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End-Sem
[Mass - Transfer]

(1) For benzene Antoine's equation constants are:-

$A = 6.91, \quad B = 1211, \quad C = 221.$

For toluene Antoine's equation constants are:-

$A = 6.95, \quad B = 1344, \quad C = 215.$

Now using Rault's Law:-

$$P = x_A P_A^{sat} + x_B P_B^{sat}$$

A → Benzene.
B → Toluene.

Now $\boxed{x_A = x_B = 0.5}$

Let

$$\cancel{f(T) = \frac{1}{2}\left[10^{6.91}\right.}$$

$$f(T) = \frac{1}{2}\left[\left(10^{\left(6.91 - \frac{1211}{T+221}\right)} + 10^{\left(6.95 - \frac{1344}{T+215}\right)}\right] - 760$$

$$\therefore f(T) = \frac{1}{2}\left[10^{\left(6.91 - \frac{1211}{T+221}\right)} + 10^{\left(6.95 - \frac{1344}{T+219}\right)}\right] - 760$$

Now

$f(100) = 196$ mm of Hg

$f(90) = (-40$ mm of Hg$)$

$f(95) = (69.2$ mm of Hg$)$

$f(92) = -(0.269)$, $f(92.01) = (-0.046)$

$\therefore$ ~~T_{bubble} of B~~

$$\boxed{(T)_{bubble} \text{ of mixture} \simeq 92^\circ C}$$

$$\therefore \boxed{T_{bubble} = 92.1^\circ C}$$

(b)

$x_1 P_A^{sat} = y_1 P$ (Rault's Law)

$x_2 P_B^{sat} = y_2 P$ (Rault's Law)

$x_1 + x_2 = 1$

$$\frac{y_1 P}{P_A^{sat}} + \frac{y_2 P}{P_A^{sat}} = 1$$

Now :-

$$\boxed{P = 760 \text{ mm of Hg}}$$

$$760\left[\frac{y_{Benzene}}{10^{\left(6.91-\frac{1211}{T+211}\right)}}+\frac{y_{toluene}}{10^{\left(6.95-\frac{1344}{T+219}\right)}}\right]=1$$

Now

$$g(T)=760\left[\frac{y_{benzene}}{10^{\left(6.91-\frac{1211}{T+211}\right)}}+\frac{y_{toluene}}{10^{\left(6.95-\frac{1344}{T+219}\right)}}\right]-1$$

Now $\boxed{y_{Benzene}=y_{toluene}=0.5}$

$\therefore$

$g(100) = (-0.036)$

$g(99) = (-0.007)$

$g(98) = (0.023)$

$g(98.5) = 0.008$

$\boxed{g(98.75) = 0.00042}$

$\therefore \boxed{T_{dew} = 98.75}$

Q-2

(a) $F = 100$ kmol/hr (Benzene = 30%)
(Toluene = 70%)

∵ Benzene is more volatile as in distillate it is recovered ∴ $(z_f = 0.3)$

Now In distillate product (Benzene conc. = 0.95)

∴ $(x_D = 0.95)$

B ∵ Reflux fluid is at bubble pt ∴ $(q=1)$ and vertical line from (z_f, z_f)

From graph:

$$\frac{x_D}{(R_m+1)} = 0.299$$

$$\therefore \frac{0.95}{(R_m+1)} = 0.293$$

$$\therefore (R_m+1) = \cancel{2.17}$$

$$\therefore \boxed{(R_{min} = \cancel{2.17})}$$

$$R_m + 1 = \frac{0.95}{0.293}$$

$$\boxed{R_m = 2.275}$$

(b) From ~~b~~ data given in book ($\alpha = 2.34$) for (benzene- toluene) system

$\therefore$ Equation of curve,

$$\boxed{y = \frac{2.34x}{1+1.34x}}$$

Now from (z_f, z_f) a vertical line is drawn as $(q=1)$

$\therefore$ at intersection with curve $(x=0.3)$

$$\therefore \quad y = \frac{2.34 \times 0.3}{1+1.34 \times 0.3} = \boxed{0.51}$$

$\therefore$ on curve (q-line meets at (0.3, 0.51))

Now from (0.95, 0.95) to (0.3 0.51)

operating line passes

Exercise Book

∴ on equating slopes:

$$\left(\frac{0.95 - 0.51}{0.95 - 0.30}\right) = \frac{R_m}{R_m+1} = 0.692$$

$$\therefore \boxed{R_m = 2.25}$$

it is ~~a~~ analytical value of (R)

∴ R_m from analytical sol^n = $\boxed{2.25}$

R_m from graph = $\boxed{2.27}$

(c) $R = R_{min} \times 1.5$

$R = 1.5 \times 2.27 = \boxed{3.405}$

Now: For derivation:

(a) Overall balance:

$F = D + W$ — (1)

$x_D = 0.95$

$x_W = 0.05$

$x_f = 0.3$

$F = 100$ kmol/hr

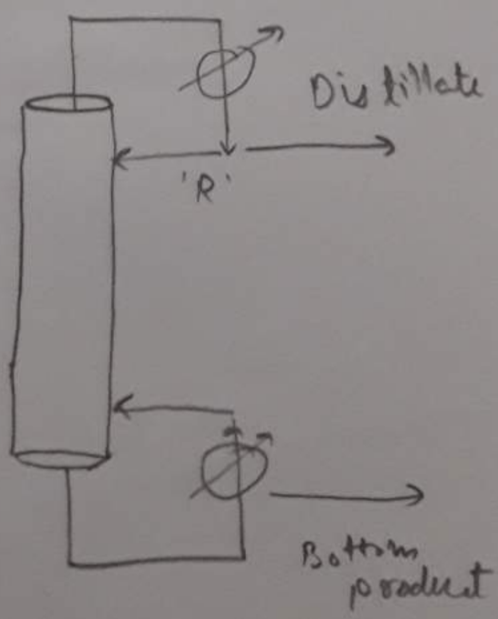
component balance

$F x_f = D x_D + W x_W$ — (2)

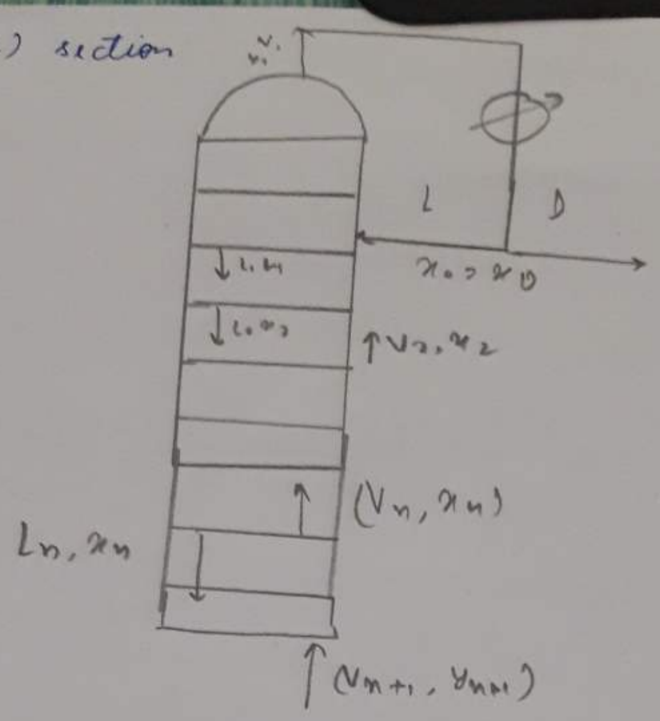
∴ from (1) and (2)

$$\boxed{\begin{aligned} D &= 27.78 \text{ kmol/hr} \\ W &= 72.22 \text{ kmol/hr} \end{aligned}}$$

(b) Now For (ROL)



For (ROL) section



Rectifying section

$$V_{n+1} = L_n + D \quad \text{—— ①} \quad \text{(Overall balance)}$$

$$(V_{n+1}) y_{n+1} = L_n x_n + D x_D \quad \text{—— ②} \quad \text{[Component balance]}$$

$$\therefore (L_n + D) y_{n+1} = L_n x_n + D x_D$$

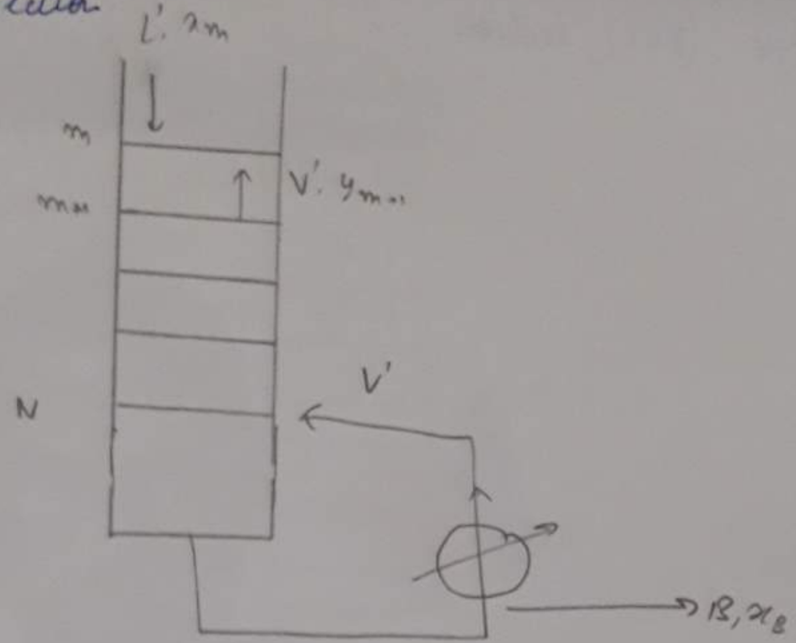
$$\therefore (y_{n+1}) = \frac{L_n x_n}{(L_n + D)} + \frac{D x_D}{(L_n + D)}$$

Assuming
$L_1 = L_2 = L_3 \ldots L_n = L$

Defining
$\left(R = \frac{L}{D}\right)$

$$\boxed{y_{n+1} = \left(\frac{R}{R+1}\right) x_n + \left(\frac{x_D}{R+1}\right)} \longrightarrow \text{Equation of (ROL)}$$

For stripping section



$$\boxed{\begin{aligned} L' &= L + qF \\ V' &= V' + (1-q)F \end{aligned}}$$

Assumming

$$L'_m = L'_{m+1} = L'_{m+2} \cdots = L_n = L'$$

and $V'_m = V'_{m+1} = V'_{m+2} \cdots V'_n = V'$

Over all balance

$$V' + B = L' \quad \text{——— (1)}$$

Meterial balance

$$L' x_m = V' y_{m+1} + B x_B \quad \text{——— (2)}$$

$$\therefore (y_{m+1}) = \left(\frac{L'}{V'}\right) x - \left(\frac{B}{V'}\right) x_B \qquad \text{and } V' = L' - B$$

$$\therefore \boxed{y = \left(\frac{L'}{L' - B}\right) x - \left(\frac{B}{L' - B}\right)} \quad \text{—— (SOL - Eq}^n\text{)}$$

∴ For Rectifying section

$$\left(y = \frac{Rx}{R+1} + \frac{x_D}{R+1}\right)$$

and For stripping section

$$\cancel{y = \left(\frac{L'x}{L'-B}\right) - \left(\frac{B'x_B}{L'-B}\right)}$$

$$\boxed{y = \left(\frac{L'}{L'-B}\right)x - \left(\frac{B}{L'-B}\right)x_B}$$

where $\boxed{B = W}$

and $\boxed{x_B = x_W}$

For $\boxed{R = 3.405}$

$$\boxed{y = 0.77x + 0.21} \longrightarrow \text{(ROL - line)}$$

and $R = \frac{L}{B}$

$\therefore L = 3.405 \times 27.78$

$\therefore \boxed{L = 94.59}$ kmol/hr

$\therefore L' = L + qF$

$= 94.59 + 100 \Rightarrow 194.59$ kmol/hr

~~$V' = V$~~ $\therefore \boxed{y = 1.59x - 0.005}$ (SOL - line)

∴ ROL line:

$$y = 0.77x + 0.21$$

SOL line

$$\boxed{y = 1.58x - 0.005}$$

From Graph. No. of theoretical stages $\boxed{= 10}$

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