R_1} = 0.14$, $y_{E_1} = 0.31$

$E_1 + R_1 = M_1 = 55 \longrightarrow (1)$

$y_{E_1} E_1 + x_{R_1} R_1 = 0.2036 \times 55 \longrightarrow (2)$

$(0.31)(E_1) + (0.14)(R_1) = 11.198$

$(0.31)(55 - R_1) + 0.14\ R_1 = 11.198$

$17.05 - 0.17\ R_1 = 11.198$

$R_1 = 34.4235 \Rightarrow E_1 = 20.5764$

$R_1 = 34.4235$ $\quad E_1 = 20.5764$

$x_{R_1} = 0.14$ $\quad y_{E_1} = 0.31$ $\quad$ STAGE 1

$R_1 + S_2 = M_2 \Rightarrow M_2 = 15 + 34.4235 = 49.4235$

$R_1 x_{R_1} + S_2 y_{S_2} = M_2 x_{M_2} \Rightarrow (34.4235)(0.14) + (15)(0) = 49.4235\ x_{M_2}$

$x_{M_2} = 0.0975$

From graph $\quad x_{R_2} = 0.06 \quad y_{E_2} = 0.14$

$E_2 y_{E_2} + R_2 x_{R_2} = 49.4235 \times 0.0975 \longrightarrow (1)$

$$E_2 + R_2 = 49.4235 \rightarrow (2)$$

$$0.14 E_2 + 0.06 R_2 = 4.8188$$

$$0.14(49.4235 - R_2) + 0.06 R_2 = 4.8188$$

$$6.919 - 0.14 R_2 + 0.06 R_2 = 4.8188$$

$$2.10049 = 0.08 R_2$$

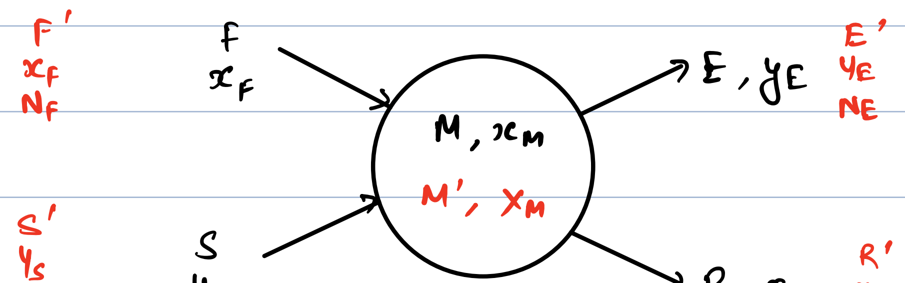
$$R_2 = 26.2561 \Rightarrow E_2 = 23.167375$$

$$\left.\begin{array}{llll} R_2 = 26.2561 & & E_2 = 23.1674 \\ x_{R_2} = 0.06 & & y_{E_2} = 0.14 \end{array}\right\} \text{STAGE 2.}$$

POST MIDSEM

$\Downarrow$

B - Free Calculation



we define X or Y.

N_S y_S $R,\ x_R$ x_R N_R

$$y_E = \frac{C_E}{\underbrace{A_E + B_E + C_E}_{(E)}} \quad , \quad x_R = \frac{C_R}{A_R + B_R + C_R}$$

X or Y

↳ B free fraction of C.

$$Y_E = \frac{C_E}{\underbrace{A_E + C_E}_{(E' - \text{B free extract flow rate})}} = \frac{C_E}{E'}$$

$$X_R = \frac{C_R}{\underbrace{A_R + C_R}_{(R' - \text{B free raffinate flow rate})}} = \frac{C}{R'}$$

N : B fraction on a B-free basis.

$$N_R = \frac{B_R}{(A_R + C_R)}$$

$$N_S = \frac{B_S}{(A_S + C_S)} \rightarrow S'$$

For a pure solvent $S' = 0$, $N_S = \infty$, $Y_S = \infty$

↳ $\left(\frac{0}{0}\right)$

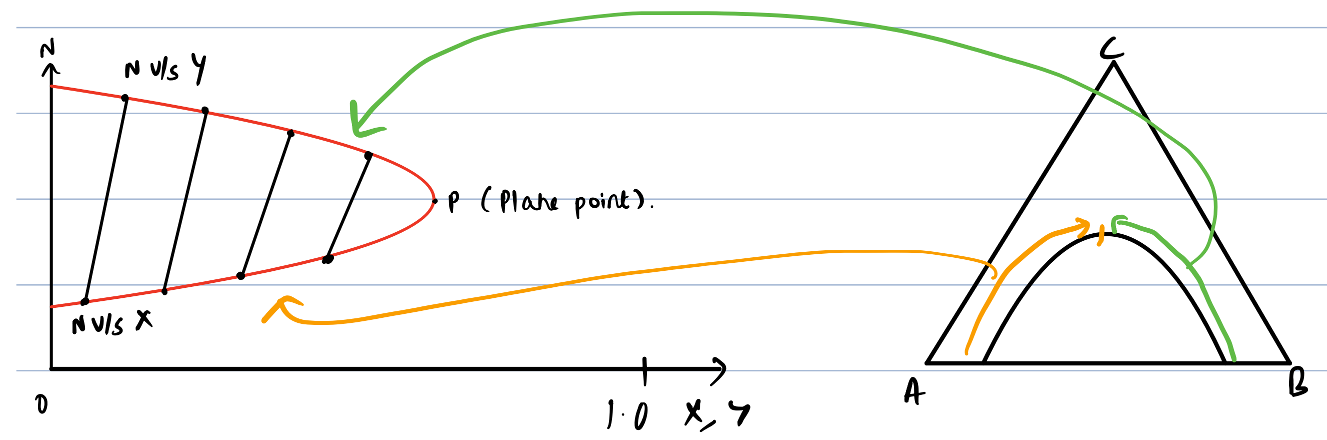
NOTE → physically E', R', F', S' do not exist.

x	Fraction of A	y	Fraction of A
0	0.91	0	0.10
0.05	0.87	0.12	0.08
0.12	0.81	0.27	0.08
0.20	0.73	0.34	0.09
0.26	0.65	0.40	0.10
0.32	0.58	0.45	0.14
0.37	0.50	0.48	0.22

$\xrightarrow[\text{B-free basis}]{\text{converting into}}$

x	A	B	X	N_x
0	0.91	0.09	$\frac{0}{0.91}$	$\frac{0.09}{0.91} = 0.099$
0.05	0.87	0.08	$\frac{0.05}{0.92}$	$\frac{0.08}{0.92} = 0.087$
⋮				
0.32	0.58	0.10	$\frac{0.32}{0.90}$	$\frac{0.10}{0.90} = 0.111$
0.12	0.81	0.07	$\frac{0.12}{0.93}$	$\frac{0.07}{0.93} = 0.075$
0.26	0.65	0.09	$\frac{0.26}{0.91}$	$\frac{0.09}{0.91}$

y	A	B	Y	N_y
0.40	0.10	0.5	$\frac{0.4}{0.5}$	$\frac{0.5}{0.5}$



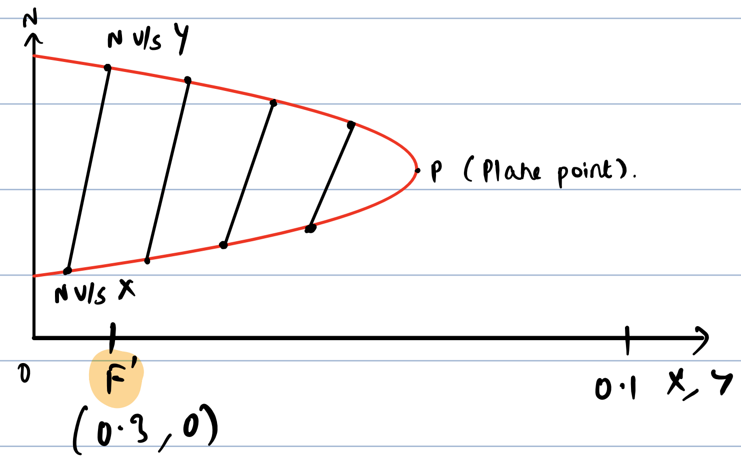
Advantage: we can plot using cartesian coordinates.

Ex:- Feed = 30% C $x_F = 0.3$ $N_F = 0$.

$x_F = 0.3$

(∵ B_F is 0 in feed)

∴ Feed point → (0.3, 0)



Overall Mass Balance:

$S + F = M = E + R$

B-Free Mass Balance:

$F' + S' = M' = E' + R'$ ⟶ ①

what is the relation b/w F and F'? ⟹ $\boxed{F = F'}$ → no B_F in feed.

Pure solvent case

$S' = 0$

Using ①

$F' + S' = M'$

$F' = M'$

$\Rightarrow \boxed{F' = M' = F}$

$$F' = A_F + C_F$$
$$x_F = \frac{C_F}{A_F + C_F}$$
$$S' = A_S + C_S$$
$$y_S = \frac{C_S}{A_S + C_S}$$
$$M' = A_M + C_M$$
$$x_M = \frac{C_M}{A_M + C_M}$$

B Free C balance:

$$F' x_F + S' y_S = M' x_M$$ where, $\Rightarrow$

For a pure solvent $\Rightarrow$ $S' y_S = 0$ (1^{st} approximation)

$$\Rightarrow \quad F' x_F = M' x_M$$

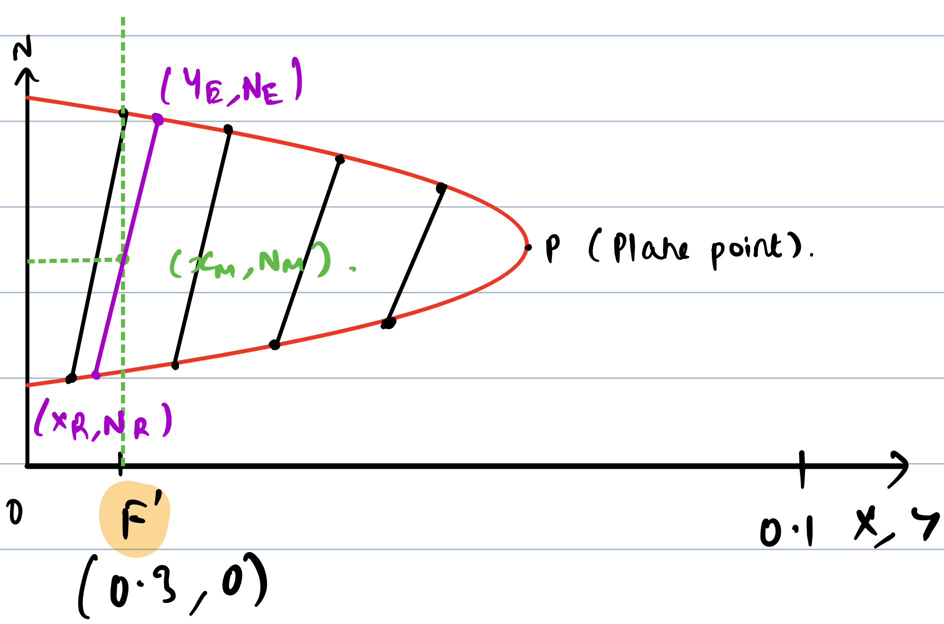
$$\Rightarrow \quad \boxed{x_F = x_M}$$

B free B balance:

$$\underbrace{N_F}_{0} F' + N_S S' = N_M M'$$

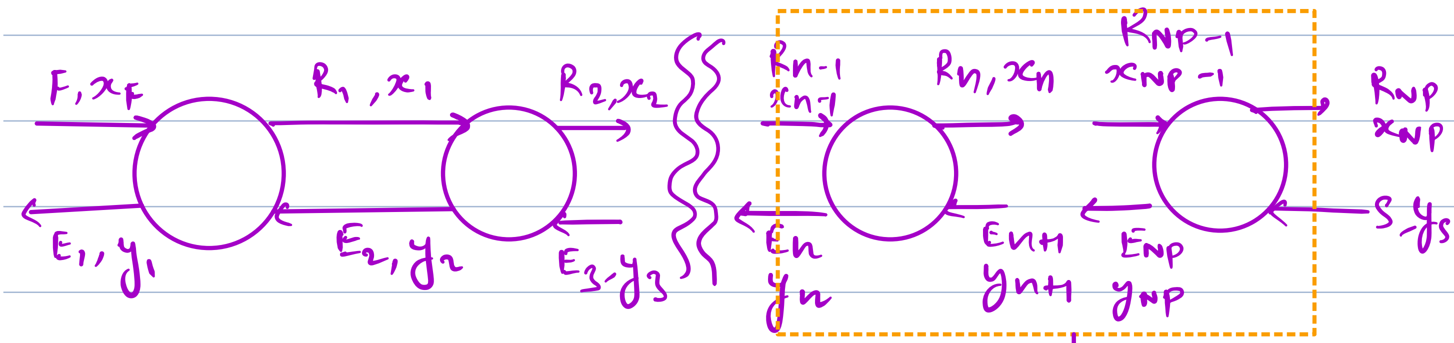
$$N_S S' = \frac{B_S}{\cancel{(A_S + C_S)}} \times \cancel{(A_S + C_S)} = B_S = S$$

$$\Rightarrow \quad N_M M' = S \quad \Rightarrow \quad \boxed{N_M = S/F}$$



(*) All main equations are valid incase of pure and impure solvent but the approximations are valid only incase of pure solvent.

Continuous Counter-current Multistage Extractor



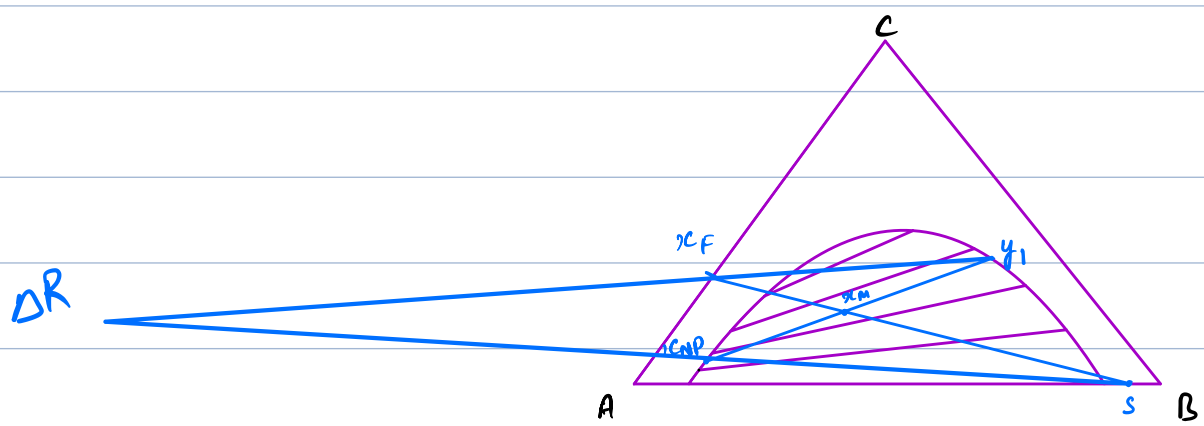
Overall balance :-

$$F + S = E_1 + R_{NP}$$

$$E_1 - F = S - R_{NP} = \Delta R$$

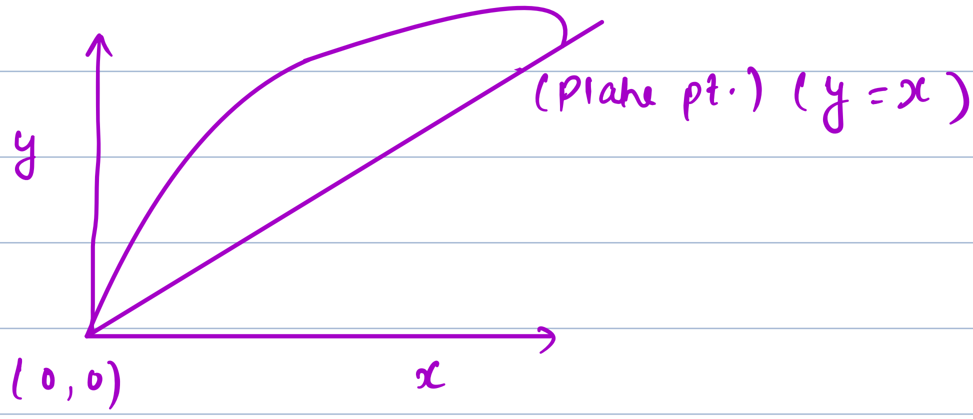
$$R_{n-1} + S = E_n + R_{NP}$$

$$E_n - R_{n-1} = S - R_{NP} = \Delta R$$

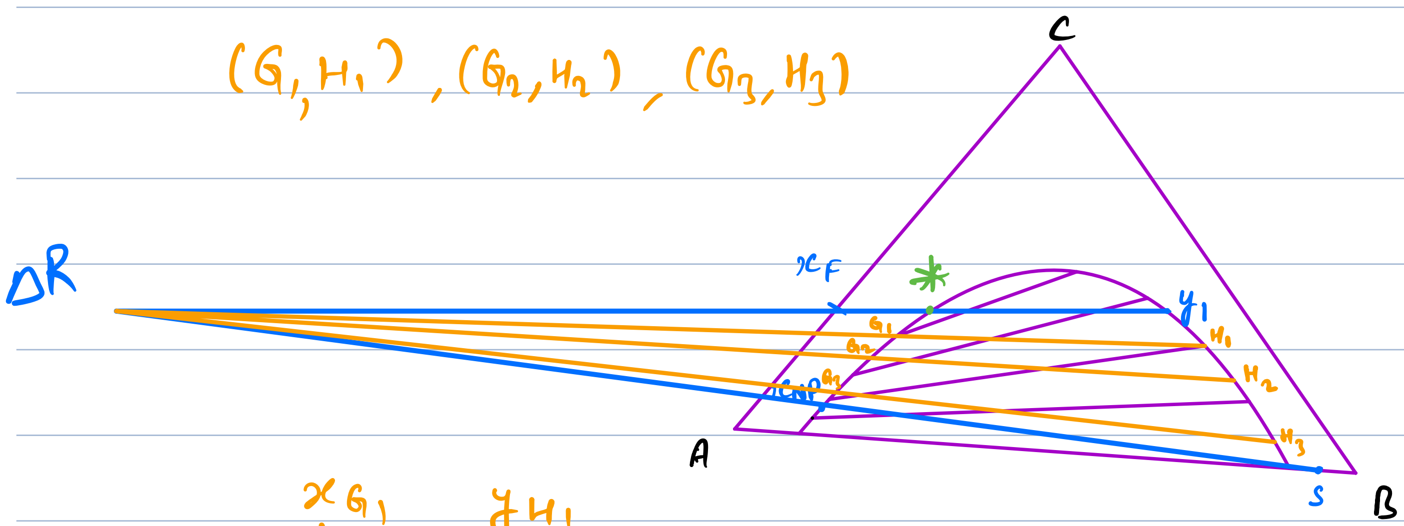


(*) y_{n+1} v/s x_n plot → **OPERATING LINE**

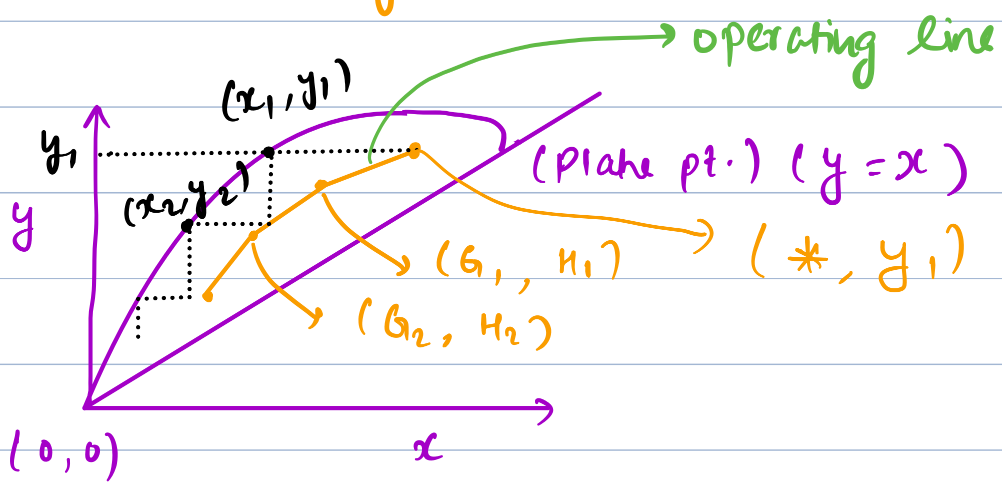
x_n v/s y_n (equilibrium plot).



(G₁, H₁), (G₂, H₂), (G₃, H₃)

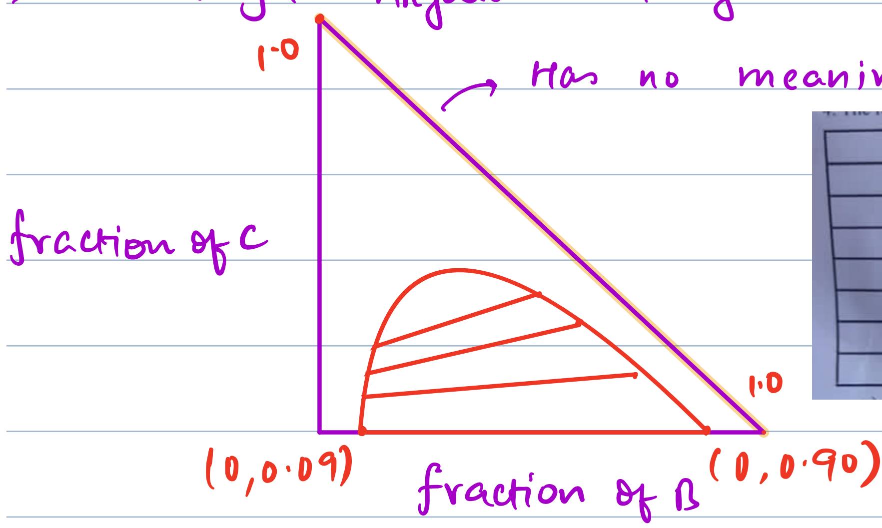


$x_{G_1} \rightarrow x_n$ $y_{H_1} \rightarrow y_{n+1}$



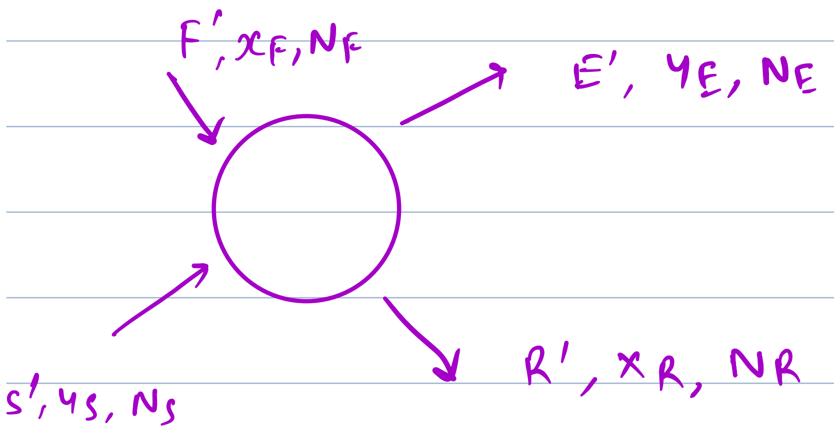
Unlike Mccb-Thiele method we don't have an analytical eq'n for the operating line and that is why we have to generate the operating line from the ΔR plot.

⇒ Right Angular Triangular Plot.



x	Fraction of B	y	Fraction of B
0	0.09	0	0.90
0.06	0.07	0.12	0.80
0.12	0.07	0.27	0.65
0.20	0.08	0.34	0.57
0.26	0.10	0.40	0.50
0.32	0.11	0.45	0.41
0.37	0.13	0.48	0.31

B-Free calculations for Multi-stage



$x_F = C_F/(A_F+B_F+C_F)$

$y_E = C_E/(A_E+B_E+C_E)$

$X_F = C_F/(A_F+C_F)$

$N_F = B_F/(A_F+C_F) = 0$

$Y_E = C_E/(A_E+C_E)$

$N_E = B_E/(A_E+C_E)$

$$X_S = \frac{C_S}{A_S+C_S} = \frac{0}{0}$$

$$N_S = \frac{B_S}{A_S+C_S} = \frac{B_S}{0}$$

Pure Solvent.

B-Free overall balance ⇒

$$F' + S' = M' = E' + R'$$

For pure solvent, $S' = 0$, $F' = M'$

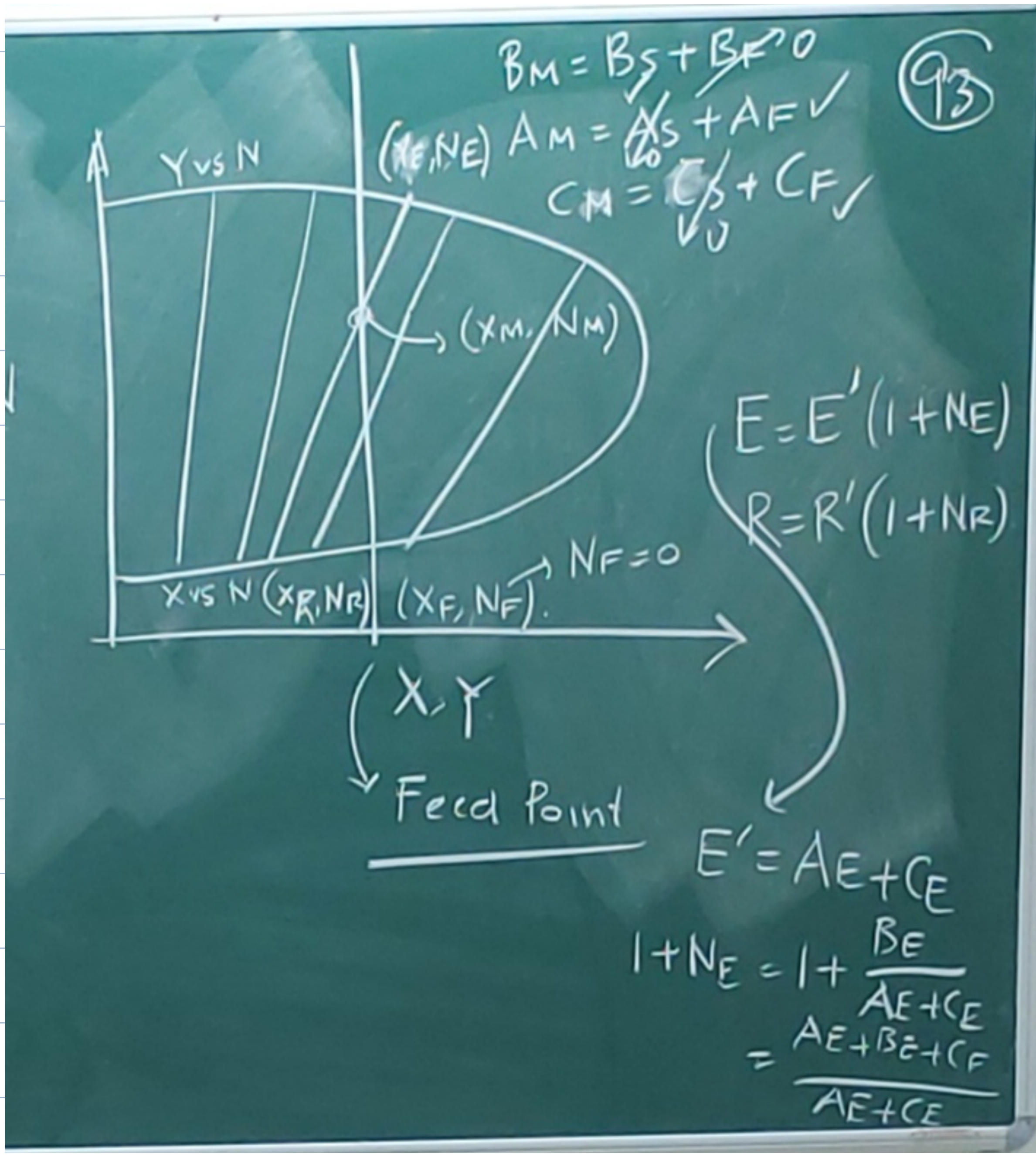
Also $F = F'$ $\Rightarrow$ $\because B_F = 0$

B-Free C balance $\Rightarrow$

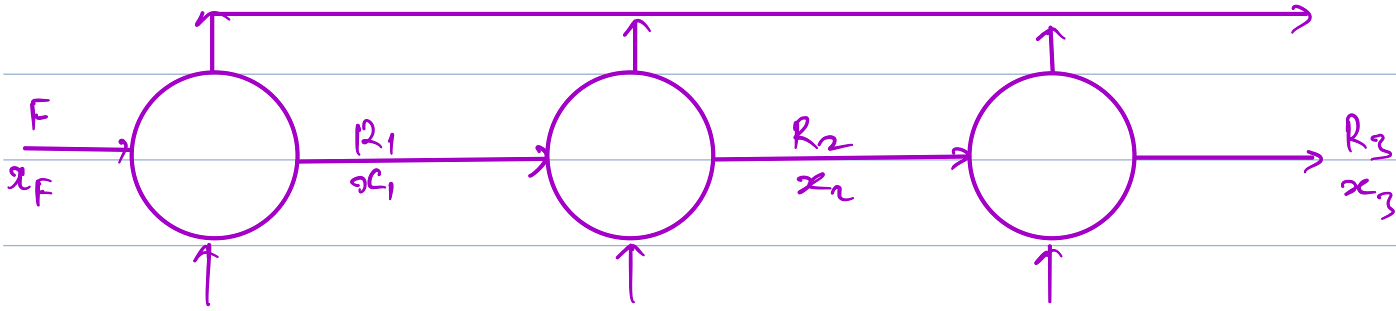
$$F' x_F + S' y_S = M' x_M$$

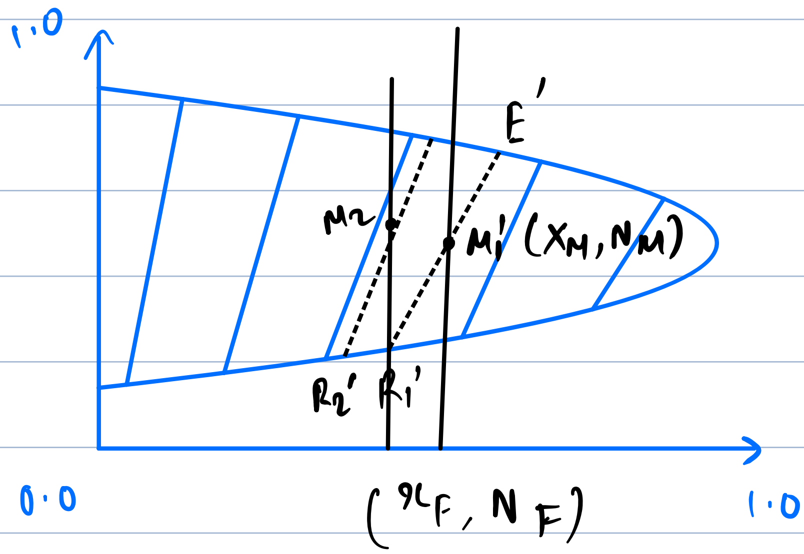
$$F' x_F = M' x_M$$

$$x_F = x_M$$



Cross Flow by B-Free Basis (Pure solvent)





Counter Flow on B Free basis

Overall balance: $F + S = M = E_1 + R_{NP}$

Overall B-Free balance: $F' + \cancel{S'} = M = E' + R_{NP}'$

$\cancel{S'} \rightarrow 0$

$F' = M'$

$F = F'$ (for Pure solvent)

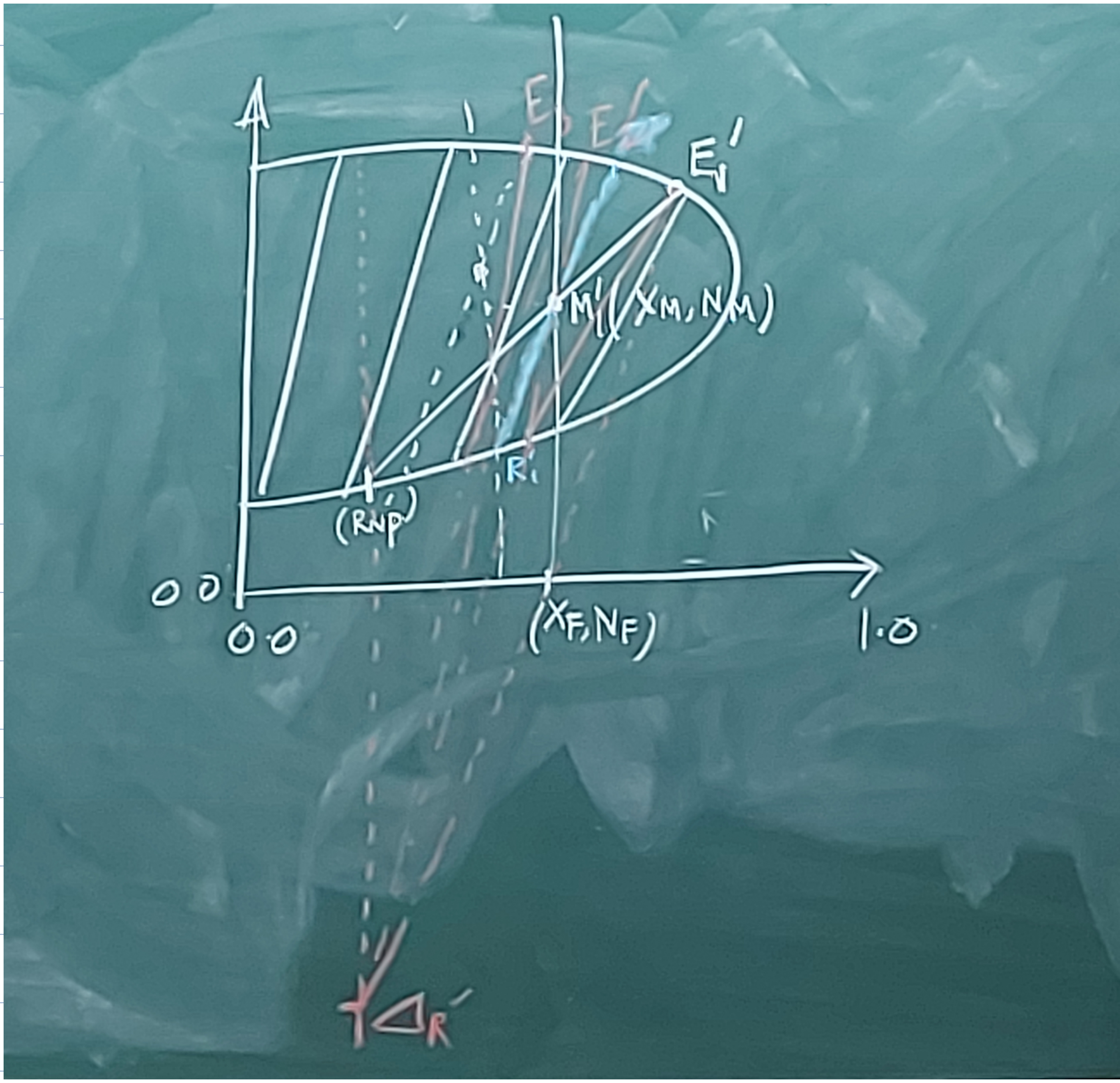
B-Free c balance:

$F' x_F + S' y_s = M' x_M = E_1' y_{E_1} + R_{NP}' x_{NP}$

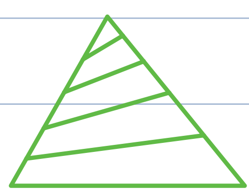
$(x_F = x_M)$

B-Free B balance :

$F'N_F + S'N_S = M'N_M$



When A, B, C are completely immiscible, the phase diagram is as follows:-



⇒ When A and B are completely immiscible we can use "C-free" notation.

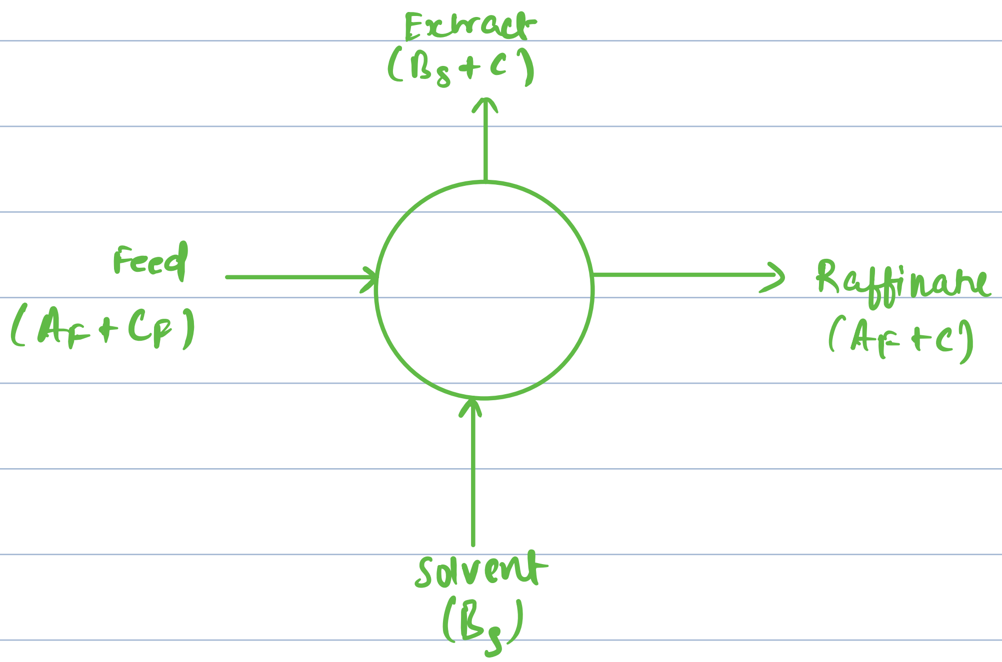
$$x' = \frac{x}{1-x}$$

x : stream of raffinate (including Feed)

$$y' = \frac{y}{1-y}$$

y: stream of extract (including solvent).

SINCE A and B are COMPLETELY IMMISCIBLE



Solute balance (C balance)

$$A_F\, x_F' + B_S\, y_S' = A_R \cdot x_{R_1}' + B_E \cdot y_{E_1}'$$

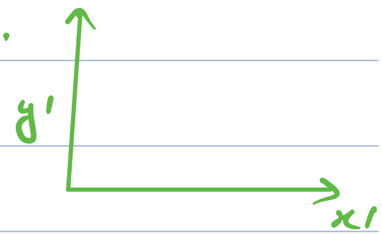
$$A_F \cdot \frac{C_F}{(A_F + \cancelto{0}{B_F})} + B_S \frac{C_S}{(\cancelto{0}{A_S} + B_S)} = A_R \cdot \frac{C_R}{(A_R + \cancelto{0}{B_R})} + B_E \cdot \frac{C_E}{(\cancelto{0}{A_E} + B_E)}$$

$$\boxed{\begin{matrix} A_R = A_F \\ B_S = B_E \end{matrix}}$$ ⇒ because of complete immiscibility of A and B.

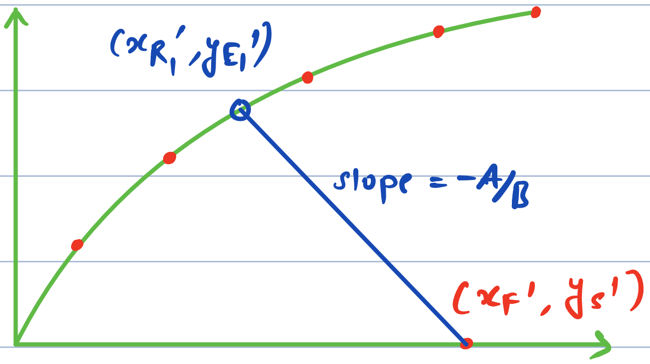
⇒ $$A x_F' + B y_s' = A x_R' + B y_E'$$

$$B(y_s' - y_E') = -A(x_F' - x_R')$$

$$\frac{y_s' - y_E'}{x_F' - x_R'} = -\frac{A}{B}$$ ⇒ Need the equilibrium data in x' v/s y' form.



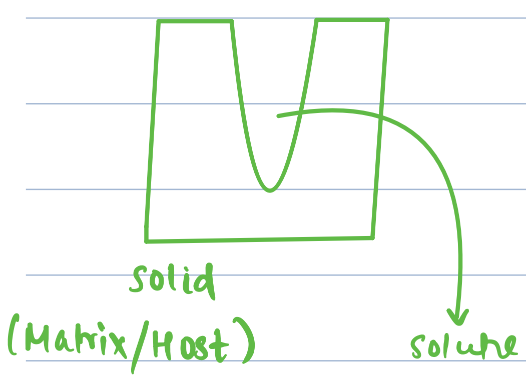
x_F' is known
Pure solvent
A, B known

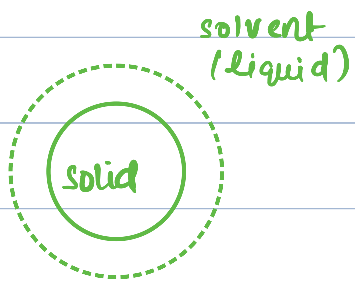


(x_F', y_s') → does not have any physical significance.

The line joining (x_R', y_E') and (x_F', y_s') has slope $-\frac{A}{B}$.

LEACHING



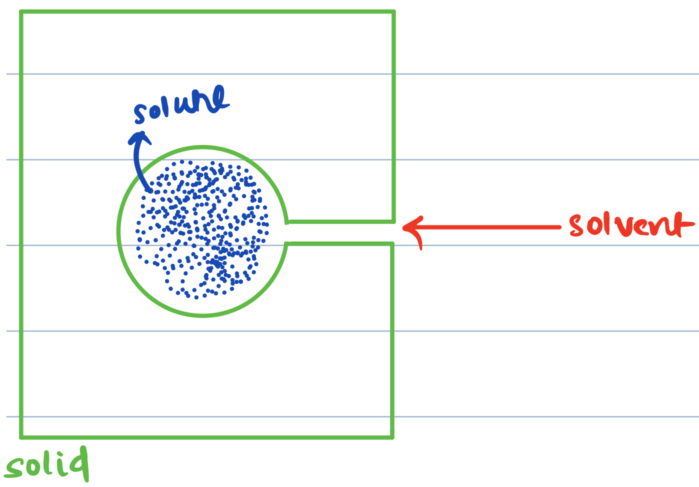


Lixivation :-

Decoction :- It is a special case of leaching when solvent is at boiling point.

Elutriation :- when the solute is mostly on the surface of the solid.

Solution Mining :-



Steps

① Diffusion of the solvent to the pores.
② Dissolution of the solute inside the pores.
③ Outward diffusion

Problem Solving

$x_F = 0.01 \Rightarrow x_F' = \frac{0.01}{0.99} = 0.010101$

1. Nicotine (C) in water (A) solution containing $\boxed{\text{1.0 \% nicotine}}$ is to be extracted with kerosene (B). Water and Kerosene are completely insoluble. Determine the percentage extraction of nicotine if 100 kg of feed solution is extracted in (a) One single stage with 150 Kg solvent; (b) three stages in cross flow configuration. All the stages use 50 Kg of kerosene.

(C) Same feed is now extracted in a counter current system. The target is to reduce the Nikotene content to 0.1%. Determine the number of stages if 115 KG of kerosene is used.

Equilibrium data:

x´ (kg nicotine / kg water)	0	0.001011	0.00246	0.00502	0.00751	0.00998	0.0204
y´ (kg nicotine / kg kerosene)*	0	0.000807	0.001961	0.00456	0.00686	0.00913	0.0187

✓

C-free balances

(a)

$x_F = 0.01$

$x_F' = 0.010101$

$F = 100 \text{ kg}$

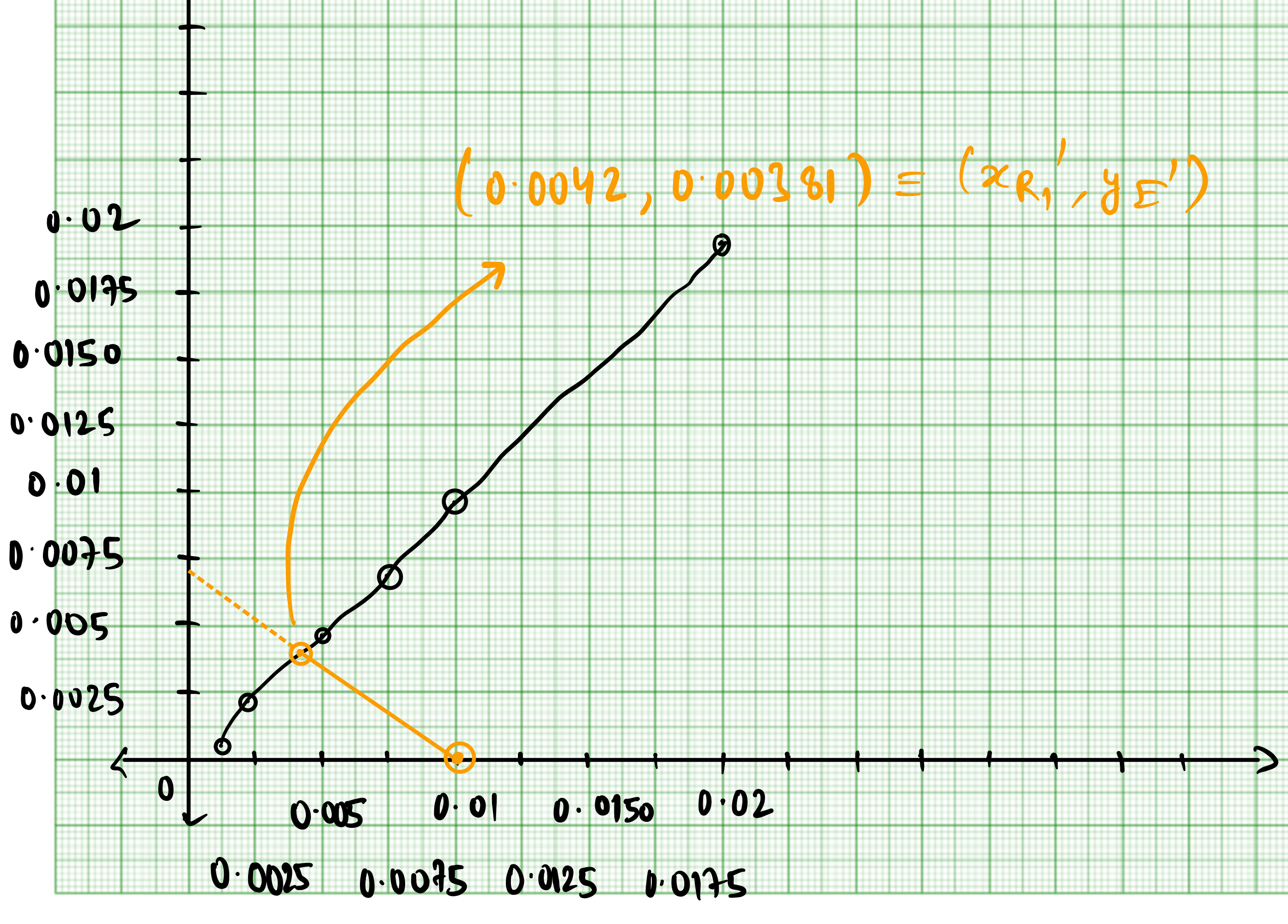
$A = A_F = 99 \text{ kg}$

$B = 150 \text{ kg}$

$y_s' = 0$

$(x_F', y_s') = (0.0101, 0)$

$-A/B = -0.666$



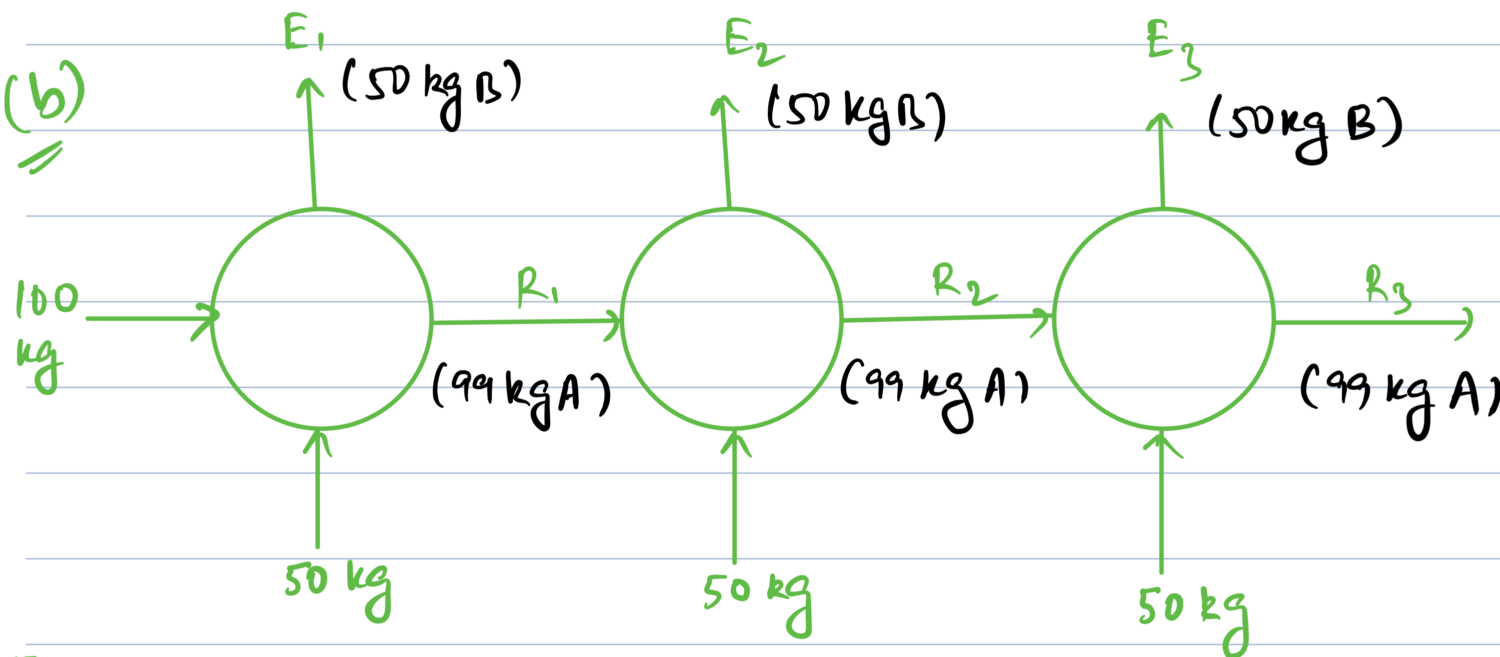
$A_F(x_F' - x_R') \Rightarrow$ Amount of C extracted

$x_F' = \dfrac{C \text{ in } F}{A \text{ in } F}$ $\qquad x_R' = \dfrac{C \text{ in } R}{A \text{ in } R}$

$99(0.010101 - 0.0042) = 0.584199$ kg

$\text{Ans} = \dfrac{0.584199}{1} \times 100\% = 58.42\%$

(b)



For stage 1

$x_F = 0.01 \Rightarrow x_F' = 0.010101$

$-A/B = \dfrac{-99}{50} = -1.98$

Final Answer = 67%

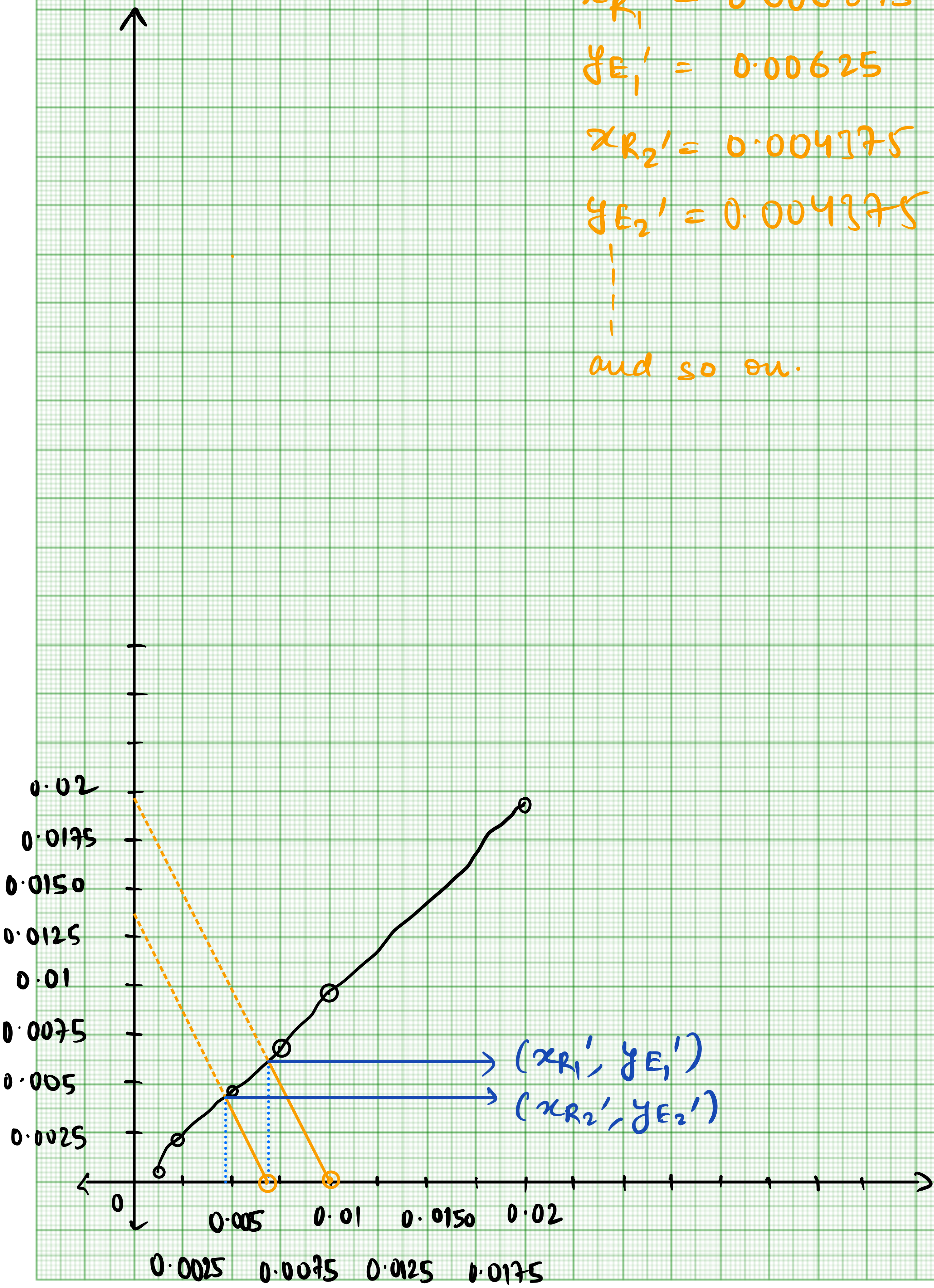
$x_{R_1}' = 0.006875$

$y_{E_1}' = 0.00625$

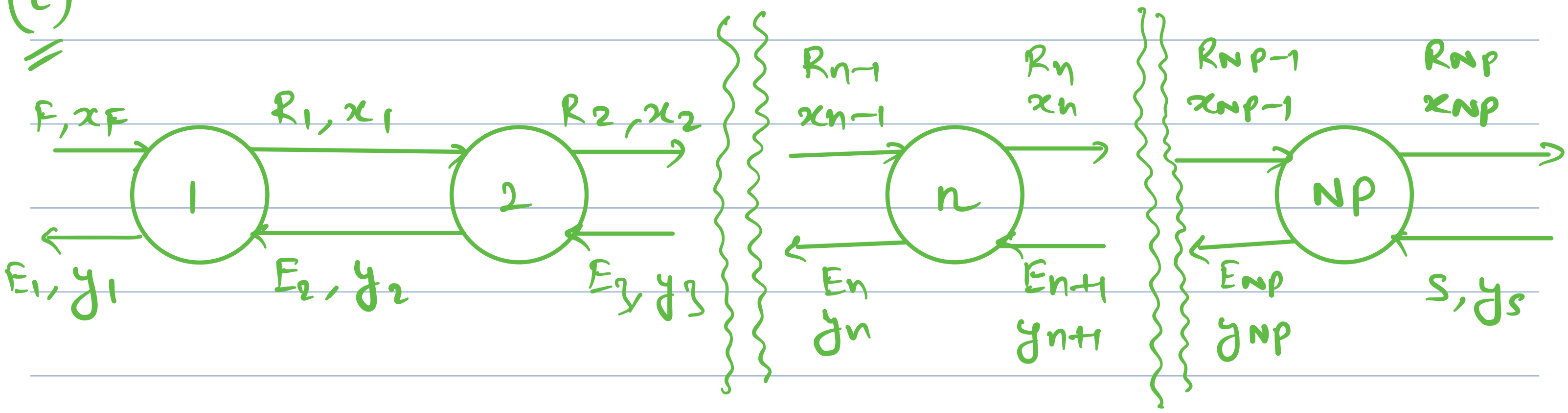
$x_{R_2}' = 0.004375$

$y_{E_2}' = 0.004375$

and so on.



(c)



Overall balance: $F x_F + S y_S = E_1 y_1 + R_{NP} x_{NP}$

C-balance

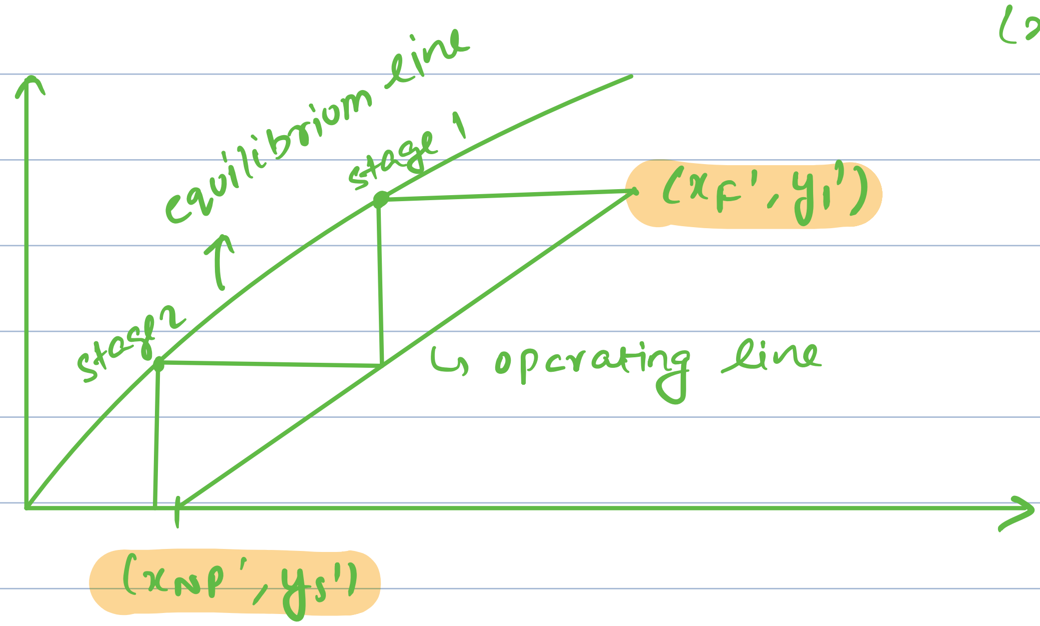
$$B y_S' + A x_F' = A x_{NP}' + B y_1'$$

C-balance on C-free basis

$\Rightarrow \quad \frac{A}{B} = \frac{y_1' - y_S'}{x_F' - x_{NP}'} \quad \Rightarrow$ Find y_1'

$\Downarrow$

Locate (x_{NP}', y_S')
(x_F', y_1')



$y_1' = 0.0078$

11 November

$B \rightarrow$ Insoluble (Inside which the solute is present).

$C \rightarrow$ solute

$A \rightarrow$ solvent

B Free coordinate

N , (x, y)

(#)

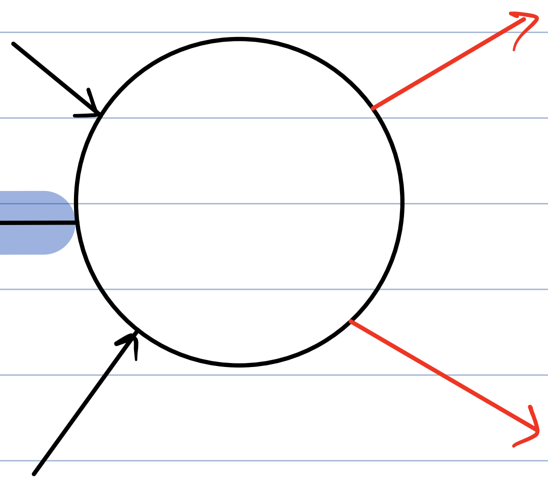
Feed

$F = (A + C)_{Feed} = C_{Feed}$

$B =$ Insoluble

$$N_F = B_F / C_F$$

$$y_F = \frac{C_F}{A_F + C_F} = 1.0$$

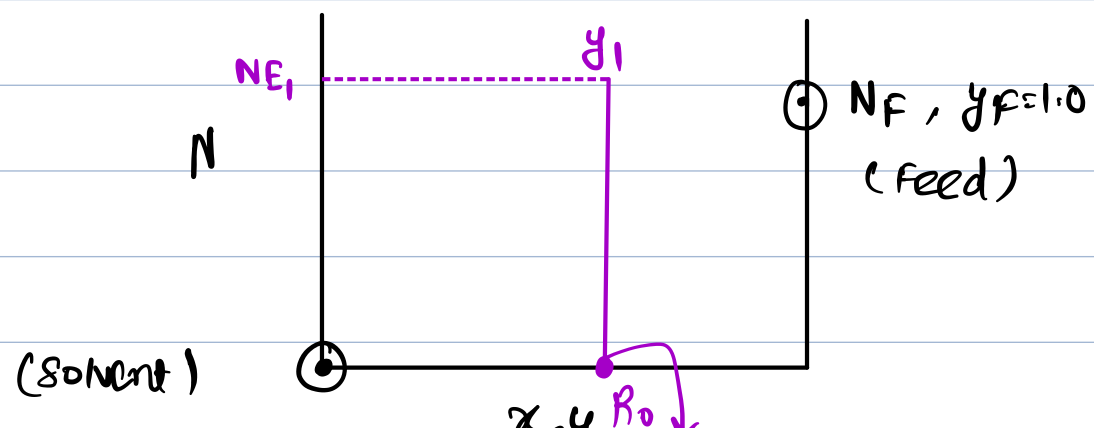


$R_0 =$ Mass of the solvent

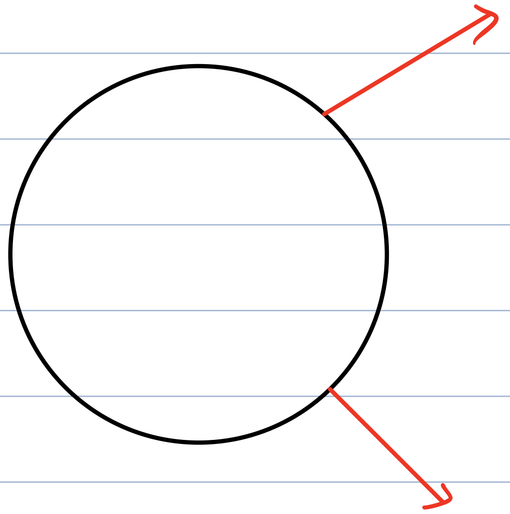
solvent $C_s + A_s$ & A_s $(C_s = 0)$

$$x_0 = \frac{C_s}{A_s + C_s} = 0$$

$$N_0 = \frac{B_s}{A_s + C_s} = 0$$



y x_1



Leached solid (E_1)

$E_1 = A + C$

$N_{E_1} = B/E_1$

$y_1 = \dfrac{C \text{ in } E}{(A+C) \text{ in } A}$

Assumption
⇒ No C, A in E_1

Leached solution (R_1)

R_1 = mass of solution

$x_1 = \dfrac{\text{Mass of } C}{(A+C) \text{ in } R}$

$N_{R_1} = \dfrac{\text{mass of } B}{(A+C) \text{ in } R}$

Assumption
⇒ No B in R_1

In practical situation

$y_1 = x_1$