10.6-4. ***Minimum Liquid Flow in a Packed Tower.*** The gas stream from a chemical reactor contains 25 mol % ammonia and the rest inert gases. The total flow is 181.4 kg mol/h to an absorption tower at 303 K and 1.013×10^5 Pa pressure, where water containing 0.005 mol frac ammonia is the scrubbing liquid. The outlet gas concentration is to be 2.0 mol % ammonia. What is the minimum flow L'_{min}? Using 1.5 times the minimum plot the equilibrium and operating lines.

Ans. $L'_{min} = 262.6$ kg mol/h

Here we have given that

$y^* = 25x^*$

so interm of molar ratio, we can write it as

$$\frac{Y^*}{1+Y^*} = 25\frac{X^*}{1+X^*}$$

after plotting this we get equillibrium curve as shown in the picture at last

and we have inlet concetration and outlet concentarion of liquid phase is

$x_2 = 4\% = 0.04$ (*inlet*)

so that can be converted into molar

$$X_2 = \frac{x_2}{1-x_2} = \frac{0.04}{1-0.04} = 0.04167$$

and

$x_1 = 0.2\% = 0.002$

$$X_1 = \frac{x_1}{1-x_1} = \frac{0.002}{1-0.002} = 2.004 \times 10^{-3}$$

Now we have to use the balace equation a

$$\frac{G_S}{L_s} = \frac{X_2 - X_1}{Y_2 - Y_1}$$

here amount of solute is comparably lower than

Here we have

$L = 300\ kmol\ (total)$

$L_s = 300(1-0.04) = 288\ kmol\ pure\ oil$

$G = G_s = 11.42\ kmol$

$Y_1 = 0$, *solvent free steam*

so that gives

$$\frac{11.42}{288} = \frac{0.04167 - 2\times10^{-3}}{Y_2 - 0}$$

by solving all, we get

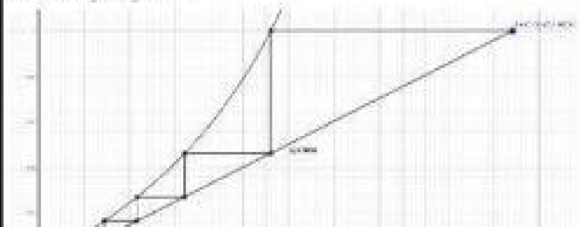
$Y_2 = 1.0003$

Now plot the point $A(X_1, Y_1)$ *and* $B(X_2, Y_2)$ *and join them tocunstruct operating line AB*

then starting from point B, streach horizontal line up to equilibrium curve and from there again go down to operating line as shown in the picture. This procedure give one count of tray and continue the same procedure upto end of operating.

At last count the number of stage, gives

Number of trays = 6



10.6-5. ***Steam Stripping and Number of Trays.*** A relatively nonvolatile hydrocarbon oil contains 4.0 mol % propane and is being stripped by direct superheated steam in a stripping tray tower to reduce the propane content to 0.2%. The temperature is held constant at 422 K by internal heating in the tower at 2.026×10^5

Pa pressure. A total of 11.42 kg mol of direct steam is used for 300 kg mol of total entering liquid. The vapor–liquid equilibria can be represented by $y = 25x$, where y is mole fraction propane in the steam and x is mole fraction propane in the oil. Steam can be considered as an inert gas and will not condense. Plot the operating and equilibrium lines and determine the number of theoretical trays needed.

Ans. 5.6 theoretical trays (stepping down from the tower top)

Given data:

Molar percent of ammonia at inlet $M_i = 25\%$

Total flow $f = 181.4$ kg.mol/h

Temperature at tower $T = 303$ K

Pressure at tower $p = 1.013\times10^5$ Pa

Mole fraction of ammonia $x = 0.005$ mol

Molar percent of ammonia at outlet $M_o = 2\%$

Calculate the outlet concentration of CO_2 in water provided 98% of CO_2 is to be removed.

$$x' = (1-0.98)(0.005)$$
$$= 0.0001$$

Consider the expression for minimum flow.

$$\left(\frac{L_m}{f}\right)_{min}\left(\frac{x'}{1-x'}-\frac{x}{1-x}\right)=\frac{y'}{1-y'}-\frac{y}{1-y}$$

Substitute the values in above equation.

$$\left(\frac{L_m}{181.4}\right)_{min}\left(\frac{0.0001}{1-0.0001}-\frac{0.005}{1-0.005}\right)=\frac{0.002}{1-0.002}-\frac{0.25}{1-0.25}$$

$$(L_m)_{min}=\frac{0.331}{0.228}\times181.4$$
$$= 262.6 \text{ kg.mol/h}$$

Calculate the new minimum flow.

$$L' = 1.5\frac{L_{min}}{f}$$

Substitute the values in above equation.

$$L' = 1.5\times\frac{262.6}{181.4}$$
$$= 2.18 \text{ kg.mol/h}$$

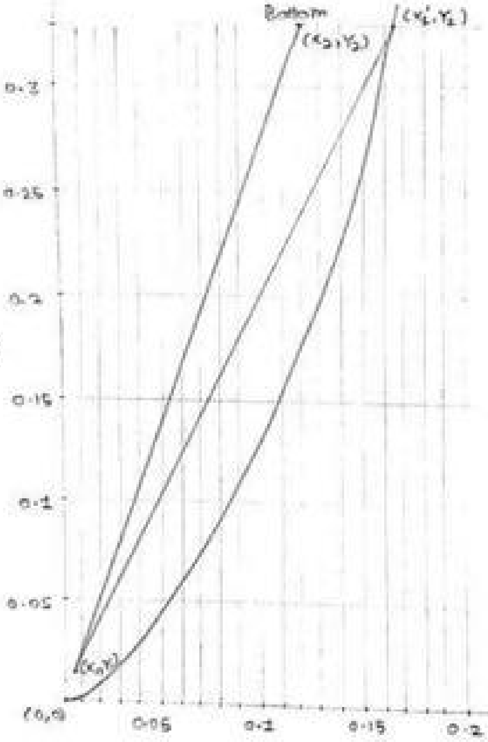
Calculate the new mole fraction.

$$\frac{L'}{f}=\frac{y_1-y_2}{x_1-x_2}$$

$$x_2 = x_1 - \frac{f}{L'}(y_1-y_2)$$

Substitute the values in above equation.

$$x_2 = 0.00503+\frac{0.333-0.02041}{2.90875}$$
$$= 0.1126$$



11.4-9. ***Stripping Tower and Direct Steam Injection.*** A liquid feed at the boiling point contains 3.3 mol % ethanol and 96.7 mol % water and enters the top tray of a stripping tower. Saturated steam is injected directly into liquid in the bottom of the tower. The overhead vapor which is withdrawn contains 99% of the alcohol in the feed. Assume equimolar overflow for this problem. Equilibrium data for mole fraction of alcohol are as follows at 101.32 kPa abs pressure (1 atm abs).

x	y	x	y
0	0	0.0296	0.250
0.0080	0.0750	0.033	0.270
0.020	0.175		

(a) For an infinite number of theoretical steps, calculate the minimum moles of steam needed per mole of feed. (*Note*: Be sure and plot the q line.)

(b) Using twice the minimum moles of steam, calculate the number of theoretical steps needed, the composition of the overhead vapor, and the bottoms composition.

Ans. (a) 0.121 mol steam/mol feed;
(b) 5.0 theoretical steps, $x_D = 0.135$, $x_W = 0.00033$

book CH 10:

10.2.2, 10.3.1, 10.6.3, 10.6.4, 10.7.4.