Assignment

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18CH30031

Q.1) $$h_T = \int_{y_2}^{y_1} \frac{G'\, dy}{K_y \cdot \bar{a}\,(1-y)(y-y_i)}$$

$$h_T = \int_{y_2}^{y_1} \frac{G' \cdot y_{iBM} \cdot dy}{K_y \cdot \bar{a} \cdot y_{iBM}\,(1-y)(y-y_i)}$$

where $y_{iBM} = (1-y)_{im} = \dfrac{(1-y_i)-(1-y)}{\ln\left(\dfrac{1-y_i}{1-y}\right)}$

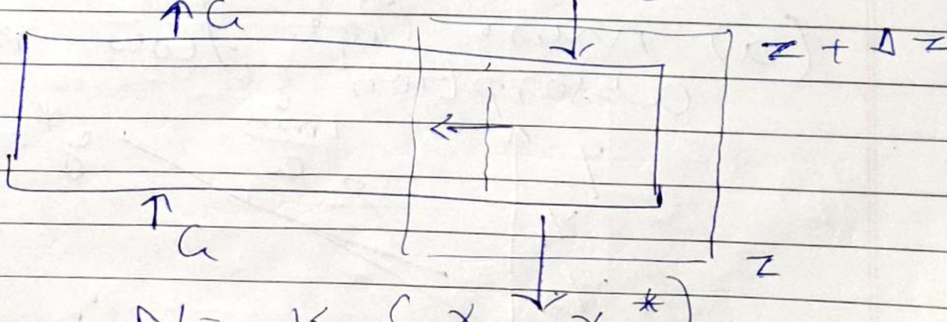
$$h_T = \frac{G'}{K_y \cdot \bar{a} \cdot (1-y)_{im}} \int_{y_2}^{y_1} \frac{(1-y)_{im} \cdot dy}{(1-y)(y-y_i)}$$

$$H_{tg} = \frac{G'}{K_y \cdot \bar{a}\,(1-y)_{im}} = \frac{G'}{K_y' \cdot \bar{a}}$$

where $K_y' = K_y (1-y)_{im}$

$$\therefore N_{tg} = \int_{y_2}^{y_1} \frac{(1-y)_{im}\, dy}{(1-y)\,(y-y_i)}$$

Q 2)



$N = K_x (x - x^*)$

Material balance

$$IN_{liq} = Out_{liq} + Out_{\text{mass transfer}}$$

$$S \cdot L \cdot x(z+\Delta z) = S \cdot L \cdot x \cdot z + N \cdot a \cdot S \cdot \Delta z$$

$$L \cdot \frac{x(z+\Delta z) - x(z)}{\Delta z} = N \cdot a$$

as $\Delta z \to 0$

$$L \cdot \frac{dx}{dz} = K_x \cdot a(x - x^*)$$

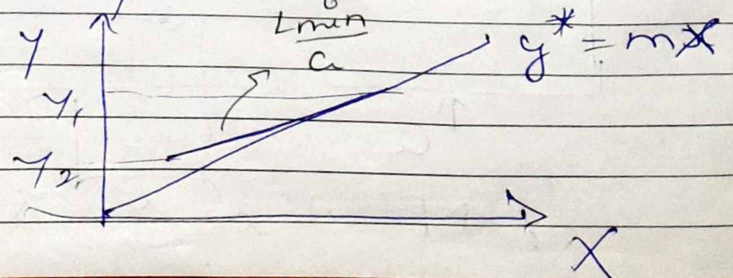
$$H = \int_0^H dz = \frac{L}{K_x \cdot a} \int_{x_1}^{x_2} \frac{dx}{x - x^*}$$

$$H_{OL} = \frac{L}{K_x \cdot a}$$

$$N_{OL} = \int_{x_1}^{x_2} \frac{dx}{x - x^*}$$

Q.3) $y^* = mx$.

(a) min. liq. flow rate for absorption.



$$G(y_1 - y_1) = L(x_1 - x_2)$$

$$x_1 = x_{max} = \frac{y_1}{m}$$

$$G(y_1 - y_2) = L\left(\frac{y_1}{m} - x_2\right)$$

$$\boxed{L_{min} = \frac{G(y_1 - y_2)}{\left(\frac{y_1}{m} - x_2\right)}}$$

(b) $N_{OG} = \frac{A}{A-1} \ln\left(\frac{1 - \frac{\alpha}{A}}{1-\alpha}\right)$

P.T.

$$\alpha = \frac{Y_1 - Y_2}{Y_1 - Y_2^*}$$

$$A = \frac{L}{Gm}$$

$$N_{OG} = \int_{Y_2}^{Y_1} \frac{dy}{y - y^*}$$

given $y^* = mx$

$$\therefore N_{OG} = \int_{y_2}^{y_1} \frac{dy}{y - mx}$$

$$Lx + Gy_2 = Lx_2 + Gy$$

$$\therefore x = \frac{y}{Am} + x_2 - \frac{y_2}{Am}$$

$$\therefore N_{OG} = \int_{y_2}^{y_1} \frac{A\,dy}{(A-1)y + y_2 - Ay_2^*}$$

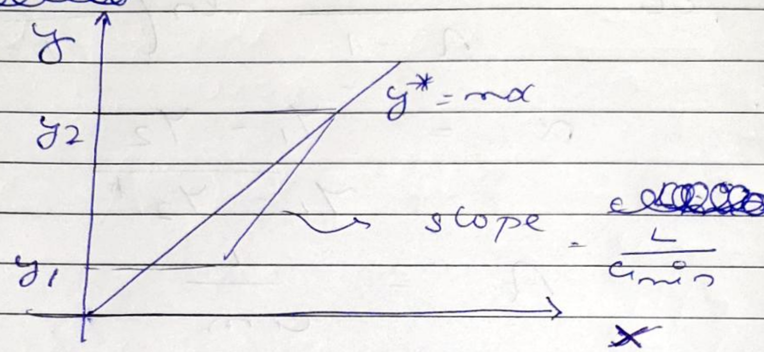
$$\therefore N_{OG} = \frac{A}{A-1} \cdot \ln\left(\frac{(A-1)y_1 + y_2 - Ay_2^*}{A(y_2 - y_2^*)}\right)$$

$$\therefore N_{OG} = \frac{A}{A-1} \cdot \ln\left(\frac{1}{A} + \frac{A-1}{A} \cdot \frac{y_1 - y_2^*}{y_2 - y_2^*}\right)$$

$$\boxed{N_{OG} = \frac{A}{A-1} \cdot \ln\left(\frac{1 - \alpha/A}{1 - \alpha}\right)}$$

Q.4)

a)



$$G y_1 + L x = L x_1 + G y$$

$$x_2 = \frac{y_2}{m}$$

$$G y_1 + \frac{L y_2}{m} = L x_1 + G y_2$$

$$G^o_{min} = \frac{L\left(x_1 - \frac{y_2}{m}\right)}{(y_1 - y_2)}$$

(b) $$\sigma = \frac{x_2 - x_1}{x_2 - x_1^*}$$

$$S = \frac{mG}{L}$$

$$N_{OL} = \int_{x_1}^{x_2} \frac{dx}{x - x^*}$$

$$\rightarrow x^* = y/m$$

$$\therefore N_{OL} = \int_{x_1}^{x_2} \frac{dx}{x - x^*} = \int_{x_1}^{x_2} \frac{dx}{x - y/m}$$

$$y = \frac{L}{G}(x - x_1) + y_1$$

$$N_{OL} = \int_{x_1}^{x_2} \frac{dx}{x - \frac{1}{S}(x - x_1) - \frac{y_1}{m}}$$

$$= \int_{x_1}^{x_2} \frac{dx}{x - \frac{1}{S}(x - x_1) - x_1}$$

$$N_{OL} = \frac{S}{S-1} \left[\ln\left((S-1)x + x_1 - S x_1^*\right) \right]_{x_1}^{x_2}$$

$$N_{OL} = \frac{S}{S-1} \ln\left(\frac{(S-1)x_2 + x_1 - S x_1^*}{S(x_1 - x_1^*)} \right)$$

$$N_{OL} = \frac{S}{S-1} \ln\left(\frac{1}{S} + \frac{S-1}{S}\left(\frac{x_2 - x_1^*}{x_1 - x_1^*}\right) \right)$$

Q.5 HTU indicates inversely the relative ease with which a given packing can accomplish separation for a particular system.

NTU indicates the difficulty of separation. The greater extent of separation desired, the less will be the ~~extent~~ ~~of~~ driving force available and larger would be the NTU.

Section 2

Q.1) $y = \dfrac{0.2x}{1+0.8x}$

x	0	0.01	0.03	0.07	0.09	0.12
y	0	0.00198	0.00586	0.0113	0.0168	0.0219

→ feed gas rate $= 80 \dfrac{kmol}{h}$

$y_1 = 0.04$

→ rate of input solute $= 80 \times 0.04 = 3.2 \dfrac{kmol}{h}$

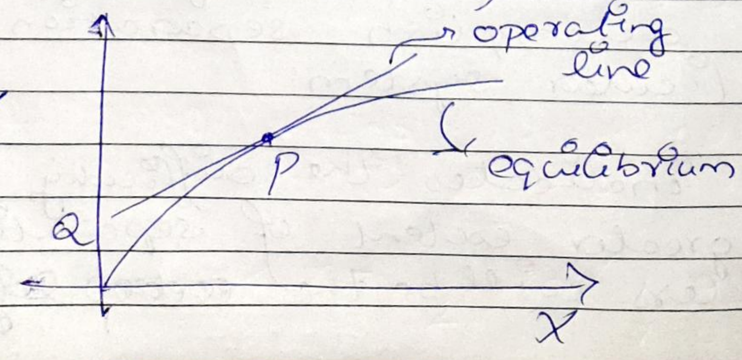
↳ cyclohexane

→ Carrier gas in, $G_S = 80 - 3.2 = 76.8 \dfrac{kmol}{h}$

→ $Y_1 = \dfrac{y_1}{1-y_1} = 0.0417$

$Y_2 = 0.02\, y_1 = 0.000834$

$X_2 = 0$ → solute free basis.



$$\left(\frac{L_s}{G_s}\right)_{min} = 0.19$$

$$G_s = 76.8 \text{ kmol/h}$$

$$(L_s)_{min} = 76.8 \times 0.19 = 14.6 \frac{\text{kmol}}{\text{h}}$$

Q.2 Molecular weight of feed

$$= 0.16 \times 17 + 0.84 \times 28.8$$
$$= 26.9$$

→ feed gas rate, $G_1' = 60 \frac{\text{kmol}}{\text{h} \cdot \text{m}^2}$

mole fraction of ammonia, $x_1 = 0.16$

mole of ammonia input $= 60 \times 0.16 = 9.6$ kmol

mole of air input $= 60 \times 0.84 = 50.4$ kmol

$= G_s'$

99% ammonia recovered.

moles of ammonia output $= 9.6 \times 0.01$

$= 0.096$ kmol.

$$G_2' = 50.4 + 0.096$$
$$= 50.496 \frac{\text{kmol}}{\text{m}^2 \cdot \text{h}}$$

conc. of ammonia in the outlet gas

$$y_2 = \frac{0.096}{50.496} = 0.002$$

Equilibrium relation →

vapour pressure of water at 25°C

$= 0.457$ psi

$P = 14.7 - 0.4574 = 14.24$ psi

$\equiv 0.969$ atm

$\therefore P = 0.969$ atm & $T = 298$ K

$$y^* = 1.017 \frac{x}{1-x}$$

→ water rate $= 70 \frac{kmol}{h} = L_s$

NH_3 absorbed $= 96 \times 0.99 = 9.504$

$$x_1 = \frac{9.504}{70 + 9.504} = 0.1195$$

$x_2 = 0$

$$G_s'\left(\frac{y_1}{1-y_1} - \frac{y}{1-y}\right) = L_s'\left(\frac{x_1}{1-x_1} - \frac{x}{1-x}\right)$$

$$\therefore \frac{y}{1-y} = 1.3889 \frac{x}{1-x} + 0.02$$

y	0.002	0.01518	0.02945	0.04302	0.06985	0.1093
y^*	0	0.0103	0.02075	0.03145	0.0535	0.08843

$$N_{toG} = 14.7 + \frac{1}{2} \ln\left(\frac{1-0.002}{1-0.16}\right)$$

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$N_{toG} = 14.8$

$K_y' \cdot \bar{a} = 100 \dfrac{kmol}{h \cdot m^2 \cdot \Delta y}$

$G' = \dfrac{(G_1' + G_2')}{2} = 55.25 \dfrac{kmol}{h \cdot m^2}$

$H_{toG} = \dfrac{G'}{k_y \cdot \bar{a} \cdot y_{BM}^*} = \dfrac{G'}{K_y' \cdot \bar{a}}$

$= \dfrac{55.25}{100} = 0.552\ m$

Packed ht $= 14.8 \times 0.552 = 8.2m$

Section 3

Q.1 $H_{OG} = 1\ m$

$X_2 = 0$ → solute free basis

$\left(\dfrac{L_S}{G_S}\right)_{min} = \dfrac{Y_1 - Y_2}{Y_1/m - X_2} = \dfrac{Y_1 - Y_2}{Y_1/m}$

$\boxed{\left(\dfrac{L_S}{G_S}\right)_{min} = m\left(1 - \dfrac{Y_2}{Y_1}\right)}$

$Y_2 = (1 - 0.99)\ Y_1$

$Y_2 = 0.01 Y_1$

$\therefore \left(\dfrac{L_S}{G_S}\right)_{min} = 0.99m$

$$\left(\frac{L_s}{G_s}\right)_{actual} = 1.75 \times m \times 0.99$$

$$= 1.7325\ m.$$

$$N_{OG} = \frac{A}{A-1} \ln\left(\frac{1}{A} + \frac{A-1}{A}\left(\frac{y_1 - y_2^*}{y_2 - y_2^*}\right)\right)$$

$$y_2^* = 0 \rightarrow \text{as } x_2 = 0$$

$$N_{OG} = 8.88$$

$$Z = H_{OG} \times N_{OG} = \boxed{8.8\ m}$$