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CH18B020

AMT Tutorial-2

① M.W. of inlet gas = $0.1\times64+0.9\times29$
$= 32.5$

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

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

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

$Y_{leaving} = 0.11\times0.03 = 0.0033$.

$X_{entry} = 0$.

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

a) $\dfrac{L_{s\,min}}{G_S} = \dfrac{Y_1 - Y_2}{X_{exit} - X_{entry}} \Rightarrow \boxed{L_{s\,min} = 1646.7\times10^3 \text{ kmol/h}}$

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

→ Use trapezoidal rule and integrate wrt y.

→ Area under curve is found to be 22.648

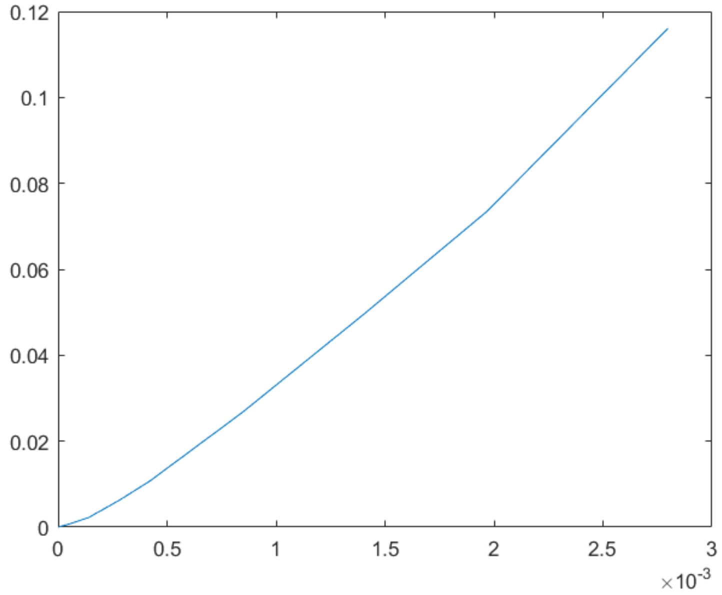
∴ Height of packed bed $= \left(\frac{V_s}{k_y a\, A}\right) \times 22.448$

$$= \frac{415385}{3600 \times 0.075 \times 0.781} \times 22.448$$

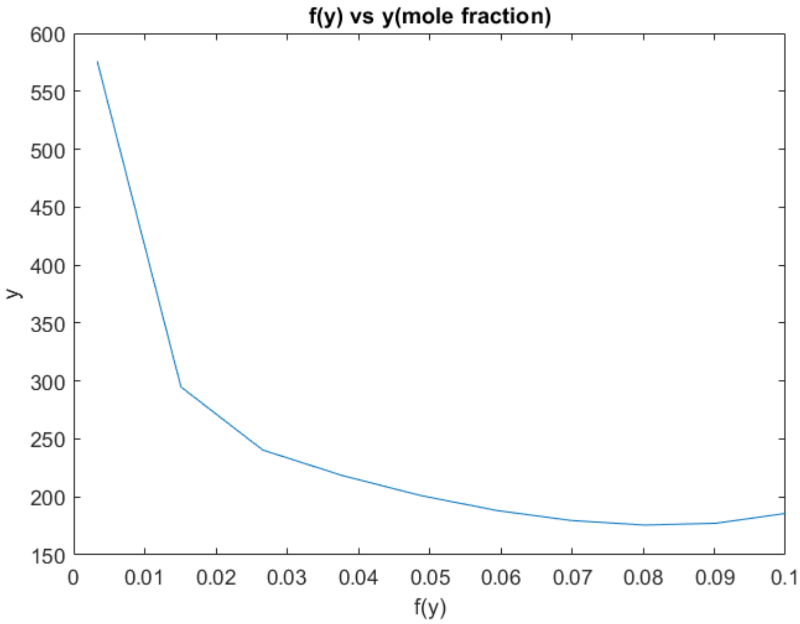
→ $\boxed{\text{Height} = 4.42 \text{ m.}}$

Question 1: Code + Graphs

Equilibrium curve(X vs Y)



F(y) vs y




```
clear; close all;
yentry = 0.1;
Yentry = yentry/(1-yentry);
xentry = 0;
yexit = 0.03*0.1/(0.03*0.1+0.9);
Yexit = yexit/(1-yexit);
mw = 0.1*64+0.9*29;
Vs = 1500/mw*0.9;
xeqbm = [0 0.562 1.403 2.8 4.22 8.42 14.03 19.65 27.9]*10^(-4);
yeqbm = [0 0.792 2.23 6.19 10.65 25.9 47.3 68.5 104]*(10^(-3));
```

```
xy = spline(yeqbm,xeqbm);
%part a
Xeqbm = xeqbm./(1-xeqbm);
Yeqbm = yeqbm./(1-yeqbm);
figure(1);
title('EqbmPlot')
xlabel('Xeqbm')
ylabel('Yeqbm')
plot(Xeqbm,Yeqbm);
XY = spline(Yeqbm,Xeqbm);
Xexit = ppval(XY,Yentry);
Lsmin = Vs*(Yentry-Yexit)/(Xexit);
%Part b
kx=1.25;
ky=0.075;
cs = 0.781;
Ls = 1.25*Lsmin;
%operating line in terms of mole ratio
OL = @(val)(Vs/Ls).*(val - Yexit);
%n points on operating line
n = 10;
Y = linspace(Yexit,Yentry,n);
X = OL(Y);
x = X./(1+X);
y = Y./(1+Y);
%From n points, draw lines of slope -kx/ky and find intersection at eqbm
%curve. Substitute Xi in terms of the line equation & curve equation,
%equate them and set to zero
func = @(yi)(-ky/kx*(yi-y)+x) - ppval(xy,yi);
yi = fsolve(func,zeros(1,n));
%Value of function to be integrated
f = (1+Y)./((y-yi).*(1-y));
%Integrate yis using trapezoidal rule
AUC = trapz(y,f);
H = AUC*(Vs/(cs*3600*ky));
figure(2);
title('f(y) vs y(mole fraction)')
xlabel('y')
ylabel('f(y)')
plot(y,f)
```

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.

$$= 8.9 \times 3600 \times 0.18 \text{ kg/h}.$$

$$\Rightarrow \boxed{L_S = 5768.9 \text{ kg/h}.}$$

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

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

(note: all are mole fraction)

K → slope of equilibrium curve.

$\Rightarrow N = 5.298$.

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

d) Given $\mu = 2\,cP = 2 \times 10^{-3}$ Pas, $\rho = 0.81 \times 10^{3} = 810$ kg/m³

and molecular weight = 18 g mol⁻¹.

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

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

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 $= \dfrac{N}{E_0} = \dfrac{6}{0.25}$

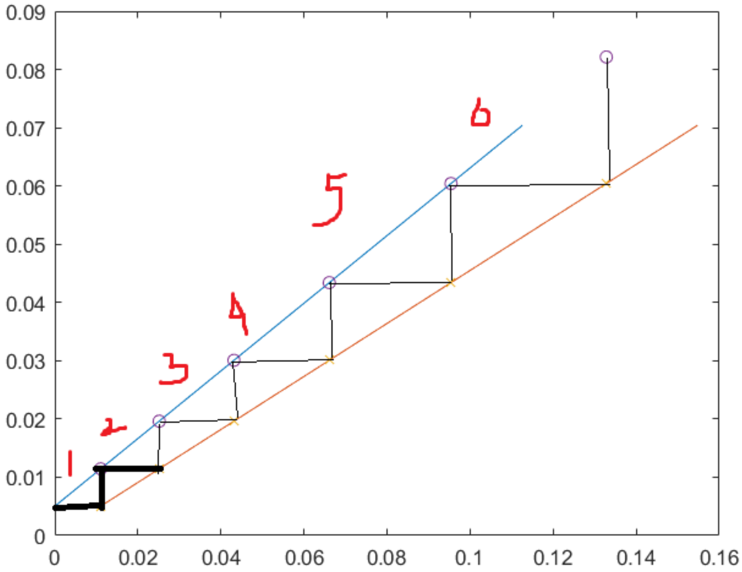
$= 24$ trays

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

we will get 22 trays)

Question 2: Code + Graphs

```
clear; close all;
Ventry = 0.4*1.013*10^5/8.314/297;
yentry = 50/760;
xentry=0;
Vs = (1-yentry)*Ventry;
Yentry = yentry/(1-yentry);
yexit = 0.005;
Yexit = yexit/(1-yexit);
xeqbm = @(y)(760/346*y);
xexit = xeqbm(yentry);
Xexit = xexit/(1-xexit);
Lsmin = Vs*(Yentry-Yexit)/(Xexit);
Ratiomin = (Yentry-Yexit)/(Xexit);
Ls = 1.5*Lsmin*180/1000*3600;
m = 1.5*Ratiomin;
y = Yexit;
i = 0;
xcoords = zeros(1,6);
ycoords = zeros(1,6);
ycoords2 = ycoords;
while y <= Yentry
   i = i + 1;
   x = (y)/0.455;
   xcoords(i) = x;
   ycoords(i) = y;
   y = Yexit + m*(x);
   ycoords2(i) = y;
end
ypoints = linspace(Yentry,Yexit,10);
OL = 1/m.*(ypoints-Yexit);
Eqbm = ypoints/0.455;
figure();
plot(OL,ypoints,Eqbm,ypoints,xcoords,ycoords,'x',xcoords,ycoords2,'o');
%Kremser's method
K = 346/760;
A = m/(K);
N = log((yentry-K*xentry)/(yexit-K*xentry)*(1-1/A)+1/A)/log(A);
%efficiency
mu = 2*10^(-3);
pho = 0.81*1000;
abs = mu*0.455*180/pho;
Eo = 0.25;
N_actual = N/Eo;
```



0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
1
2
3
4
5
6