

Purification: Only latent heat is transferred
 Latent heat of both components are same
 Equimolar & Counter diffusion
 One phase is created from other (original)

Phase Rule

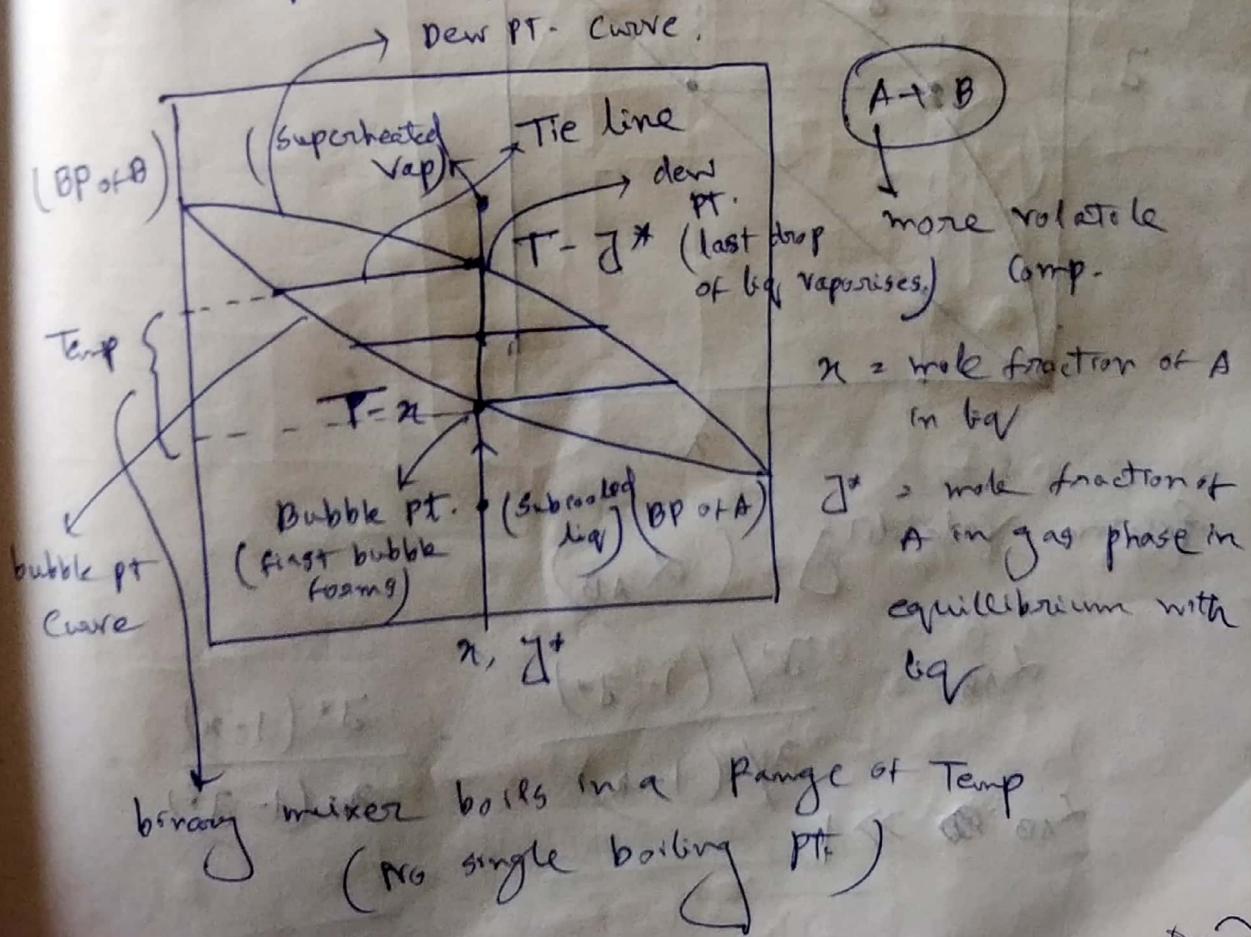
$$F = C - P + 2 \quad C=2 \\ P=2$$

$$\therefore F = 2$$

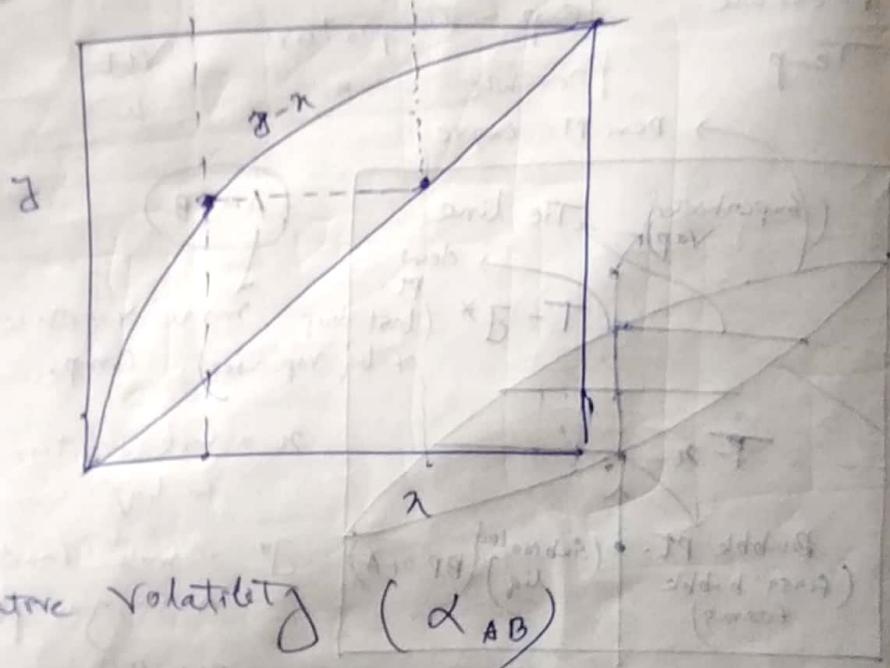
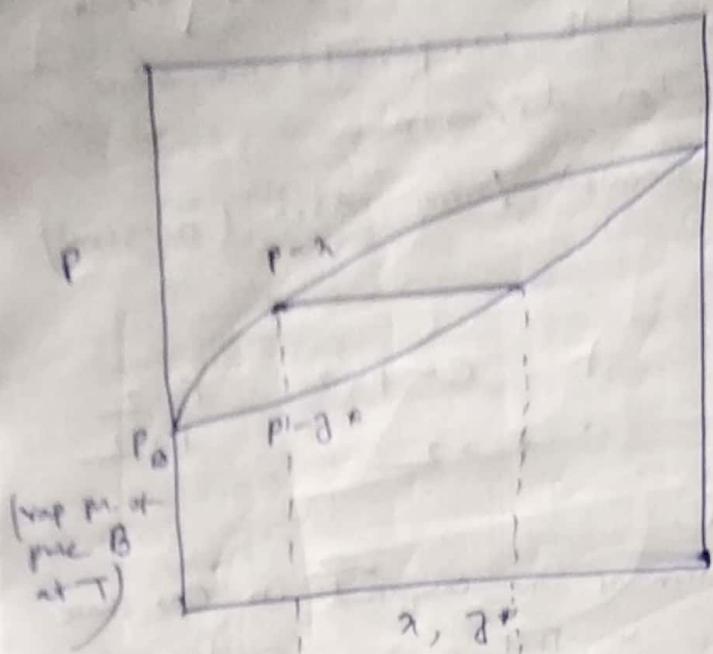
Variables: $P, T,$

Composition of one component in Gas phase
 n u That v \sim liq u

Const	Pressure	Temp - Composition	VLE
n	Temp	Pressure	n



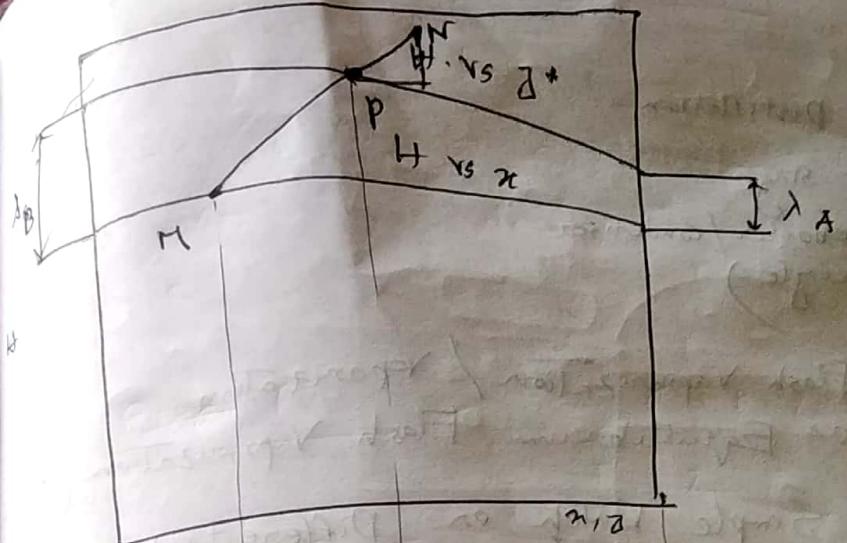
Const T:



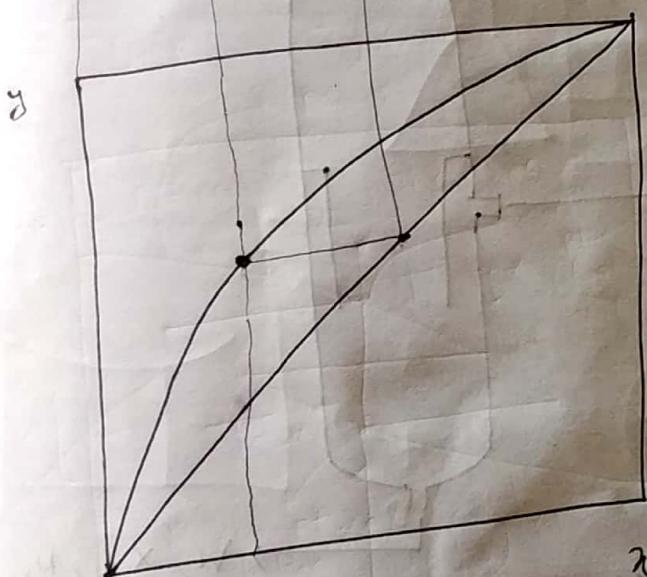
relative volatility (α_{AB})

$$\alpha_{AB} = \frac{y^*/(1-y^*)}{x/(1-x)}, \quad \frac{y^*(1-n)}{n(1-y^*)}$$

$$\alpha_{AB} \gg 1$$



For equal molar latent heat for vaporization
for the entire conc. and Temp range, these 2 lines
are parallel.



M (Z_M, H_M)

M moles of mixture

Z_M = Composition of more volatile

H_M = molar enthalpy

N (Z_N, H_N)

P (Z_P, H_P)

$$M + N = P$$

$$M Z_M + N Z_N = P Z_P$$

$$M H_M + N H_N = P H_P$$

$$\frac{M}{N} = \frac{Z_N - Z_P}{Z_P - Z_M} = \frac{H_N - H_P}{H_P - H_M}$$

M (Z_M, H_M)

are in straight line.

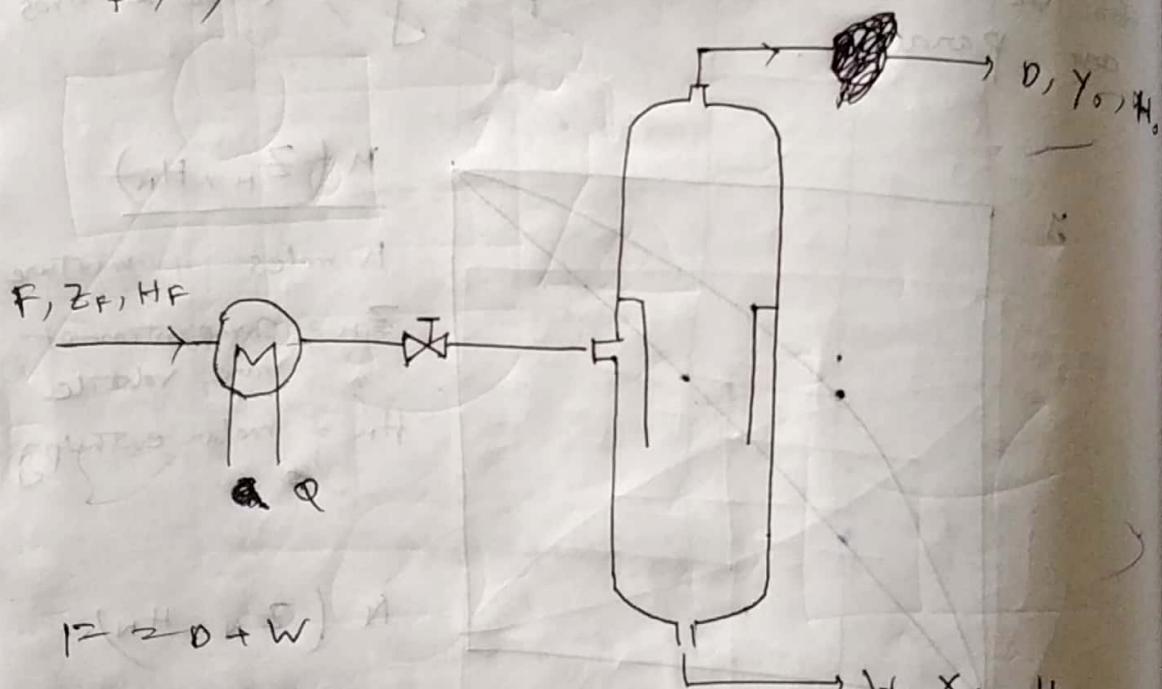
N (Z_N, H_N) & P (Z_P, H_P)

Simple Distillation

(Single Stage)

No. reboiler / condenser
No recycle)

- 1) Flash Vaporization / Vaporization
or Equilibrium Flash Vaporization (ERV)
- 2) Simple Batch or Differential Distillation
- 3) Steam Distillation



$$F = D + W$$

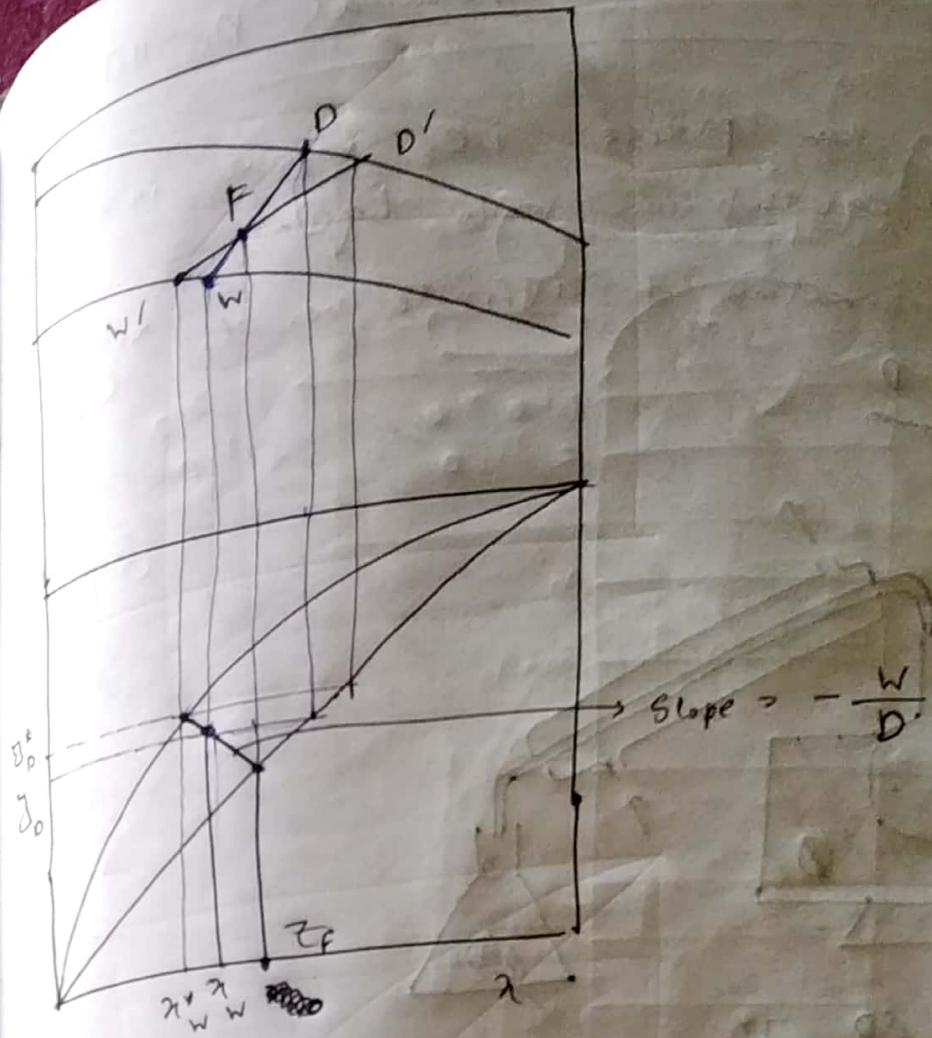
$$Fz_F = DY_D + WX_W$$

$$FH_F + Q = DH_D + WH_W$$

$$F(H_F + \frac{Q}{F}) = DH_D + WH_W$$

$$\therefore -\frac{W}{D} = \frac{Y_D - z_F}{X_W - z_F} = \frac{H_D - (H_F + \frac{Q}{F})}{H_W - (H_F + \frac{Q}{F})}$$

Straight line of slope $-\frac{W}{D}$



Multi Component Mixture

$$\bar{z}_{j,D}^* = m_j \cancel{\pi_{j,w}} \quad \text{or} \quad \pi_{j,w}$$

$$\frac{w}{D} \rightarrow \frac{\bar{z}_{j,D}^* - z_{j,F}}{z_{j,F} - \pi_{j,w}} = \frac{\bar{z}_{j,D}^* - z_{j,F}}{z_{j,F} - \bar{z}_{j,D}^*}$$

$$\bar{z}_{j,D}^* = \frac{z_{j,F} (1 + w/D)}{(1 + w/Dm_j)}$$

$$\sum \bar{z}_{j,D}^* = 1$$

Multi Component Partial Condensation:

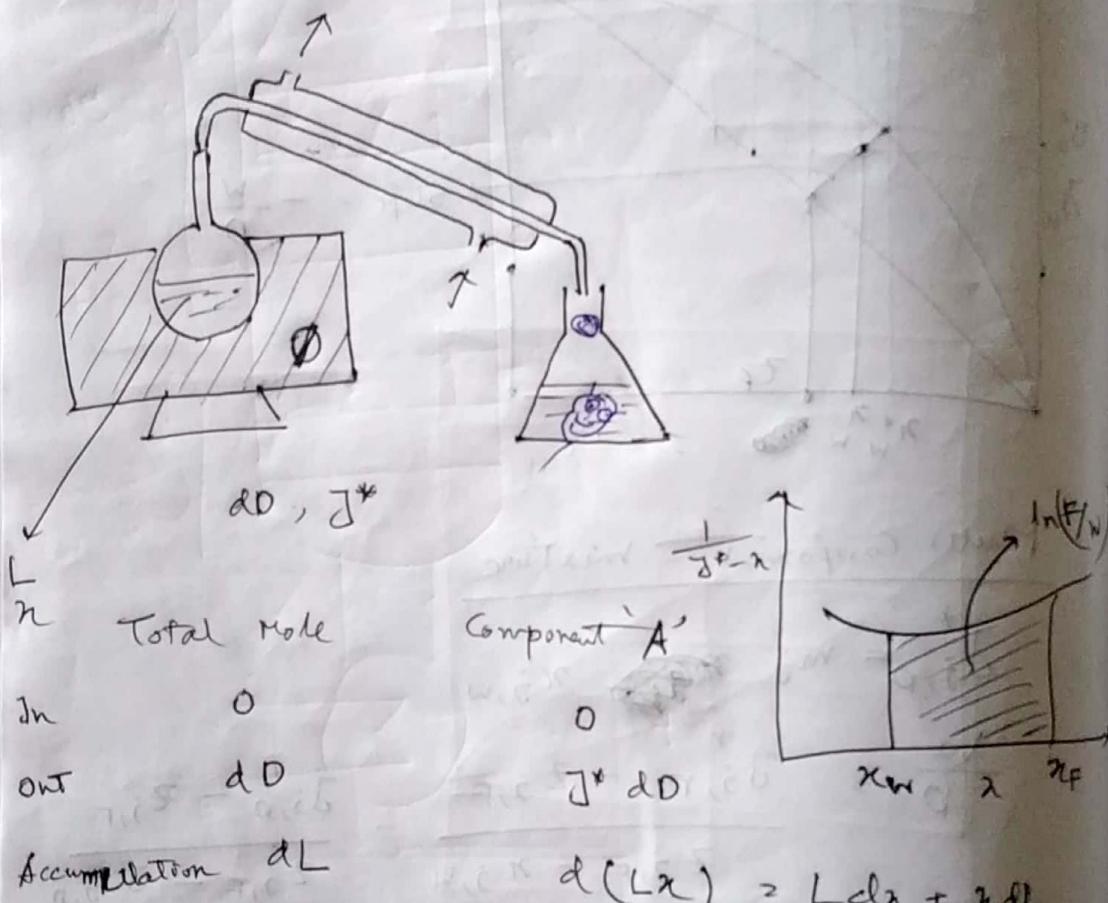
$$\pi_{j,w} = \frac{z_{j,w} \cancel{(1+w/D)}}{(m_j + w/D)}$$

$$\sum \pi_{j,w} = 1.0$$

Simple Batch on Differential Distillation

→ very slow process
in equilibrium with big no. of very small

→ combination of EFD



$$d(Lx) = Ldx + xdl$$

$$\text{In} - \text{out} \rightarrow \text{Accumulation}$$

$$0 - \Delta D = dL$$

$$0 - \bar{J}^* \Delta D = Ldx + xdl$$

$$\therefore (\bar{J}^* - x) dl = Ldx$$

$$\int_F^W \frac{dl}{L} = \int_{x_w}^{x_f} \frac{dx}{\bar{J}^* - x}$$

$$\ln \frac{F}{W} = \int_{x_w}^{x_f} \frac{dx}{\bar{J}^* - x}$$

Rayleigh Eqn

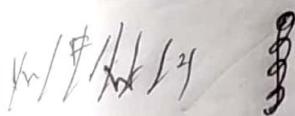
Differential Condensation

$$\ln \frac{P/F}{w/x_F} = \int_{x_F}^{x} \frac{dx}{y - x}$$

If relative volatility const. $y^* = \frac{\alpha x}{1 + (\alpha - 1)x}$

Separation is possible when $\alpha > 1$

$\alpha = 1 \Rightarrow$ Azeotropic mixture



$$\ln \frac{P x_F}{w x_w}$$

$$= \ln \frac{P(1-x_F)}{w(1-x_w)}$$

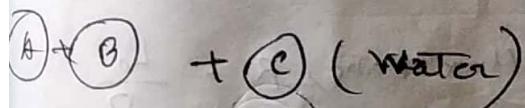
$$P x_F = b(\bar{y}_{\text{ave}} + w x_w)$$

Ternary Distillation Average composition

volatile non volatile



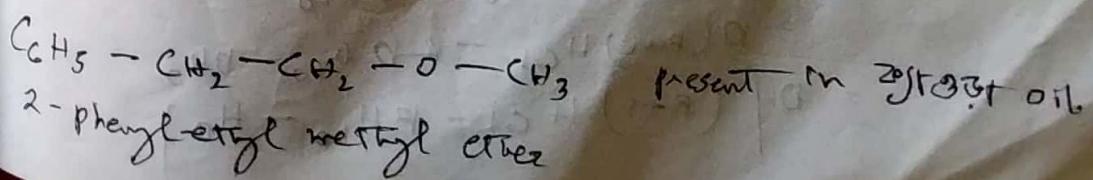
A decomposes at its ~~boiling~~ boiling pt.



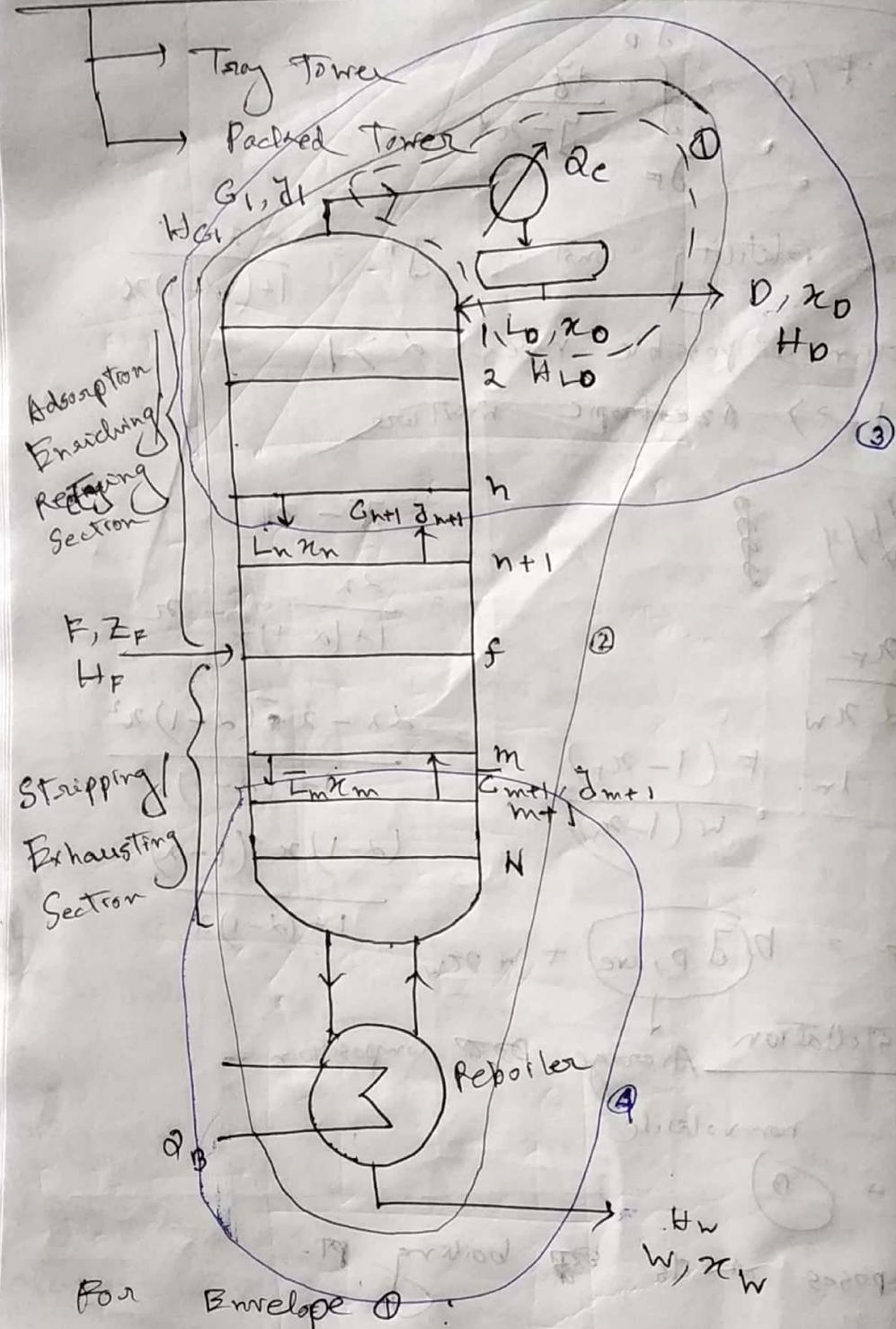
$$P_T = P_A + P_C \quad \bar{y}_A = \frac{P_A}{P_T} \quad \bar{y}_C = \frac{P_C}{P_T}$$

boils at lower temp. \rightarrow no. decomposition of A

but conc. of A decreases.



Continuous Distillation



For Envelope ①:

$$G_1 = L_0 + D$$

$$= RD + D \quad \text{Reflux Ratio, } R = \frac{L_0}{D}$$

$$C_1 H_{G1} = Q_C + D H_D + L_0 H_{L0}$$

$$Q_C = C_1 H_{C1} - D H_D - L_0 H_{L0}$$

$$= D(R+1)H_{C1} - RD H_{L0} - DH_D$$

$$= D \left[(R+1) + C_1 - RH_{L0} - H_D \right]$$

Envelope ②,

$$P_{HP} + Q_B = D_{H_D} + W H_W + Q_C + Q_L$$

$$Q_L = D_{H_D} + W H_W + Q_C + Q_L - F_{HF}$$

heat loss from
the Tower wall

Method of

Method of



Assumption:

Liq and gas flow state is
const for all trays in Adsorption or Stripping
Section.

Ponchon and Sarazin
McCabe and Thiele
we can use it in
our system

Principle of Equimolar overflow and vaporization

If 1 mol of vapour gets condensed then 1 mol of
Liq vaporizes. (heat loss and heat of solution
are minimum)

Envelope ③, $G = L + D \Rightarrow PD + D = D(R+1)$

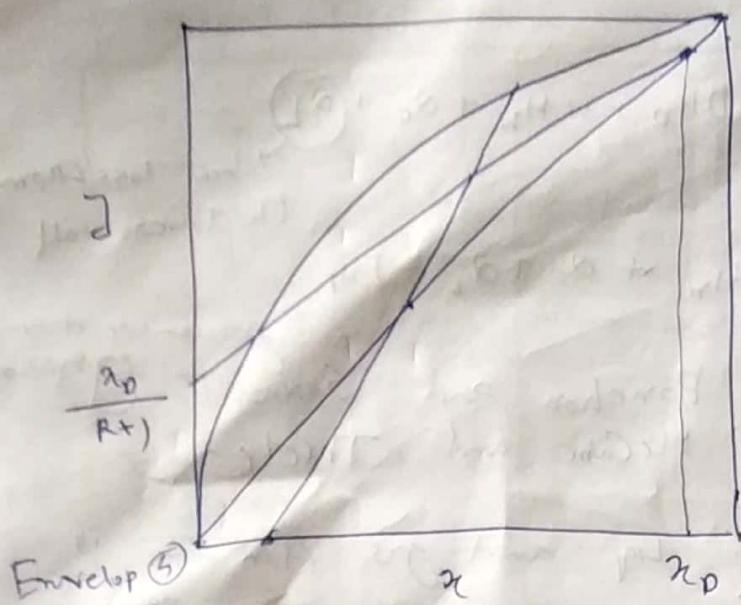
$$G Y_{n+1} = L x_n + D x_0$$

$$\Rightarrow Y_{n+1} = \frac{L}{G} x_n + \frac{D}{G} x_0 \\ = \frac{PD}{D(R+1)} x_n + \frac{D}{D(R+1)} x_0$$

$$Y_{n+1} = \frac{P}{R+1} x_n + \frac{1}{R+1} x_0$$

Operating line.

$$\text{If } x_n = x_0, \quad Y_{n+1} = x_0$$



Envelope ③

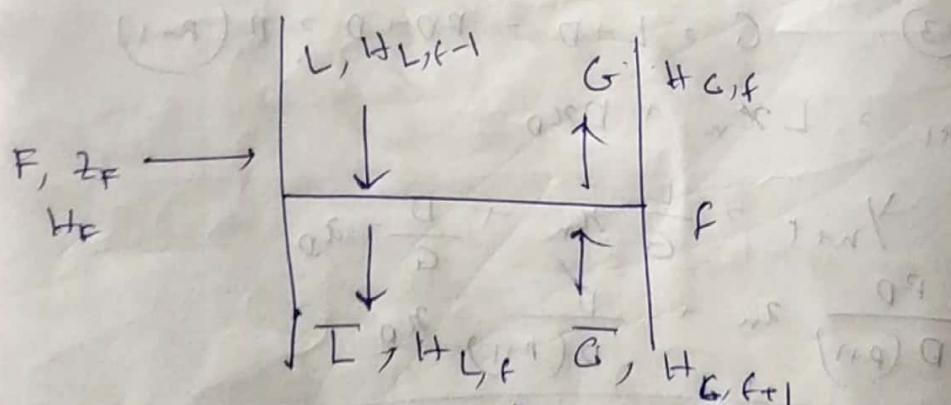
$$L = C + w$$

$$L x_m = \bar{G} y_{m+1} + w x_m$$

$$y_{m+1} = \frac{L}{\bar{G}} x_m - \frac{w}{\bar{G}} x_m$$

$$\boxed{y_{m+1} = \frac{L}{L-w} x_m - \frac{w}{L-w} x_w}$$

~~$x_m = x_w$~~



$$H_F + L H_{L,f-1} + \frac{F + L + \bar{G}}{\bar{G}} H_{G,f+1} = L + C$$

$$= L H_{L,f} + C H_{G,f}$$

Assuming composition does not change
much in only 1 tray,

$$(\bar{C} - G) = (L - F)$$

$$H_F = H_{L,F} - H_G, \dots$$

$$H_{L,F} = H_{L,F-1} = H_L$$

$$H_{G,F} = H_{G,F-1} = H_G$$

$$\text{Assume } R_H F + L H_L + \bar{C} H_G = L H_L + G H_G$$

$$(C - G) H_G = (T - L) H_L - F H_F$$

$$(T - L) H_G - F H_G = (T - L) H_L - R_H F$$

$$\frac{T - L}{F} = \frac{(H_G - H_F)}{(H_G - H_L)} = q \quad \begin{array}{l} \text{heat required to convert 1 mol} \\ \text{of feed to saturated} \\ \text{vapour.} \end{array}$$

wolar latent heat of
Vaporization

$$H_F = 0.4 H_G + 0.6 H_L$$

$$0.6 H_G - H_L$$

Absorption Section

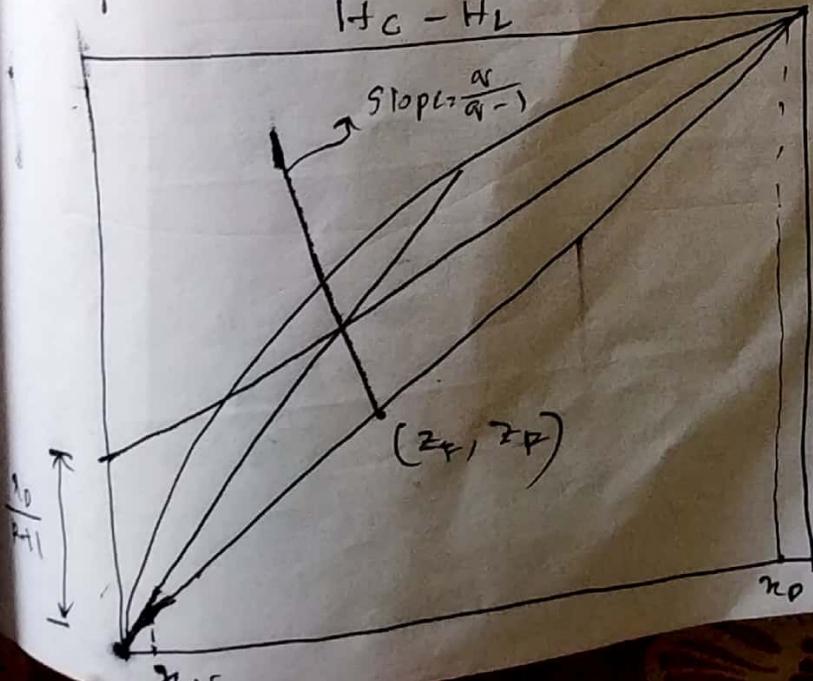
$$C Y_{n+1} = L x_n + D x_0 \quad z_{n+1} = \frac{P}{P+1} z_n + \frac{x_0}{P+1}$$

Stripping Section

$$\bar{C} \bar{z}_{n+1} = T z_m - W z_n$$

$$\bar{z}_{n+1} = \frac{T}{T-W} z_m - \frac{W}{T-W} z_n$$

$$\frac{T - L}{F} = \frac{H_G - H_F}{H_G - H_L} = q$$



$$Fz_F = Dz_D + w_{Z_H}$$

$$\bar{G}Y \rightarrow F\lambda + w_{Z_H}$$

$$GJ = L\lambda + Dz_D$$

$$\underline{\bar{G} - G} J = \underline{L - L} \lambda + \underline{Dz_D + w_{Z_H}}$$

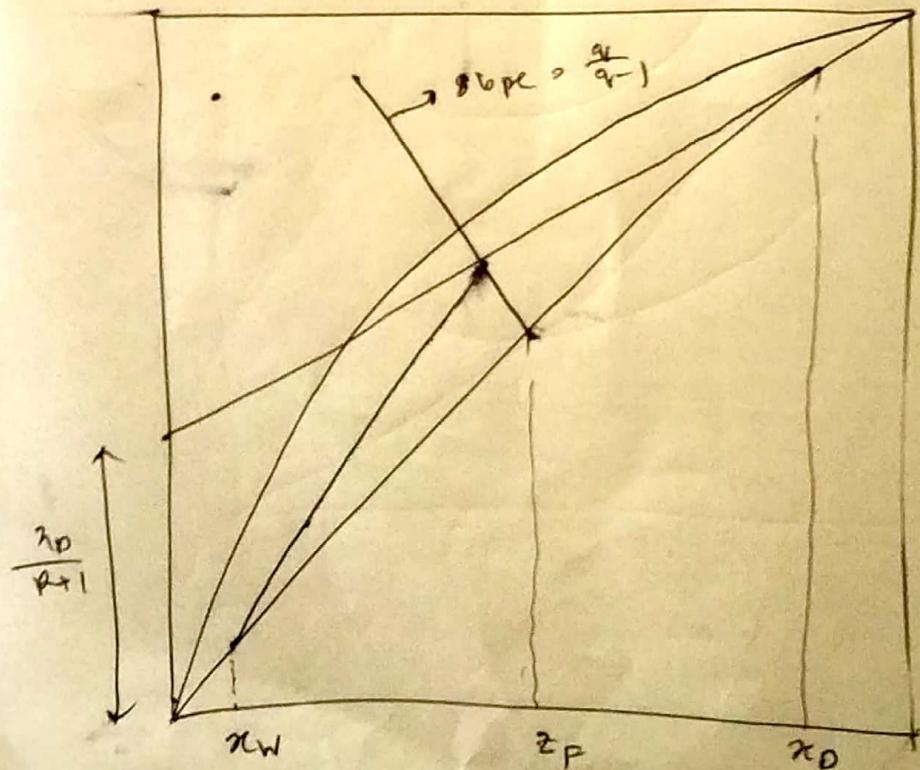
$$\bar{G} + P + L = \bar{L} + G$$

$$\bar{G} - G = (\bar{L} - L) - R \rightarrow F\bar{q} - F = F(\bar{q}-1)$$

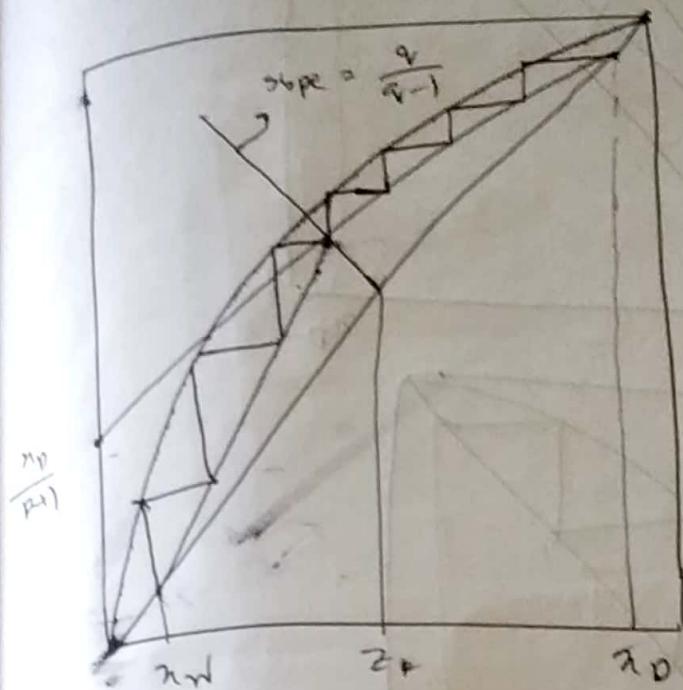
$$J = \frac{\bar{L} - L}{\bar{L} - G} \lambda - \frac{Fz_F}{\bar{L} - G}$$

$$= \frac{F\bar{q}}{F(\bar{q}-1)} \lambda - \frac{Fz_F}{F(\bar{q}-1)}$$

$$\therefore \boxed{J = -\frac{\bar{q}}{\bar{q}-1} \lambda - \frac{z_F}{\bar{q}-1}}$$



Saturated vap. $q = 0$ slope = 0
 Sub-vap $q = 1$ $\rightarrow \infty$
 Subcooled liquid $q > 1$ $\rightarrow >0$
 Superheated vap $q < 0$

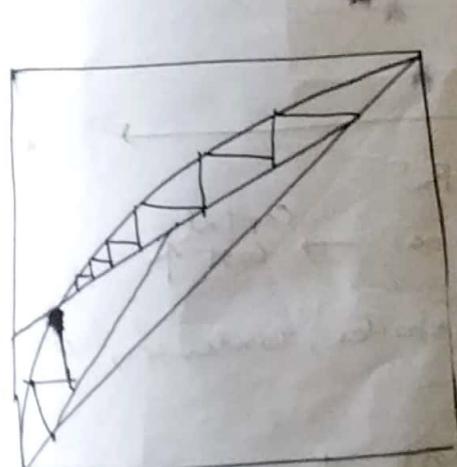


optimum location of feed rate

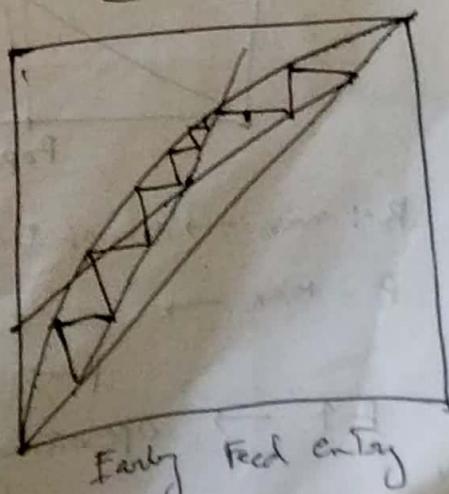
{ Delayed Feed entry \rightarrow If changeover occurs below optimum pt.

Early Feed entry \rightarrow If changeover occurs above optimum pt

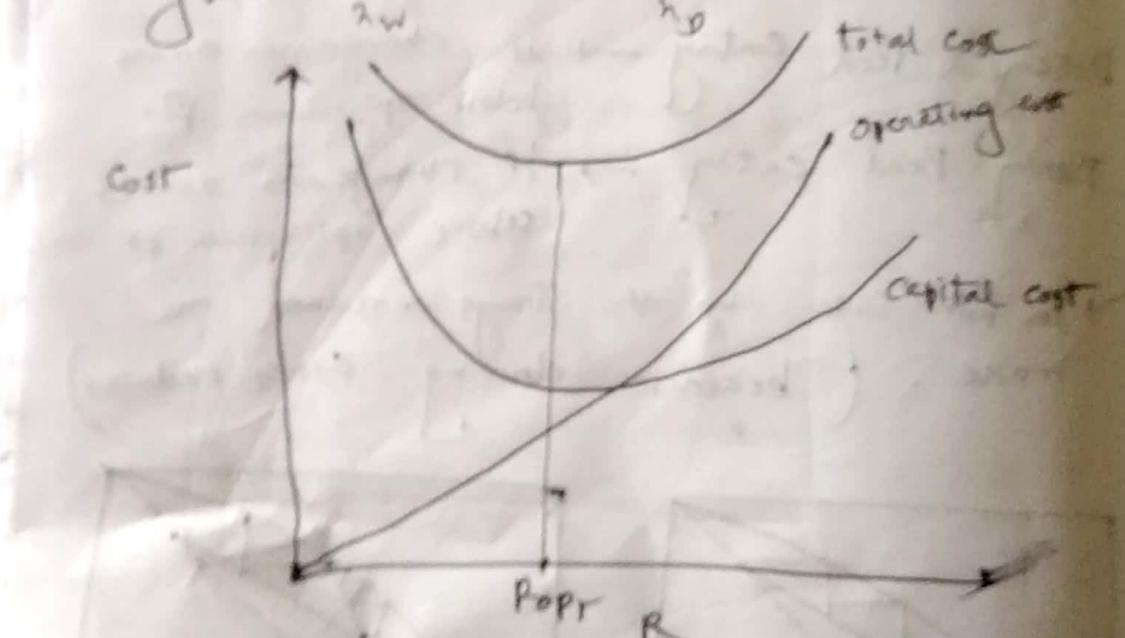
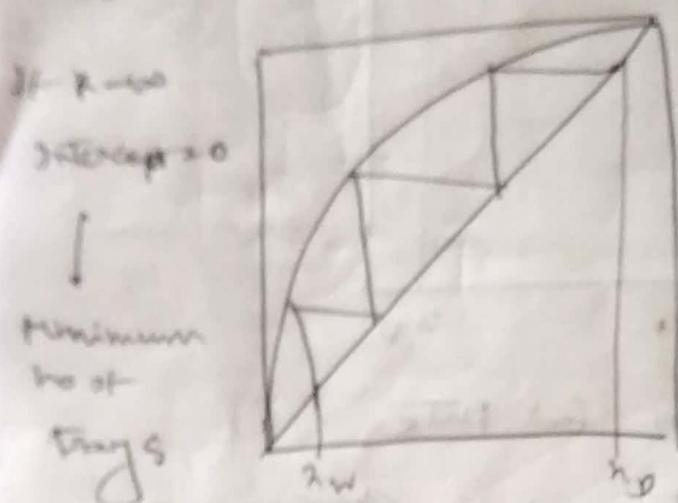
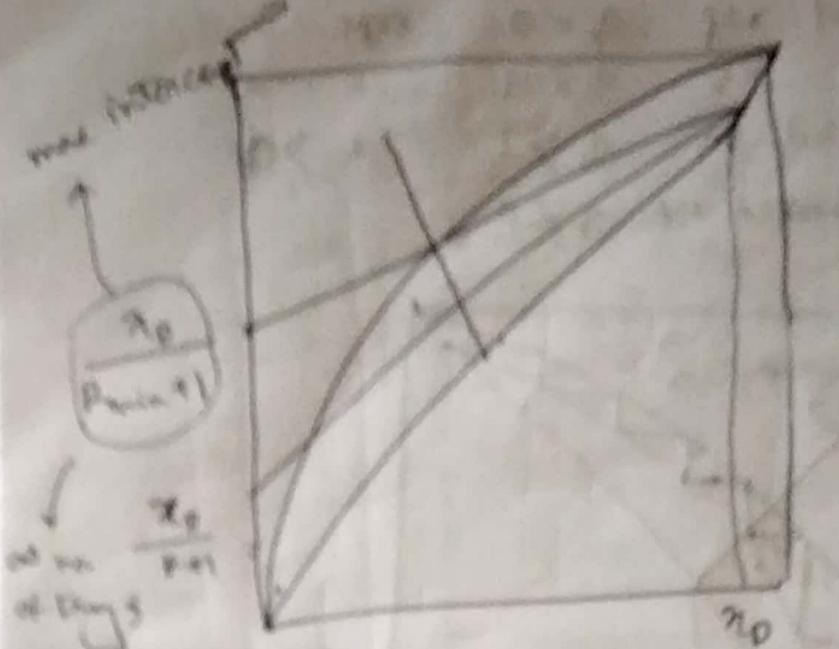
\rightarrow In both cases no. of trays required are more. (because driving force reduces)



Delayed Feed entry



Early Feed entry



R : min \rightarrow No. of trays $\downarrow \rightarrow$ Capital cost \uparrow

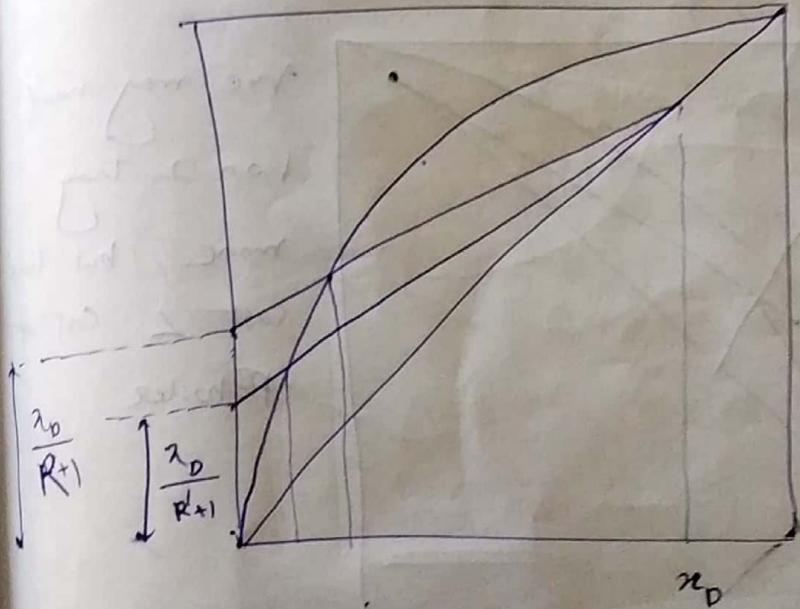
R : Max \rightarrow Cost of reboiler, condenser, reflux pump \uparrow

$R \uparrow \rightarrow$ Operating cost \uparrow

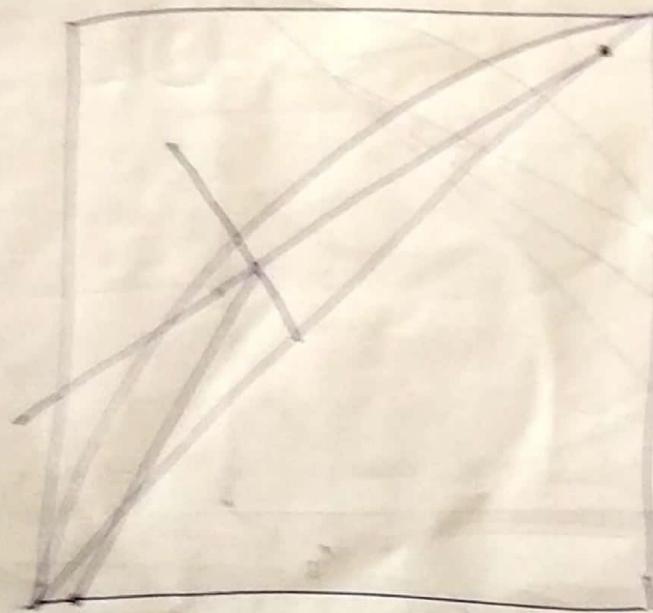
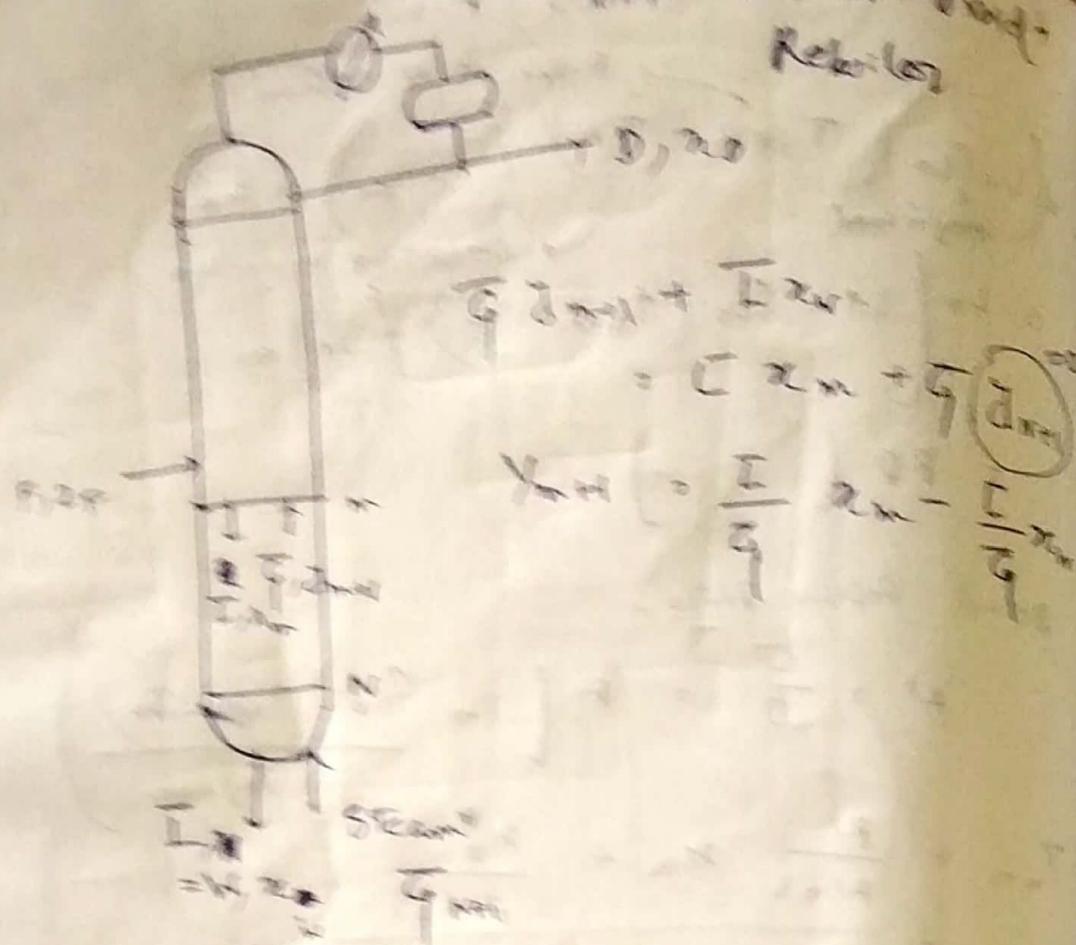
$$\begin{aligned}
 & R_{\text{PT}} = \frac{(1.2 \text{ L to } 1.5) R_{\text{min}}}{\text{Bubble PT at reflux}} \\
 & \left(1 + C_{D,0} \left(T_{\text{BPR}} - T_a \right) / (\lambda_m)_{\text{ave}} \right) + L_0 \\
 & L_0 \left[1 + C_{D,0} \left(T_{\text{BPR}} - T_a \right) / (\lambda_m)_{\text{ave}} \right] \\
 & = RP \left(" \right)
 \end{aligned}$$

Actual Reflux Ratio,

$$\begin{aligned}
 p^1 &= \frac{L}{D} = R \left[1 + \frac{C_{D,0} (T_{\text{BPR}} - T_a)}{(\lambda_m)_{\text{ave}}} \right] \\
 \text{Yield} &= \frac{R^1}{p^1 + 1} n_m + \frac{n_D}{p^1 + 1}
 \end{aligned}$$



When reflux temp. $<$ Bubble pt. \rightarrow quality \uparrow



If Superheated Steam is used

$$\bar{E} = \bar{G}_{\text{inlet}} + \bar{T}_{\text{inlet}} \left(H_{G,\text{sat}} - H_{G,\text{set}} \right) / \lambda_{\text{inlet}}$$

$$= \bar{T}_{\text{inlet}} \left[1 + \frac{H_{G,\text{sat}} - H_{G,\text{set}}}{\lambda_{\text{inlet}}} \right]$$

$P_1 + \frac{E}{B} +$

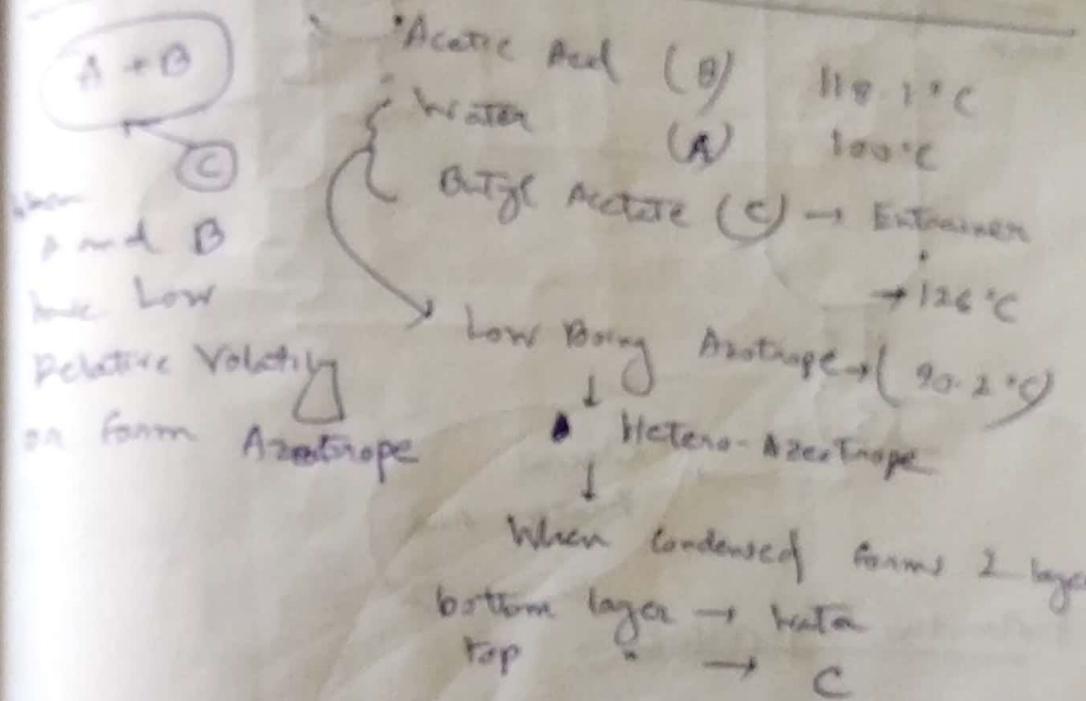
operating line close to diagonal line

No. of trays required

We need more no. of trays than required

\Rightarrow Relying ↑

Azeotropic Distillation & Extractive Distillation

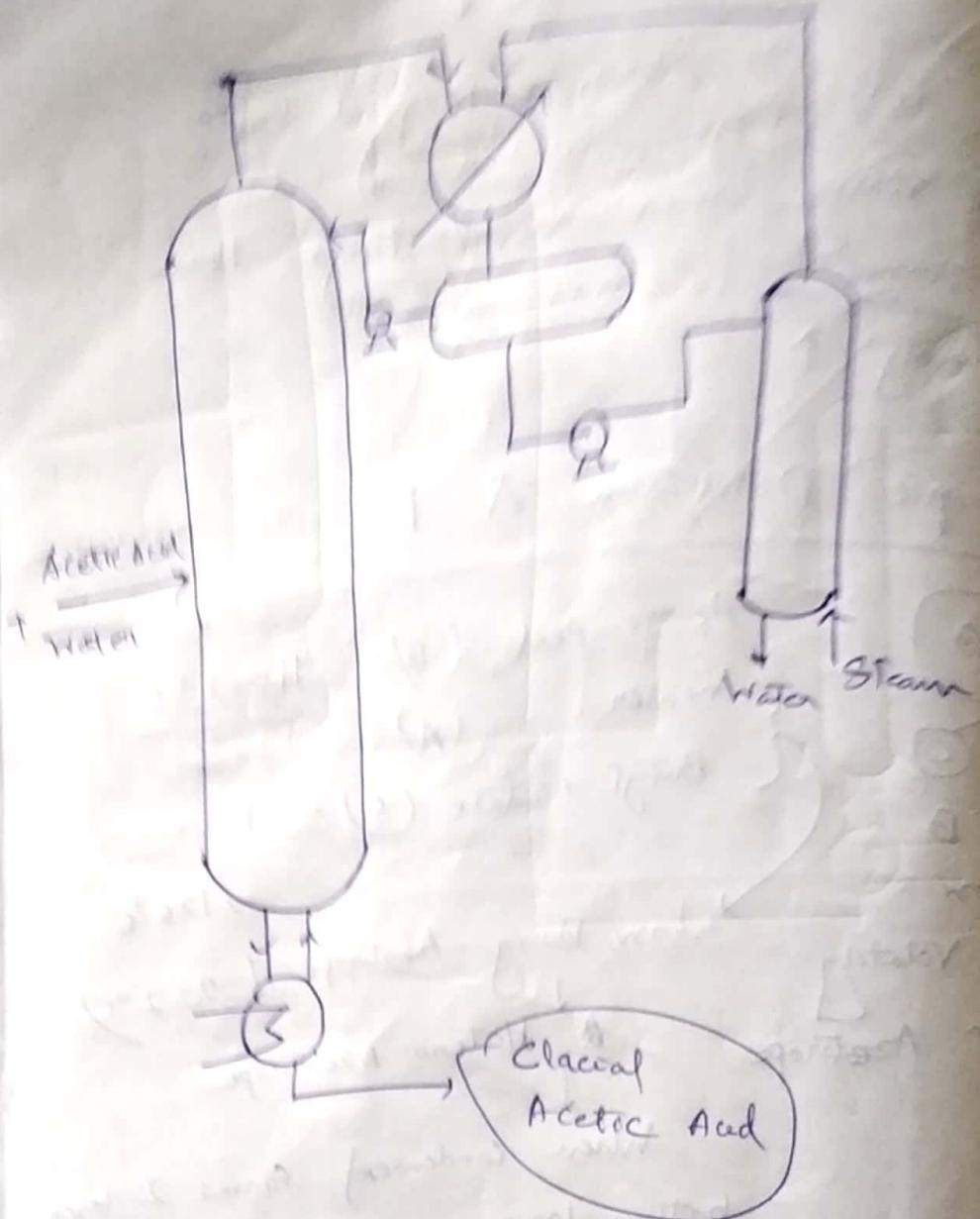


Selectivity: Vapour and liq. phase should be interchangable

(i) Low Relative Volatility

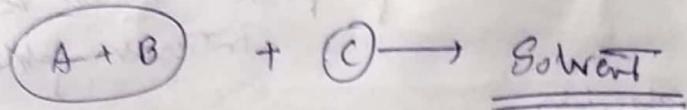
(ii) ~~low~~ higher hetero-Azeotrope

Component present in minimum form L.B. Azeotrope
with entrainer



Extractive Distillation:

→ For low relative volatility



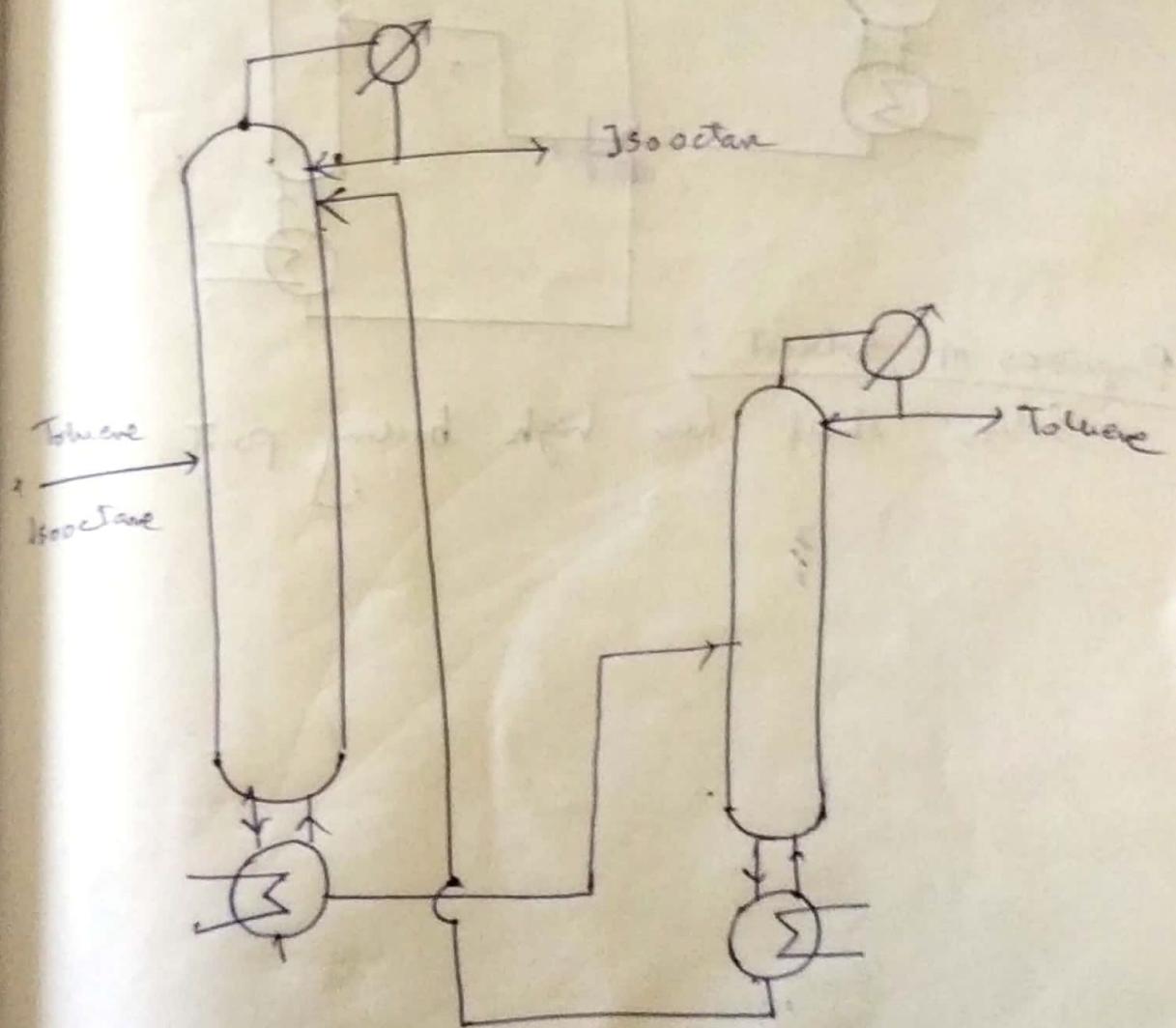
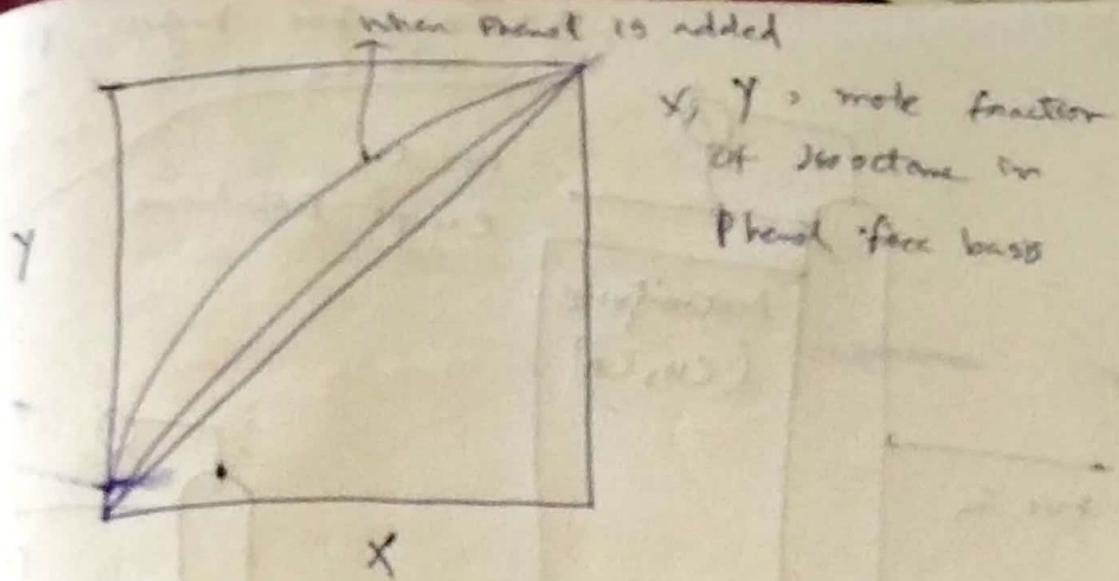
A Toluene (110.8°C)

B Isooctane (92.3°C)

C Phenol (101.4°C)

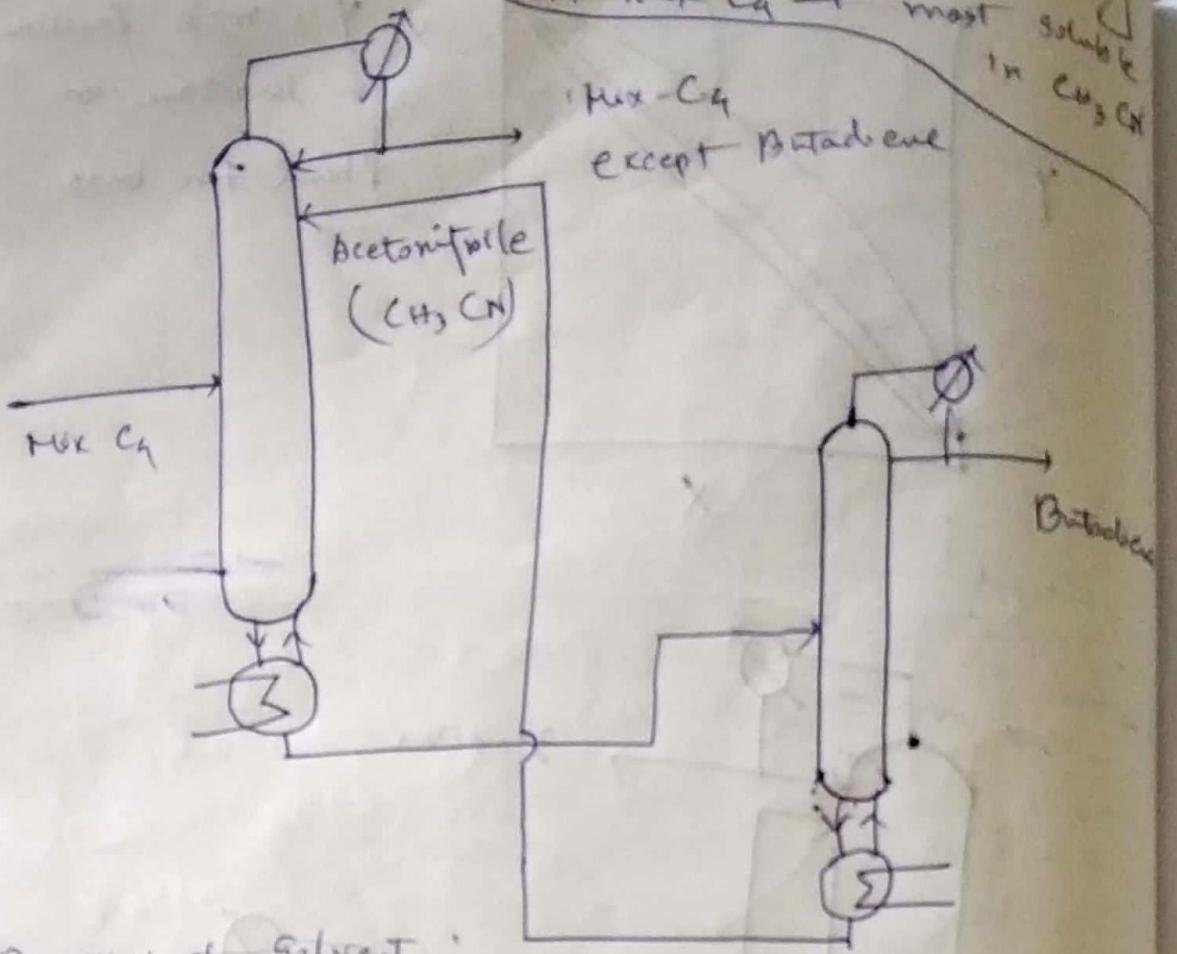
Solubility of Toluene in Phenol is higher.

↓
Increases Relative Volatility of System



Cracking of light naptha \rightarrow Olefines
 C_1, C_2, C_3, C_4

Mix $C_4 \rightarrow$ butadiene (47%)
 Separated by Extractive Distillation



Properties of Solvent :

Solvent should have high boiling point