Exam :- T.E Chemical Sem-V CBSGS Nov/Dec 2017.
Subject :- Mass Transfer Operations - I
Exam date :- 14/12/2017
Q.P. Code :- 26251

Q. No. 2 A] $Z = 0.1\ cm$

$= 0.1 \times 10^{-2}\ m$

Butanol [A] and water [B]

at point 1, concentration of A = 10 wt %

$\therefore x_{A1} = \frac{(10/74)}{(10/74)+(90/18)} = \frac{0.135}{0.135+5} = 0.0263$

at point 2, concentration of A = 4 wt %

$\therefore x_{A2} = \frac{(4/74)}{(4/74)+(96/18)} = \frac{0.0540}{0.0540+5.33} = 0.01$

$x_{B1} = 1 - x_{A1}$
$= 1 - 0.0263$
$= 0.9737$

$x_{B2} = 1 - x_{A2}$
$= 1 - 0.01$
$= 0.99$

$x_{BM} = \frac{x_{B2} - x_{B1}}{\ln\left[\frac{x_{B2}}{x_{B1}}\right]} = \frac{0.99 - 0.9737}{\ln\left[\frac{0.99}{0.9737}\right]}$

$= 0.982$

At point 1

$M_{avg1} = x_{A1} M_A + (1 - x_{A1}) M_B$

$= 0.0263 \times 74 + (1 - 0.0263) \times 18$

$= 19.47.$

At point 2

$M_{avg2} = x_{A2} M_A + (1 - x_{A2}) M_B$

$= 0.01 \times 74 + (1 - 0.01) \times 18$

$= 18.56$

At point 1, $\rho_1 = 0.971\ g/cc$

$= 971\ kg/m^3$

$\therefore \frac{\rho_1}{M_{avg_1}} = \frac{971}{19.47} = 49.87$

At point 2, $\rho_2 = 0.992\ g/cc$

$= 992\ kg/m^3$

$\therefore \frac{\rho_2}{M_{avg_2}} = \frac{992}{18.56} = 53.45$

$$\therefore \left(\frac{\rho}{M_w}\right)_{avg} = \frac{\frac{\rho_1}{M_{avg1}} + \frac{\rho_2}{M_{avg2}}}{2} = \frac{49.87 + 53.45}{2}$$

$= 51.66$

$D_{AB} = 5.9 \times 10^{-6}\ cm^2/s$

$= 5.9 \times 10^{-6} \times 10^{-4}\ m^2/s$

$= 5.9 \times 10^{-10}\ m^2/s$

Now —

$$N_A = \frac{D_{AB}}{Z} \left(\frac{\rho}{M_{avg}}\right) \frac{(x_{A1} - x_{A2})}{x_{BM}}$$

$$\therefore N_A = \frac{5.9 \times 10^{-10}}{0.1 \times 10^{-2}} \times 51.66 \times \frac{[0.0263 - 0.01]}{0.982}$$

$$\boxed{\therefore N_A = 5.06 \times 10^{-7}\ Kmole/m^2 s}$$

First Q. NO. 3 B] $P = 1$ bar

$= 1 \times 10^5 \ N/m^2$

$= 100 \ kN/m^2$

$L = 825 \ mm$

$= 0.825 \ m$

$D = 15 \ mm$

$= 15 \times 10^{-3} \ m.$

Hence area for mass transfer is–

$A = \pi D L$

$= \pi \times 15 \times 10^{-3} \times 0.825$

$= 0.0389 \ m^2$

Now mass transfer flux is calculated as–

$$N_A = \frac{\text{Rate of absorption}}{A}$$

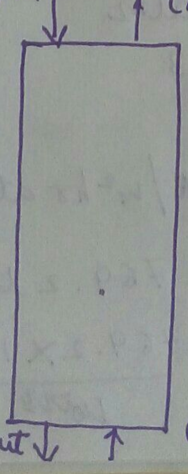
$$= \frac{1.12 \times 10^{-6}}{0.0389}$$

$$= 2.88 \times 10^{-5} \ \text{Kmole}/m^2 s$$

Since in this case, ammonia from ammonia-air mixture is absorbed into dilute H_2SO_4, The reaction between ammonia & H_2SO_4 can be neglected.

The situation is schematically shown in the following figure

H_2SO_4 in $(NH_3 + Air)$ out $P_{A2} = 2 \ kN/m^2$, ammonia in $H_2SO_4 = 0$



$y_{A2} = \frac{P_{A2}}{P} = \frac{2}{100} = 0.02$

$y_{A1} = \frac{P_{A1}}{P} = \frac{7.5}{100} = 0.075$

H_2SO_4 out $(NH_3 + air)$ in $P_{A1} = 7.5 \ kN/m^2$ ammonia in $H_2SO_4 \simeq 0$

Now

driving force at inlet $= y_{A1} - 0$

$= 0.075 - 0$

$= 0.075.$

Driving force at outlet $= y_{A2} - 0$

$= 0.02 - 0$

$= 0.02$

Hence logarithmic average driving force =

$$DF_m = \frac{0.075 - 0.02}{\ln\left[\frac{0.075}{0.02}\right]} = 0.042$$

Now -

$$N_A = K_y \, DF_M$$

$$\therefore \; 2.88 \times 10^{-5} = K_y \times 0.042$$

$$\therefore \; K_y = \frac{2.88 \times 10^{-5}}{0.042} = 6.86 \times 10^{-4} \text{ Kmole/m}^2\text{s.}$$

$$\boxed{\therefore \; K_y = 6.86 \times 10^{-4} \text{ kmole/m}^2\text{s}}$$

Second Q.NO.3 A] $P_{AG} = 12$ mm of Hg

$= \frac{12}{760}$ atm

$= 0.0158$ atm

$C_{AL} = 4 \text{ kmole/m}^3$

$K_G = 0.269 \text{ kmol A/m}^2 \text{ hr atm}$

Henry's law constant $= m = 769.2$ lit atm/kmole

$= 769.2 \times 10^{-3} \frac{\text{m}^3 \text{ atm}}{\text{kmole}}$

$m = 769.2 \ m^3 \, atm/kmole$

Since 56 % of total mass transfer resistance is in gas film then-

$$\frac{56}{100} = \frac{1/k_g}{1/K_G}$$

$$\therefore \ 0.56 = \frac{1/k_g}{1/0.269}$$

$$\therefore \ 2.08 = 1/k_g$$

$$\therefore \ k_g = 0.480 \ kmole/m^2 \, hr \, atm.$$

We know that -

$$\frac{1}{K_G} = \frac{1}{k_g} + \frac{m}{K_L}$$

$$\frac{1}{0.2} = \frac{1}{0.480} + \frac{769.2 \times 10^{-3}}{K_L}$$

$$5 = 2.08 + \frac{769.2 \times 10^{-3}}{K_L}$$

$$2.92 = \frac{769.2 \times 10^{-3}}{K_L}$$

$$K_L = \frac{769.2 \times 10^{-3}}{2.92} = 263.42 \times 10^{-3} \ kmole/m^2 \, hr \, atm$$

$$= 0.26342$$

Henry's law -

$P_A = m \, C_A$

~~$P_A^* = m C_A$~~

$P_A^* = m \, C_{AL}$

$\therefore P_A^* = 4x$

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[Please give marks based upon approach for this problem]

Q.NO.4 A]

$y_1 = 0.05$

$Y_1 = \frac{y_1}{1-y_1} = \frac{0.05}{1-0.05} = 0.0562$

$y_2 = 0.005$

$\therefore Y_2 = \frac{y_2}{1-y_2} = \frac{0.005}{1-0.005} = 5.025 \times 10^{-3}$

Equilibrium relationship is–

$y = 0.5x$

$\frac{Y}{1+Y} = 0.5 \frac{X}{1+X}$

$\frac{1+Y}{Y} = \frac{1+X}{0.5X}$

$\frac{1}{Y} + 1 = \frac{1+X}{0.5X}$

$\frac{1}{Y} = \frac{1+X}{0.5X} - 1$

$\frac{1}{Y} = \frac{1+X-0.5X}{0.5X}$

$\frac{1}{Y} = \frac{1+0.5X}{0.5X}$

$\therefore Y = \frac{0.5X}{1+0.5X}$

$G_1 = 1500$ Kmol/hr

$\therefore G_s = 1500 [1-y_1]$

$= 1500 [1-0.05] = 1425$ Kmol/hr.

For minimum liquid rate the operating line touches the equilibrium curve. In this case the point is [X_{1max} & Y_1]
Since this point lies on the equilibrium curve, it should satisfy the equilibrium relations

$$Y_1 = \frac{0.5 X_{1max}}{1+0.5 X_{1max}}$$

$$0.0562 = \frac{0.5 X_{1max}}{1+0.5 X_{1max}}$$

$$\therefore 0.0562 + 0.0281 X_{1max} = 0.5 X_{1max}$$

$$\therefore X_{1max} = 0.119$$

Now -

$$\frac{L_{smin}}{G_s} = \frac{Y_1 - Y_2}{X_{1max} - X_2}$$

$$\therefore \frac{L_{smin}}{G_s} = \frac{0.0562 - 5.025\times10^{-3}}{0.119 - 0} \quad [\because X_2 = 0]$$

(a)

$$\therefore \frac{L_{smin}}{G_s} = 0.430$$

(b) If $\frac{L_s}{G_s} = 1.5 \frac{L_{smin}}{G_s} = 1.5 \times 0.430 = 0.645$

Hence equation of operating line is -

$$0.645 = \frac{Y_1 - Y_2}{X_1 - X_2}$$

Q. NO. 6 c]

$t_1 = 25.4 \, mm$

$= 25.4 \times 10^{-3} \, m$

$N_c = 2.05 \, \frac{kg}{kg \, hr \, m^2}$

$\frac{L_s}{A} = 24.4$

$X_1 = 0.55, \; X_2 = 0.3$

$X_c = 0.22 \qquad \underline{X_2 > X_c}$

Thus drying occurs only in constant rate period.

Now time required during constant rate period is-

$$\theta_c = \frac{L_s [X_1 - X_c]}{A N_c}$$

For second case the area is doubled but mass is also doubled.

Hence for second case - $\frac{L_s}{A}$ remain same.

But X_1 for this case is 0.45

Hence -

$$\theta = \frac{L_s}{A N_c} [X_1 - X_2]$$

$$\therefore \theta = \frac{24.4 \times [0.45 - 0.3]}{2.05}$$

$\therefore \theta = 1.785$ Hours.