BY: S. VISHAL
CH18B020

AMT Tutorial - 2

① M.W. of inlet gas = $0.1 \times 64 + 0.9 \times 29$.
$= 32.5$

Molar flow rate of inlet gas, $G = \frac{1500}{32.5} = 46.15$ kmol/h.

Molar flow rate of solute-free gas, $G_s = 0.9\,G$
$= 41.5385$ kmol/h.

Mole ratios: $Y_{entry} = \frac{0.1}{0.9} = 0.11$

$Y_{leaving} = 0.11 \times 0.03 = 0.0033$.

$X_{entry} = 0$.

At minimum solvent flow rate, Exiting solvent will be in equilibrium with entering vapour.

a) $\frac{L_{s\,min}}{G_s} = \frac{Y_1 - Y_2}{X_{exit} - X_{entry}} \Rightarrow \boxed{L_{s\,min} = 1646.7 \times 10^3 \text{ kmol/h}}$

b) $L_s = 1.25\,L_{s\,min}$ (given)

$\Rightarrow L_s = 2058.4$ kmol/h.

To obtain the height of the packed be we need to evaluate

$$H = \int_{y_{exit}}^{y_{entry}} \frac{G'}{k_y a} \frac{dy}{(1-y)(y-y_i)} = \left(\frac{V_s}{k_y a\,A}\right) \int \frac{(1+y)\,dy}{(1-y)(y-y_i)}$$

where G' is molar flow rate per unit area (flux)
y_i is the interfacial concentration of solute.

→ Using 2 film theory we know, $k_x(x - x_i) = k_y(y_i - y)$

→ Since (x_i, y_i) will lie on eqbm curve and (x, y) will lie on operating line, all we need to do is draw lines of slope $\frac{-k_x}{k_y}$ from a point on operating line and find out where it intersects at eqbm curve (the point of intersection is the required y_i)

→ This is done in MATLAB by taking 10 points along the ~~curve~~ operating line and solving the equation : $\left(\frac{k_y}{k_x}(y_i - y) + x\right) - f(y_i) = 0.$

where $f(y_i)$ is the eqbm curve eq.

→ Using y_i we can evaluate the necessary function in the integral and integrate wrt y.

→ Use trapezoidal rule

→ Area under curve is found to be 22.448

$\therefore$ Height of packed bed $= \left(\frac{V_s}{k_y a\, A}\right) \times 22.448$

$$= \frac{41538.5}{3600 \times 0.075 \times 0.781} \times 22.448$$

→ $\boxed{\text{Height} = 4.42 \text{ m.}}$

AMT CH3030 - Tutorial 2

(2) Inlet & outlet feed flowrate

$$V_{entry} = \frac{P\dot{V}}{RT} = \frac{0.4 \times 1.013 \times 10^5}{8.314 \times 297} = 16.41 \text{ mol/s}$$

$$Y_{entry} = \frac{\text{partial pressure of solute}}{\text{partial pressure of solvent}} = \frac{50}{710} = 0.0704$$

$$Y_{exit} = \frac{y_{exit}}{1-y_{exit}} = \frac{5\times10^{-3}}{1-5\times10^{-3}} = 5.025 \times 10^{-3}$$

$$V_S = \frac{710}{760} \times V_{entry} = 15.33 \text{ mol/s}$$

Eqbm curve : Raoult's law.

$$y\,P_{total} = x\,(P_{vapour})$$

$$\Rightarrow y = 0.455x.$$

At $L_{s\,min}$, X_{exit} will be in equilibrium with Y_{entry}

$$\rightarrow X_{exit} = 0.1689 \simeq 0.169.$$

a) ∴ Min. liquid gas ratio, $\frac{L_{s\,min}}{V_s} = \frac{Y_{entry} - Y_{exit}}{X_{exit} - X_{entry}} = \boxed{0.387.}$

b) If $\frac{L_s}{V_s} = 1.5\frac{L_{s\,min}}{V_s}$, then $L_s = 8.9$ mol/s.

$= 8.9 \times 3600 \times 0.18$ kg/h.

$$\rightarrow \boxed{L_s = 5768.9 \text{ kg/h.}}$$

c) For no. of steps graphical method, starting we start from bottom of operating line (X_{entry}, Y_{exit}) . move to eqbm curve keeping y constant, then keep x constant and move to the operating line. this procedure is repeated till we cross the Y- Y_{entry}

Number of steps were found to be $\boxed{6}$

Kremser's method

Absorption factor, $A = \dfrac{\text{slope of operating line}}{\text{slope of equilibrium curve}} = \dfrac{0.581}{0.455}$

≈ 1.28

$$N = \frac{\log\left(\left(\dfrac{Y_{entry} - K \times K X_{entry}}{Y_{exit} - K X_{exit}}\right) \times \left(1 - \dfrac{1}{A}\right) + \dfrac{1}{A}\right)}{\log A}$$

$K \rightarrow$ slope of equilibrium curve. (note: all are mole fraction)

$\Rightarrow N = 5.298$.

$\therefore$ $\boxed{\text{No. of steps} = 6.}$

d) Given $\mu = 2\,cP = 2 \times 10^{-3}$ Pa s, $\rho = 0.81 \times 10^3 = 810$ kg/m^3

and molecular weight = 18 g mol^{-1}.

Value of x-axis = $\dfrac{(\text{slope of eqbm curve}) \times (\text{Mol. weight}) \times \mu}{\rho}$

$= 2.02 \times 10^{-4}$.

From the overall tray efficiency graph, we can see that

$\boxed{E_0 = 0.25}$ (efficiency)

$$E_0 = \frac{\text{no. of ideal trays}}{\text{real no. of trays reqd.}}$$

$\Rightarrow$ Real number of trays required $= \frac{N}{E_0} = \frac{6}{0.25}$

$= 24$ trays

(Note: if we put $N = 5.29$ (value obtained through Kremser equation) we will get 22 trays)