The effect of Reflux Ration on Number of stages,

1- Maximum Reflux Ratio:

Top operating line: $y_n = \frac{R}{R+1} x_{n+1} + \frac{x_D}{R+1}$

$R = \frac{L_n}{D}$

At maximum reflux ratio i.e total reflux and there is no product withdrawn from the still i.e at total reflux $\Rightarrow D = 0$

$R = \frac{L_n}{D} \Rightarrow R = \infty$

slope of top operating line $= \frac{R}{R+1}$

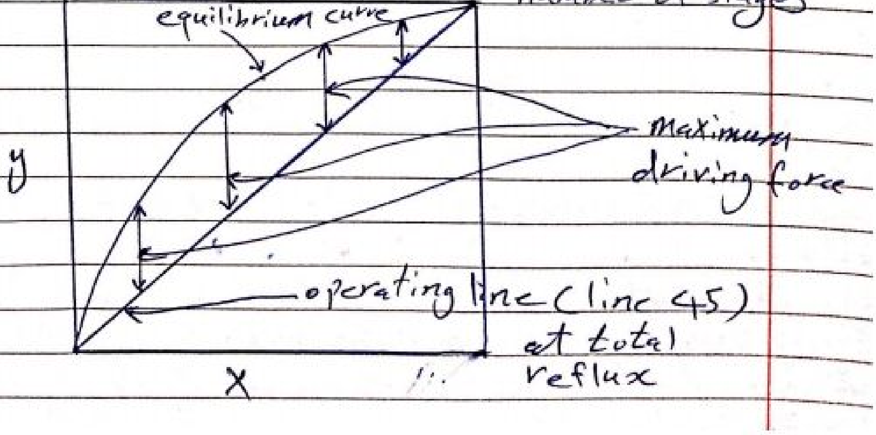
$$\frac{\frac{R}{R}}{\frac{R}{R} + \frac{1}{R}} = \frac{1}{1 + \frac{1}{\infty}} = \frac{1}{1+0} = 1$$

intersept of top operating line $= \frac{x_D}{R+1} = 0$

∴ The top operating line has maximum slope = 1 and intersept = 0

∴ line 45° is top operating line.

∴ at total reflux maximum driving force and minimum number of stages

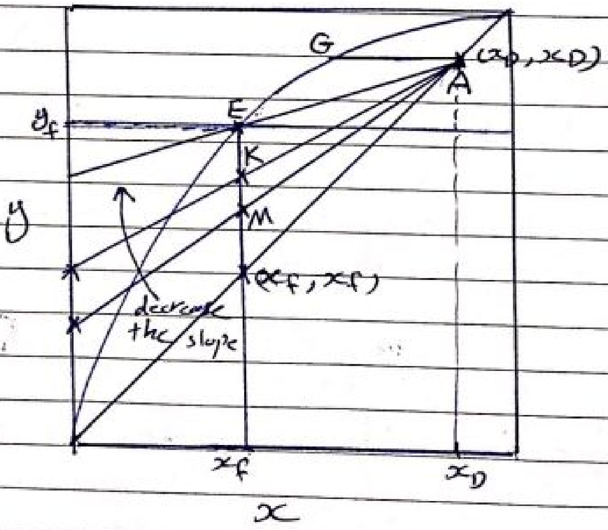


2- Minimum Reflux Ratio:

If the reflux ratio is reduced the slope of the operating line is reduce and more stage are required to pass from x_D to x_f. The slope of line change from AM → AK → AE further reduction in R bring the operating line to AE. When an infinite number of stages is needed to pass from x_D to x_f

This condition are known as minimum reflux $R_{min.}$

$R > R_{min.}$ workable system (AK, AM)
$R < R_{min.}$ impossible system (AG)



$$\frac{R_{min.}}{R_{min}+1} = \frac{x_D - y_f}{x_D - x_f} = \text{slope of operating line at } R_{min.}$$

Conclusion: decrease Reflux Ration ⇒ decrease the slope of operating line ⇒ decrease driving force ⇒ increase the number of stages.

Ex. 11.7: A continuous fractionating column is required to separate a mixture containing 0.695 mol. fraction n-heptane (C_7H_{16}) and 0.305 mol. fraction n-octane (C_8H_{18}) into a product of 99% purity. The column is to operate at a pressure of 101.3 kN/m^2 with a vapor velocity 0.6 m/s. The feed is all liquid at it's boiling point and is supllied to the column at 1.25 kg/s. The boiling point at the top of the column may be taken as 372 K and equilibrium data are.

y (mol. fraction) heptan in vap.	0.96	0.9	0.83	0.74	0.65	0.5	0.37	0.24
x (mol. fraction) heptan in liquid	0.96	0.82	0.69	0.57	0.46	0.32	0.22	0.13

Determine: (1) the minimum reflux ratio that will be required

(2) what diameter of the column would be required if the reflux used where twice the minimum possible.

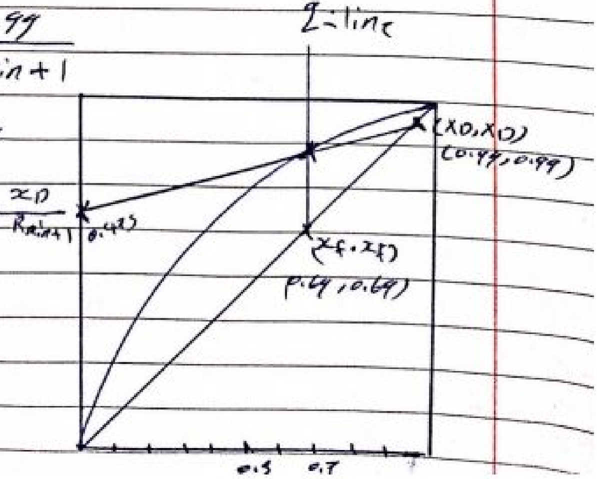
Solution:

1- plot the equilibrium curve

2- The feed is at its (b.p) there fore q-line is vertical

3- The minimum reflux ratio may be found by joining the point (x_D, x_D) with the intersection of the q-line and equilibrium curve. This line when produce to the y-axis give an intersection of

$$0.475 = \frac{x_D}{R_{min}+1} = \frac{0.99}{R_{min}+1}$$



$0.475\, R_{min} + 0.475 = 0.99$

$R_{min} = 1.08$

$R_{op.} = 2\, R_{min}.$

$R_{op.} = 2 \times 1.08 = 2.16$

$R = \frac{L_n}{D} = 2.16$

The mean molecular weight of the feed

$$= (0.695 \times 90) + (0.305 \times 114)$$

$$= 97.3 \text{ kg/kmol}$$

Feed rate $= 1.25 \frac{kg}{s} \times \frac{1}{97.3 \text{ kg/kmol}} = 0.0128 \frac{kmol}{s}$

$F = D + W$

<u>overall Material balance on the n-heptane</u>

$0.0128 = D + W$ —— ①

$0.0128 \times 0.695 = 0.99 D + 0.01 W$ —— ②

$D = 0.00895$ kmol

$W = 0.00385$ kmol

$L_n = D \times R$

$L_n = 0.00895 \times 2.16 = 0.0193$

$V_n = L_n + D = 0.0193 + 0.00895$

$V_n = 0.028$ kmol/s

The vapor density at the top of column.

$$= \frac{1}{22.4} \times \frac{273}{372} = 0.0328 \frac{kmol}{m^3}$$

The Volumetric flow rate $= 0.028 \frac{kmol}{s} \times \frac{1}{0.0328 \frac{kmol}{m^3}}$

$$= 0.853 \frac{m^3}{s}$$

$\therefore$ Area (m) $= \frac{Q\ (m^3/s)}{u\ (m/s)}$

The area required $= 0.853 \frac{m^3}{s} \times \frac{1}{0.6 m/s} = 1.42 m^2$

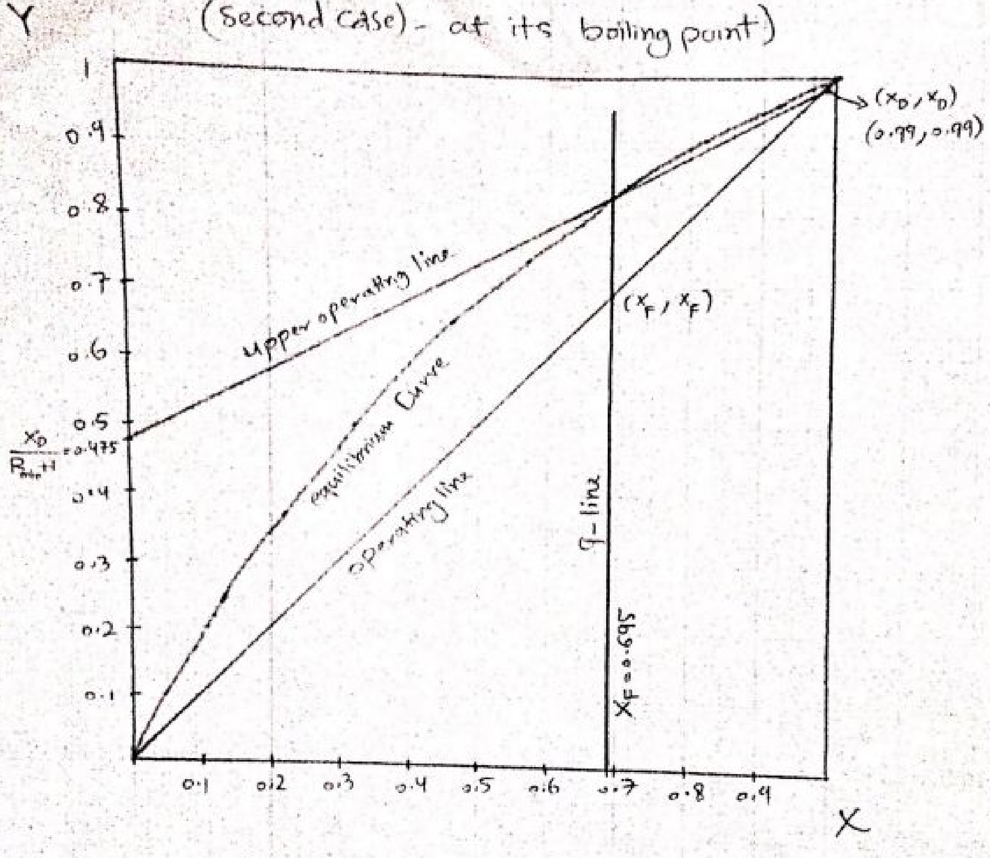
$A = \frac{D^2}{4} \times \pi$

$D = \sqrt{\frac{4A}{\pi}} = \sqrt{\frac{4 \times 1.42}{\pi}}$

Diameter $D = 1.34$ m

Examp (11-7)

Show how to calculat (R_{min}) by knowing (x_D, x_D) & the case of Feed (second case) - at its boiling point)

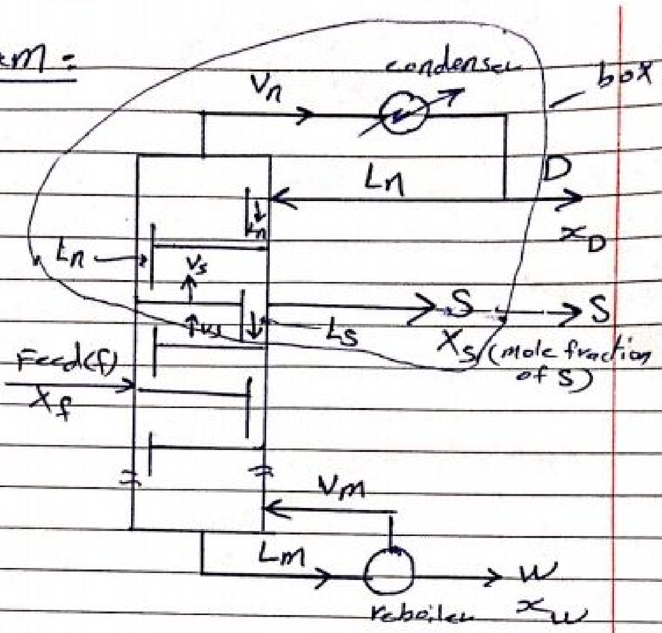


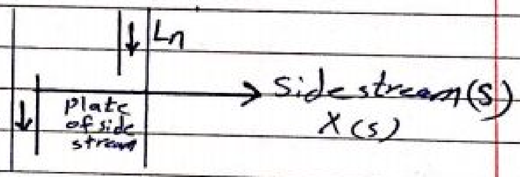
(R_{min}): It is found by joining the point (x_D, x_D) with the intersection of the (q-line) with equilibrium curve. This line will produce the intersept of (u.o.L) with y-axis

$$\text{intersept} = 0.475 = \frac{x_D}{R_{min}+1}$$

$$\therefore R_{min} = 1.08$$

Side stream:





$L_n = L_s + S$
$L_s = L_n - S$

Top operating line for the part above side stream

$$y_n = \frac{L_n}{V_n} X_{n+1} + \frac{D}{V_n} X_D$$

Material Balance for the part of tower above a plate between the feed plat and side stream, (box I)

$V_s = L_s + S + D$
$V_s y_n = L_s X_{n+1} + S X_s + D X_D$

$$\boxed{y_n = \frac{L_s}{V_s} X_{n+1} + \frac{S X_s + D X_D}{V_s}}$$

operating line of side stream of slope $\frac{L_s}{V_s}$ & intersept of $\frac{s X_s + D X_s}{V_s}$

$V_s = V_n$ (لأن الخروج سائل
ولا يؤثر على البخار

slope of operating line $= \frac{L_s}{V_s}$

$L_n = L_s + S$

$L_s = L_n - S$

$\therefore L_n > L_s \quad (L_s < L_n)$

$\because V_s = V_n$

$\therefore \frac{L_s}{V_s} < \frac{L_n}{V_n}$ (slope of operating line of side stream < slope of operating line of top operating line)

* side stream are most often remove with multicomponent system but they can be use with binary mixture.
* This additional operating line cuts the y=x and the two operating lines (Top and side stream) will intersect at $x = x_s$.
* The removal of side stream increases the number of plates required owing to the decrease in liquid rate below the side stream.
* The effect of any additional side stream is to introduce an additional operating line.
* operating line of slope $\frac{L_s}{V_s}$ and pass through $y = x$ when $y = \frac{Sx_s + Dx_D}{S + D}$

when $y = x \Rightarrow x = \frac{L_s}{V_s} x + \frac{Sx_s + Dx_D}{V_s}$

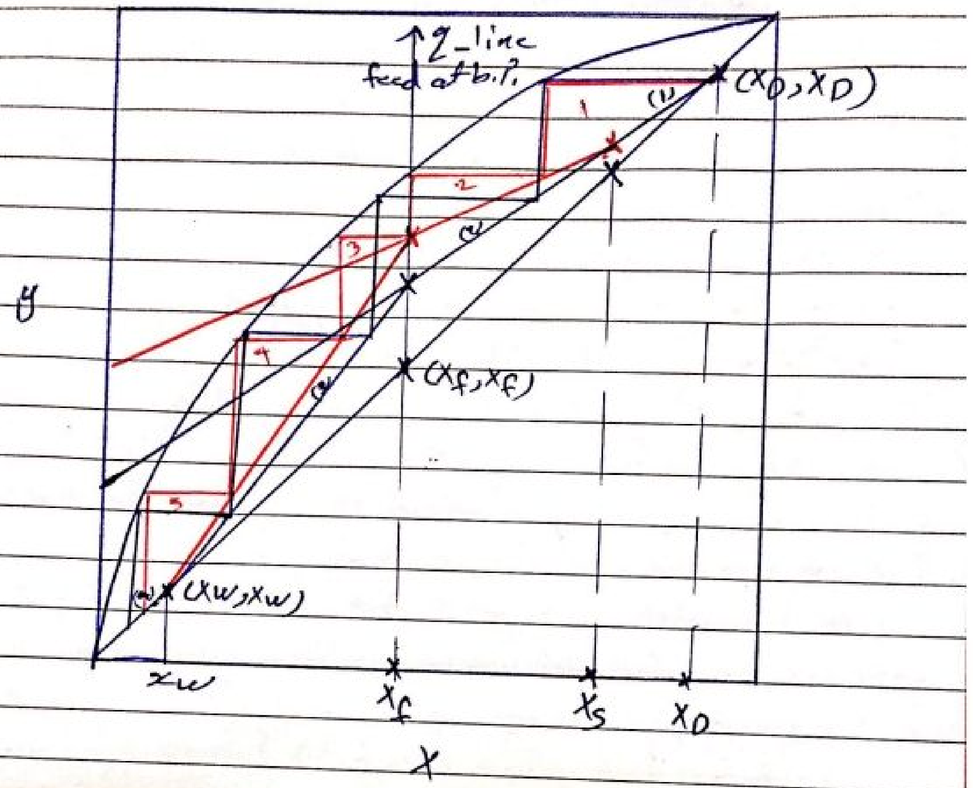
$$x\left(1 - \frac{L_s}{V_s}\right) = \frac{Sx_s + Dx_D}{V_s}$$

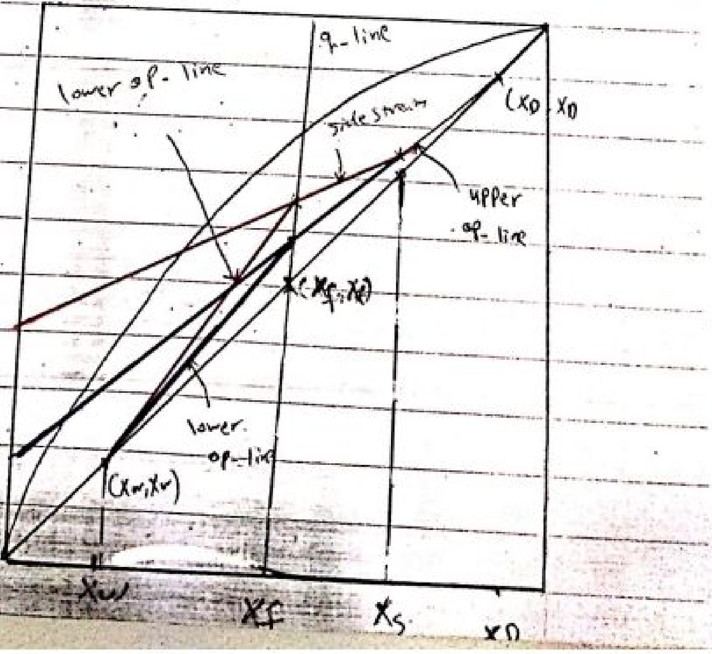
$$x\left(\frac{V_s - L_s}{\cancel{V_s}}\right) = \frac{Sx_s + Dx_D}{\cancel{V_s}}$$

$$x(V_s - L_s) = Sx_s + Dx_D$$

$$x = \frac{Sx_s + Dx_D}{V_n - L_s} = \frac{Sx_s + Dx_D}{V_n - (L_n - S)} = \frac{Sx_s + Dx_D}{\underbrace{V_n - L_n}_{D} + S}$$

$$x = \frac{Sx_s + Dx_D}{S + D}$$


q_line
feed at b.p.
(xD, xD)
(1)
1
2
3
4
5
y
(xf, xf)
(xw, xw)
xw
xf
xs
xD
X


q_ line
lower op_ line
side stream
(xD, xD)
upper op_ line
(xf, xf)
lower op_line
(xw, xw)
xw
xf
xs
xD

EX: 11.3:

A mixture of water and ethyl alcohol containing 0.16 mol fraction alcohol is continuously distilled in a plate fractionating column to give a product containing 0.77 mol fraction alcohol and a waste of 0.02 mol. fraction alcohol. It is proposed to withdraw 25% of the alcohol in the entering stream as a side stream with mol. fraction of 0.5 alcohol. Determine the number of theoretical plates required and the plate from which the side stream should be withdrawn, if the feed is liquid at the boiling point and reflux ratio = 2.

x = 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9

y = 0.35 0.5 0.55 0.6 0.68 0.66 0.73 0.8 0.9

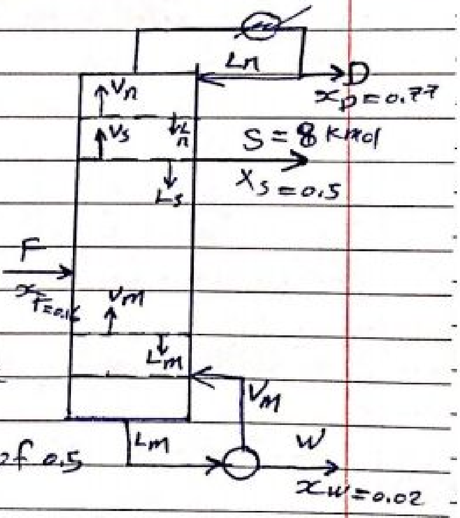
Solution:

Basis = 100 kmol of feed

x_f = 0.16 mol fraction alcohol

$\frac{16}{100} \times 100 = 16$ kmol alcohol in the intering feed

$\frac{25}{100} \times 16 = 4$ kmol alcohol are to be removed in the side stream.



Side stream has a composition of 0.5 mol. fraction alcohol

∴ Side stream (cohol and water) = 8

overall Material balance:

$F = D + W + S$

$100 = D + W + 8$ —— ①

$92 = D + W$ —— ①

Alcohol M.B: $100 \times 0.16 = 0.77D + 0.02W + 4$

$12 = 0.77D + 0.02W$ —— ②

∴ D = 13.55 kmol & W = 78.45 kmol

1) The section between side stream and the top,

$R = \frac{L_n}{D} = 2 \Rightarrow L_n = 2D = 2 \times 13.55 = 27.1$ kmol

$V_n = L_n + D$

$= 27.1 + 13.55 = 40.65$ kmol.

2) The section between the feed and side stream.

$V_s = V_n = 40.65$ kmol.

$L_n = S + L_s$ & $L_s = L_n - S$

$L_s = 27.1 - 8 = 19.10$

3) The section in the bottom of the column.

$L_m = L_s + F$

$= 19.1 + 100 = 119.1$ kmol.

if the feed is at its boiling point

$V_m = L_m - W$

$= 119.1 - 78.45 = 40.65.$

The slope of top operating line $= \frac{L_n}{V_n} = \frac{27.1}{40.65}$

$= 0.67$ from (x_D, x_D)

$(0.77, 0.77)$

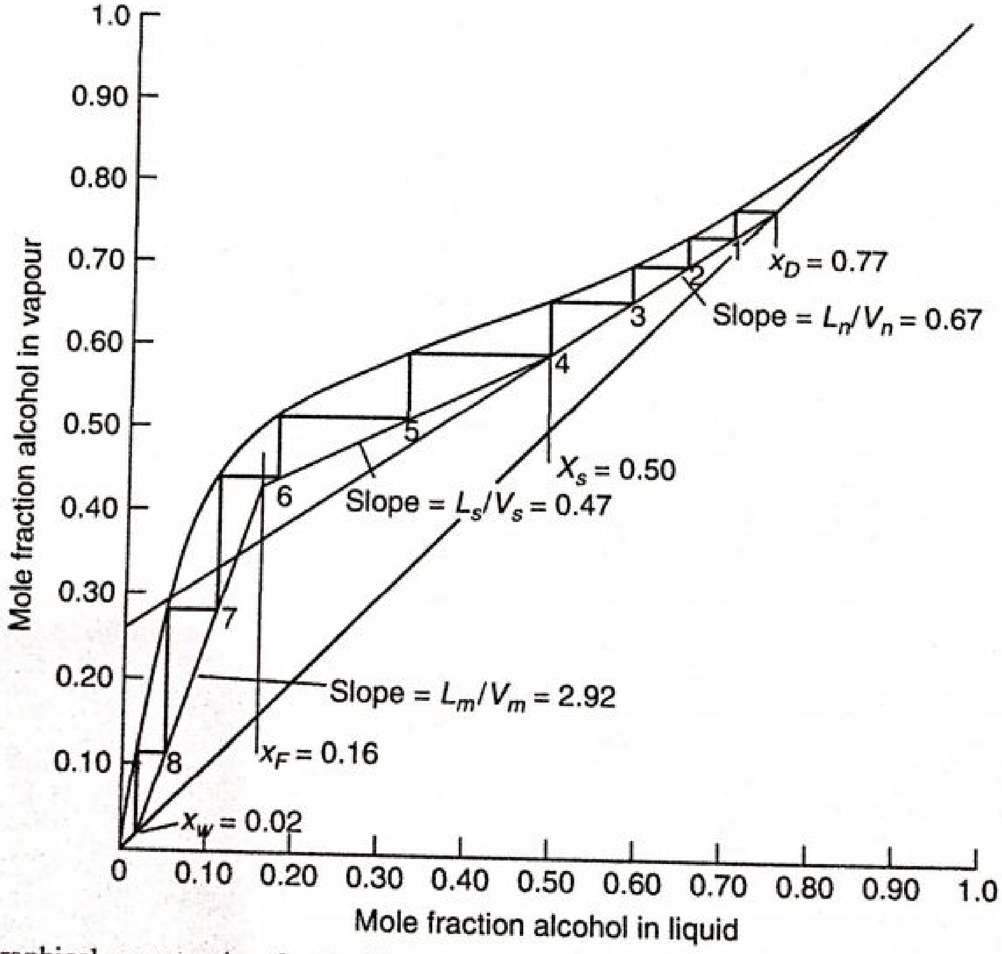
The slope of side stream $= \frac{L_s}{V_s} = \frac{19.1}{40.65} = 0.47$ from

$(x_s, x_s) = (0.5, 0.5)$

The slope of lower operating line $= \frac{L_m}{V_m} = \frac{119.1}{40.65}$

$= 2.95$ from (x_w, x_w)

$(0.02, 0.02)$



Graphical construction for Problem 11.3

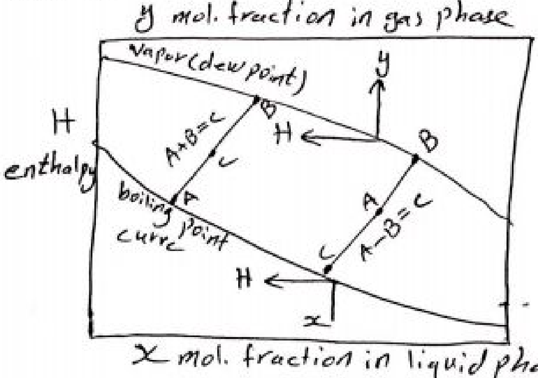
② d.

(H-x) Enthalpy composition system

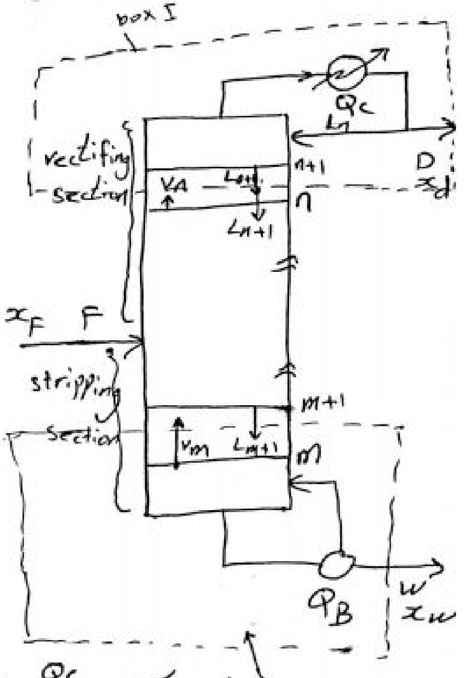
5

- This diagram (Ponchon & Savarit) used for a non-ideal system, where the molar laten heat is no longer constant and there is a large heat of mixing.

* The diagram may be drawn for unit mass or for one mole of material and more convenient to use unit mass as the basis.



In this diagram V & L in mass unit $\frac{kg}{s}$ and composition of stream as mas fraction.



let:

H^V = enthalpy of vapor J/kmol, J/kg

H^L = enthalpy of liquid J/kmol, J/kg

Q_c = heat removed in condenser, W

Q_B = heat put into the boiler, W

box I. M.B

$$V_n = L_{n+1} + D \text{ ——— ①}$$

$$V_n y_n = L_{n+1} x_{n+1} + D x_d$$

$$V_n y_n - L_{n+1} x_{n+1} = D x_d \text{ — ②}$$

$$V_n H_n^V - L_{n+1} H_{n+1}^L = D H_d^L + Q_c \text{ — ③}$$

$$V_n H_n^V = L_{n+1} H_{n+1}^L + D H_d^L + Q_c$$

Putting $\boxed{H_d' = H_d^L + \frac{Q_c}{d}} \Rightarrow \frac{Q_c}{d} = H_d' - H_d^L$ box II

eq. (3) may be written as: $V_n H_n^V = L_{n+1} H_{n+1}^L + D H_d'$

② from eq. (1) & (2)

$$(L_{n+1}+D)\,y_n - L_{n+1}\,x_{n+1} = D\,x_d \Rightarrow L_{n+1}\,y_n - L_{n+1}\,x_{n+1} = D\,x_D - D\,y_n$$

$$\frac{L_{n+1}}{D} = \frac{x_d - y_n}{y_n - x_{n+1}} \quad \text{—— (5)}$$

and from eq. (1) & (4)

$$(L_{n+1}+D)\,H_n^V - L_{n+1}\,H_{n+1}^L = D\,H_d'$$

$$\frac{L_{n+1}}{D} = \frac{H_d' - H_n^V}{H_n^V - H_{n+1}^L} \quad \text{—— (6)}$$

from eq. (5) & (6)

$$\frac{H_d' - H_n^V}{H_n^V - H_{n+1}^L} = \frac{x_d - y_n}{y_n - x_{n+1}} \quad \text{—— (7)}$$

$$(H_d' - H_n^V)(y_n - x_{n+1}) = (H_n^V - H_{n+1}^L)(x_d - y_n)$$

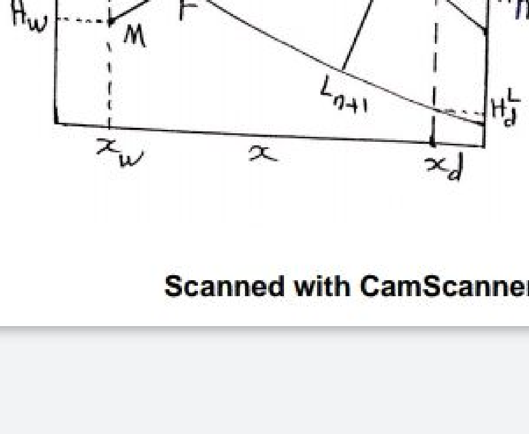
$$\boxed{y_n = \left[\frac{H_d' - H_n^V}{H_d' - H_{n+1}^L}\right] x_{n+1} + \left[\frac{H_n^V - H_{n+1}^L}{H_d' - H_{n+1}^L}\right] x_d} \quad \text{—— (8)}$$

equation (8) is the equation of operating line relating the composition of the vapor y_n rising from a plate to the composition of liquid entering the plate (or the relation between the composition of the vapor and liquid stream between any plates).

from equation (7) it will be seen that all such operating line pass through common pole N of coordinate x_d and H_d'.

a stream N may be defined with mass equal to the difference between the vapor and liquid stream, between two plates of composition x_d and H_d'

$$N = V_n - L_{n+1}$$



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③ ∴ box II . M. B

$$\therefore V_m + W = L_{m+1} \quad \text{or} \quad -V_m + L_{m+1} = W \quad \text{—— (9)}$$

$$V_m y_m + W x_w = L_{m+1} x_{m+1}$$

$$\text{or} \quad -V_m y_m + L_m x_{m+1} = W x_w \quad \text{—— (10)}$$

$$V_m H_m^V + W H_w^L = L_{m+1} H_{m+1}^L + Q_B$$

$$-V_m H_m^V + L_{m+1} H_{m+1}^L = W H_w^L - Q_B \quad \text{—— (11)}$$

putting $\boxed{H_w' = H_w^L - \frac{Q_B}{W}} \longrightarrow (12) \Longrightarrow \boxed{\frac{Q_B}{W} = q_B = H_w^L - H_w'}$

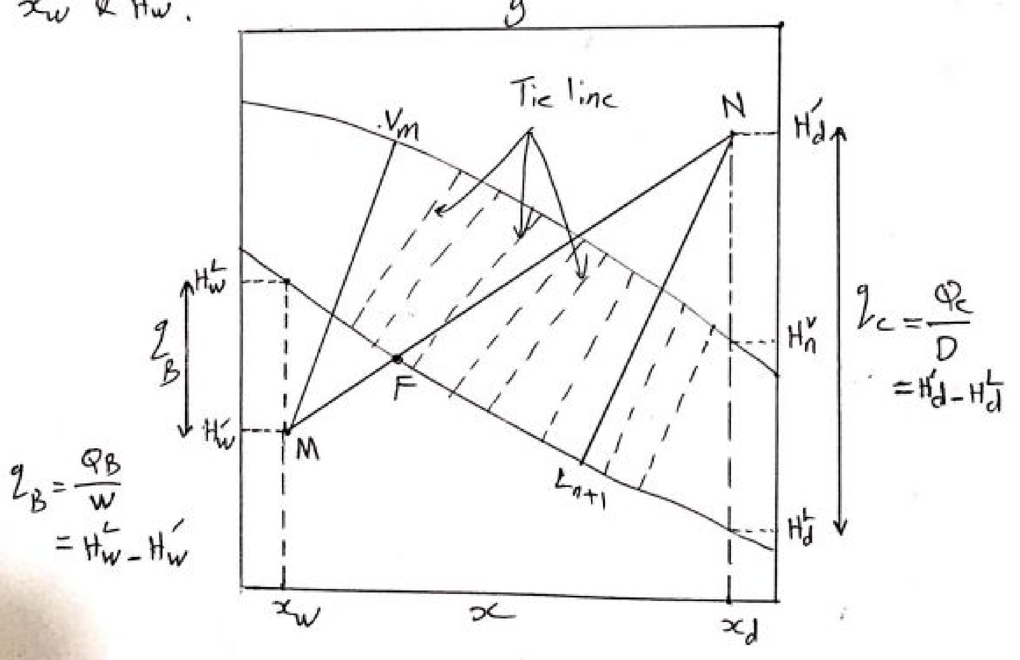
$$-V H_m^V + L_{m+1} H_{m+1}^L = W H_w' \quad \text{—— (13)}$$

then $\frac{L_{m+1}}{W} = \frac{-x_w + y_m}{y_m - x_{m+1}}$ —— (14)

and $\frac{L_{m+1}}{W} = \frac{-H_w' + H_m^V}{H_m^V - H_{m+1}^L}$ —— (15) & $\frac{-H_w' + H_m^V}{H_m^V - H_{m+1}^L} = \frac{-x_w + y_m}{y_m - x_{m+1}}$

$$\boxed{y_m = \left[\frac{-H_w' + H_m^V}{-H_w' - H_{m+1}^L}\right] x_{m+1} - \left[\frac{H_m^V - H_{m+1}^L}{-H_w' - H_{m+1}^L}\right] x_w} \quad \text{—— (16)}$$

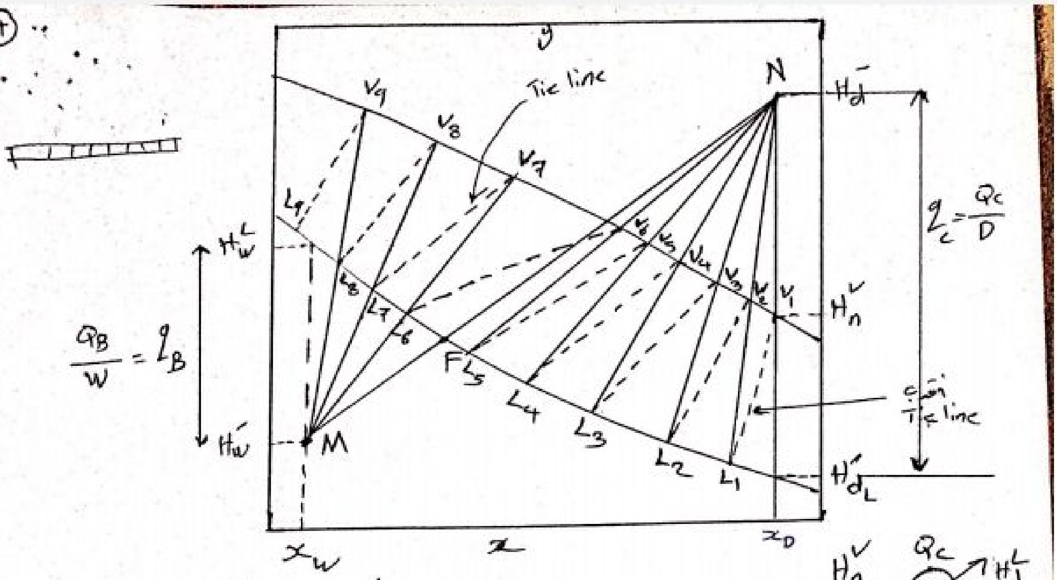
equation (16) represent any operating line below the feed plate and show all lines pass through a common pole point (M) of coordinates x_w & H_w'.

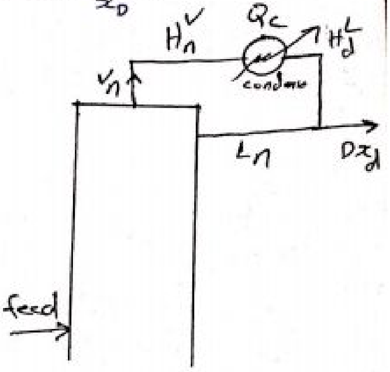


$$q_B = \frac{Q_B}{W} = H_w^L - H_w'$$

$$q_c = \frac{Q_c}{D} = H_d' - H_d^L$$

④





Reflux Ratio

$$H'_d = H^L_d + \frac{Q_c}{d} \quad \text{——} ①$$

$$Q_c = V_n\,(H^V_n - H^L_d) \quad \text{——} ②$$

$$V_n = D_L + L_{n+1}$$

$$H'_d = H^L_d + \frac{D_L + L_{n+1}}{d}\,(H^V_n - H^L_d)$$

$$H'_d = H^L_d + \frac{\frac{d}{d} + \frac{L_{n+1}}{d}}{\frac{d}{d}}\,(H^V_n - H^L_d)$$

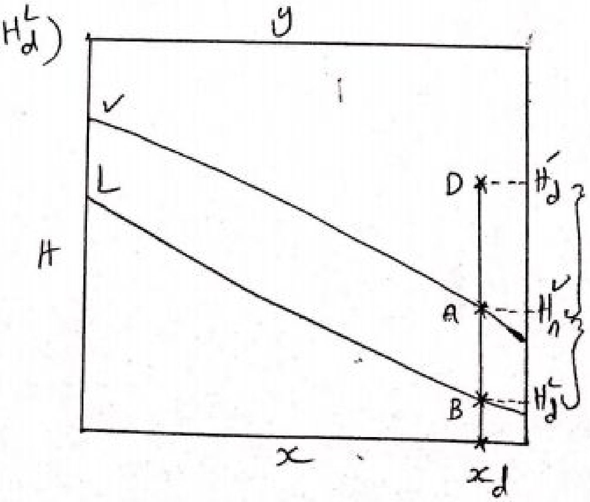
$$H'_d = H^L_d + (1+R)(H^V_n - H^L_d)$$

$$1 + R = \frac{H'_d - H^L_d}{H^V_n - H^L_d}$$

$$R = \frac{H'_d - H^L_d}{H^V_n - H^L_d} - 1$$

$$R = \frac{H'_d - \cancel{H^L_d} - H^V_n + \cancel{H^L_d}}{H^V_n - H^L_d}$$

$$R = \frac{H'_d - H^V_n}{H^V_n - H^L_d} = \frac{DA}{AB}$$



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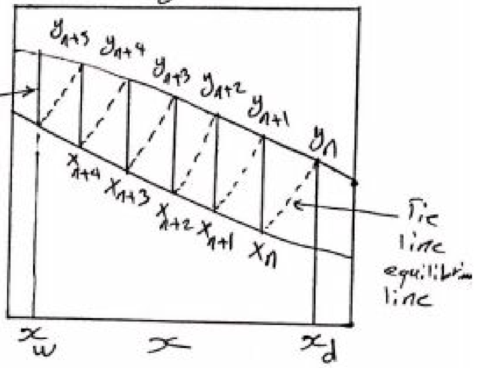
⑤ ∵ Maximum & Minimam Reflux Ratio

1) Maximum Reflux Ratio at total Reflux

$d=0$

$H'_d = H^L_d + \frac{Q_c}{d}$ when $d=0 \Rightarrow H'_d \rightarrow \infty$

وعندما لا توجد نقطة N ووصل $H'_d \rightarrow \infty$ فتصبح جميع الخطوط عمودية



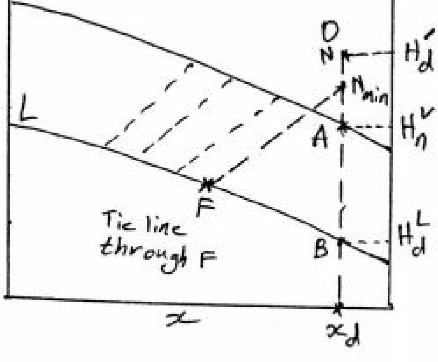
2) Minimum Reflux Ratio

The pole N has coordinate $[X_d, H^L_d + \frac{Q_c}{d}]$

$(\frac{Q_c}{d})$ is the heat removed in the condenser per unit mass of product

IF N is lowered to say N′ the heat q_c falls, but the number of plate required increases. When N lies at N_{min} on the isothermal through F q_c is a minimum but the number of plates required becomes infinite.

N min: For minimum reflux is found by drawing a tie line through F to cut the line of x_D.



* The advantage of H-X chart in the fact that the heat quantities required for the distillation are clearly indicate

* The higher reflux ratio the more heat must be removed per mol. of product and point N rises (both q_c and Q_B are increase)

Multicomponent Distillation

4

- For a binary mixture under constant pressure the equilibrium curve for two component is unique, and if the concentration of one component is known in the liquid phase the compositions of the liquid and of the vapor are fixed.
- For a ternary system the conditions of equilibrium are more complex

The mole fraction y_A in the vapor depends not only on x_A in the liquid, but also on the relative volatility of the other components.

For example volatilities relative to o-cresol

	Temperature (K)		
	353	393	453
phenol	1.25	1.25	1.25
o-cresol	1	1	1
m-cresol	0.57	0.62	0.7
xylenos	0.3	0.38	0.42

Light and heavy key components

In the distillation of multicomponent mixtures the essential requirement is the separation of two components. Such components are called the key components.

- IF four-component mixture A-B-C-D in which A is the most volatile and D is the least volatile is to be separated as shown below.

Feed	Top Product	Bottoms
A	A	
B	B	B ← light key
C	C ← heavy key	C
D		D

Then B is the lightest component appearing in the bottoms and is called the <u>light key component.</u> C is heaviest component appearing in the Distillate and is called the <u>heavy key component</u>
The main purpose of the fractionation is the separation of B from C

<u>The calculation of the number of plates required for a given separation</u> (Lewis & Matheson) (stage to stage calculation)

- If the composition of the liquid on any plate is known then the composition of the vapor in equilibrium is calculated from a knowledge of the vapor pressure or relative volatilities of the individual components. The composition of the liquid on the plate above is then found by using an operating equation.

IF a mixture of components A, B, C, D and so on has mole fraction x_A, x_B, x_C, x_D and so on in the liquid and y_a, y_B, y_C, y_D and so on in the vapor than:

$$y_A + y_B + y_C + y_D + \dots = 1 \text{ —— ①}$$

$$\boxed{\frac{y_A}{y_B} = \alpha_{AB}\frac{x_A}{x_B}}$$

$$\frac{y_A}{y_B} + \frac{y_B}{y_B} + \frac{y_C}{y_B} + \frac{y_D}{y_B} + \dots = \frac{1}{y_B}$$

$$\alpha_{AB}\frac{x_A}{x_B} + \alpha_{BB}\frac{x_B}{x_B} + \alpha_{CB}\frac{x_C}{x_B} + \alpha_{DB}\frac{x_D}{x_B} + \dots = \frac{1}{y_B}$$

$$\Sigma(\alpha_{AB}x_A) = \frac{x_B}{y_B} \text{ —— ②}$$

$$\boxed{y_B = \frac{x_B}{\Sigma\alpha_{AB}x_A}} \text{ —— ③}$$

and similary:

$$\boxed{y_A = \frac{x_A\alpha_{AB}}{\Sigma\alpha_{AB}x_A}} \text{ —— ④}$$

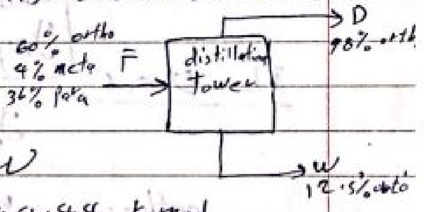
$$\boxed{y_C = \frac{x_C\alpha_{CB}}{\Sigma\alpha_{AB}x_A}} \text{ —— ④}$$

$$\boxed{y_D = \frac{x_D\alpha_{DB}}{\Sigma\alpha_{AB}x_A}} \text{ —— ④}$$

Example: A mixture of ortho, meta, and para-mononitro-
1 toluenes containing 60, 4, and 36 mole percent respectively of the three isomers is to be continuously distilled to give a top product of 98 mole percent ortho, and the bottom is to contain 12.5 mole percent ortho. The mixture is to be distilled at a temperature of 410 K. requiring a pressure in the boiler of about 6.0 kN/m². If a reflux ratio of 5 is used, how many ideal plates will be required and what will be the approximate compositions of the product stream? The volatility of ortho relative to the meta isomer may be taken as 1.7 and of the meta to para as 1.16 over a temp. range of 380-415 K.

$\alpha_{om}=1.7$
$\alpha_{mp}=1.16$

Solution: suppose that the distillate contains 0.6 mol% meta and 1.4 mol% para.



$$F = D + W$$
$$100 = D + W$$

ortho balance $60 = 0.98D + 0.125W$

$$D = 55.56 \text{ kmol} \ \& \ W = 44.44 \text{ kmol}$$

Meta balance

$$0.04 \times 100 = \frac{0.6}{100} \times 55.56 + x_M \times 44.44$$
$$4 = 0.33 + x_M \times 44.44$$
$$\therefore x_M = 8.3 \text{ mol\%}$$

	Feed		Distillate		Bottom	
	kmol	mol %	kmol	mol %	kmol	% mol
ortho	60	60	54.44	98	5.56	12.5
Meta	4	4	0.33	0.6	3.67	8.3
Para	36	36	0.79	1.4	35.21	79.2
	100	100	55.56	100	44.44	100

equation of operating lines:

liquid downflow $L_n = 5D = 277.8$

$$R = \frac{L_n}{D} \Rightarrow L_n = RD$$

$$V_n = L_n + D$$
$$= 277.8 + 55.56$$

below the feed-point, assume the feed is liquid at its boiling point then:

$$L_m = L_n + F$$

$$L_m = 277.8 + 100 = 377.8$$

$$V_m = L_m - W = (377.8 - 44.44) = 333.4$$

The L.O.L

$$y_m = \frac{L_m}{V_m} x_{m+1} - \frac{W}{V_m} x_w$$

ortho: $y_{mo} = \left(\frac{377.8}{333.4}\right) x_{m+1} - \left(\frac{44.44}{333.4}\right) x_w \rightarrow = 0.125$

$$\boxed{\begin{array}{l} y_{mo} = 1.133\, x_{m+1} - 0.0166 \\ y_{mm} = 1.133\, x_{m+1} - 0.011 \\ y_{mp} = 1.133\, x_{m+1} - 0.105 \end{array}} \text{ — ①}$$

The U.O.L

$$y_n = \frac{L_n}{V_n} x_{n+1} + \frac{D}{V_n} x_D$$

ortho: $y_{no} = \left(\frac{277.8}{333.4}\right) x_{n+1} + \left(\frac{55.56}{333.4}\right) 0.98$

$$\boxed{\begin{array}{l} y_{no} = 0.833\, x_{n+1} + 0.163 \\ y_{nm} = 0.833\, x_{n+1} + 0.001 \\ y_{np} = 0.833\, x_{n+1} + 0.007 \end{array}} \text{ — ②}$$

composition of liquid on first plate

- The temp of distillation is fixed = 410K
- The pressure in the still = 6 kN/m^2 (from
- The composition of the vapor in the still from: the relation $y_{so} = \alpha_o x_{so} / \sum \alpha x_s \Rightarrow y_{so} = 1.7 \times 0.125 / 1.099 = 0.191$
- The liquid composition of the first plate for ortho from eq. ①

$$0.191 = (1.133\, x_1 - 0.0166)$$

$$x = 0.183$$

نبدأ من الاسفل صعودا للاعلى يعني: Bottom ↓ Top

$\alpha_{om} = 1.7$ | 1.7×0.12
$\alpha_{mp} = 1.16$ | 1.16×0.08
$\alpha_{pp} = 1$ | 1×0.79
$\sum = 1.099$

- The values of the compositions as found in this way are shown in the following table.
- The liquid on plate 7 has a composition about that in the feed.

⑤ $y_s = \alpha_o x_{so} / \Sigma \alpha x_s$ — تستخدم لكل مادة

$y_s = 1.133\, x_{m+1} - 0.0166$

and the feed will therefore be introduced on this plate. Above this plate the same method is used but the operating equations are equations (2).

- The vapor from the 16th plate has the required concentration of the ortho isomer. Therefore 16 plates will be required

Plate compositions below the feed plate — نستخدم معادلات رقم ①

	component	x_s	αx_s	y_s	x_1	αx_1	y_1
$\alpha = 1.7$	O	0.125	0.211	0.191	0.183	0.308	0.27
$\alpha = 1.16$	M	0.083	0.096	0.088	0.088	0.102	0.09
$\alpha = 1$	P	0.792	0.792	0.721	0.729	0.729	0.64
		1	1.099			1.139	

$y_s = 1.133\, x_{m+1} - 0.0166$

$\frac{0.27 + 0.0166}{1.133} = x_2 = 0.255$

	x_2	αx_2	y_2	x_3	αx_3	y_3
O	0.253	0.43	0.357	0.33	0.561	0.45
M	0.089	0.103	0.086	0.086	0.10	0.08
P	0.658	0.658	0.557	0.584	0.584	0.47
	1	1.191	1		1.245	1

	x_4	αx_4	y_4	x_5	αx_5	y_5
O	0.411	0.698	0.537	0.488	0.83	0.613
M	0.08	0.093	0.071	0.072	0.083	0.061
P	0.509	0.509	0.392	0.44	0.44	0.326
	1	1.30	1	1	1.353	1

	x_6	αx_6	y_6	x_7	αx_7	y_7
O	0.556	0.949	0.674	0.609	1.035	0.721
M	0.063	0.073	0.052	0.055	0.064	0.044
P	0.381	0.381	0.274	0.336	0.336	0.235
	1	1.398			1.435	

تحت feed نستخدم معادلات ②

⑥

plate composition above the feed plate.

	component	x_7	αx_7	y_7	x_8	αx_8	y_8
$\alpha=1.7$	O	0.609	1.035	0.721	0.699	1.136	0.77
$\alpha=1.16$	M	0.055	0.064	0.044	0.051	0.059	0.04
$\alpha=1$	P	0.336	0.336	0.235	0.28	0.28	0.19
		1	1.435	1		1.475	1

فوق ال feed نشغل معادلات رقم ②

	x_9	αx_9	y_9	x_{10}	αx_{10}	y_{10}
O	0.728	1.238	0.816	0.782	1.33	0.856
M	0.047	0.054	0.035	0.041	0.047	0.03
P	0.225	0.225	0.149	0.177	0.177	0.144
		1.517	1		1.554	

	x_{11}	αx_{11}	y_{11}	x_{12}	αx_{12}	y_{12}
O	0.832	1.415	0.891	0.874	1.485	0.92
M	0.035	0.04	0.025	0.029	0.033	0.02
P	0.133	0.133	0.084	0.097	0.097	0.06
	1	1.588	1		1.615	

	x_{13}	αx_{13}	y_{13}	x_{14}	αx_{14}	y_{14}
O	0.907	1.542	0.94	0.932	1.585	0.957
M	0.023	0.027	0.017	0.019	0.022	0.013
P	0.07	0.07	0.043	0.049	0.049	0.03
	1	1.639	1			

	x_{15}	αx_{15}	y_{15}	x_{16}	αx_{16}	y_{16}
O	0.953	1.62	0.97	0.968	1.632	0.98
M	0.014	0.016	0.01	0.01	0.012	0.007
P	0.033	0.033	0.02	0.022	0.022	0.013
		1.669			1.666	

stage No 16 has a compositio about that in the Distillate, therefore we have 16 stages,