Problem 1) (30 points)

100 kg mole/hr of a binary ethanol-water saturated vapor is processed in a system consisting of two unit operations. The feed is first fed into a partial condenser. The liquid stream exiting from the partial condenser chamber is then sent to a flash chamber where the vapor stream exiting from the flash chamber is recycled back into the initial partial condenser. The compositions of the two vapor feeds to the initial partial condenser are set to be exactly the same. 54.3 % of the total vapor fed into the partial condenser is condensed. The liquid exiting from the flash chamber contains only 6 mole % ethanol. Calculate the following after constructing a flow chart of this process.

1) The vapor and liquid compositions leaving the two unit operations.

2) The percent vaporized in the flash chamber.

3) The liquid and vapor flow rates leaving the overall process.

4) The yield of the overall process for water recovery in the exiting liquid stream.

Note: The equilibrium curve for the Ethanol/Water system is given in accompanying figure.
Equilibrium Data for Ethanol-Water at 101.43 kPa
Problem 2) 30 points

A still is charged with 30 mol of a mixture of benzene and toluene containing 0.38 mole fraction benzene. Feed of the same composition is supplied at a rate of 8 mol/h and the heat rate is adjusted so that the liquid level in the still remains constant. No liquid leaves the still pot and $K = 2.1$. (note: assume that you can use a constant K approximation for this problem). How long will it be before the instantaneous distillate composition (the one in equilibrium with the liquid) falls to 0.47 mole fraction benzene. (hint you will need to carry out a differential mass balance to obtain the proper form of the Rayleigh equation for this problem).

\[ \frac{D}{dt} = F y_d \]

\[ \frac{dW}{dt} = 0 \]

\[ W_i = 30 \]

\[ W \]

\[ \int \frac{F}{W_o} \frac{dW}{dt} = \frac{8}{30} \]

\[ = \int 0.224 \times 0.47 \times t \]

\[ = \int 0.38 \times 0.38 - 2.1x \]

\[ = 0.73 \]

\[ \frac{8}{30} t = 0.73 \]

\[ t = 2.74 \text{ hrs} \]
Problem 3) 30 points

An enriching distillation column is fed with a 150 kg mole/hr of a saturated vapor feed of 40 mole % ethanol. A total condenser is employed in this system. 76.3 % of the ethanol is recovered in the distillate product. The liquid leaving the second tray from the top of the tower has a composition of 54 mole % ethanol and the vapor rising from the third tray from the top of the tower has a composition of 64.5 mole % ethanol. You may assume constant molal overflow in this problem. Carry out a McCabe Thiele analysis and determine the following:

1) All external flow rates and compositions.

2) The reflux ratio for this column.

3) On the accompanying figure construct the appropriate operating line.

4) the composition of the liquid and vapor streams leaving the first tray from the top of the column.

5,6) Determine the number of stages for this process.

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[Image of the diagram with notes and calculations]

(1) balance around control volume

\[(150)(0.6045) = D \times x_D + B(0.54)\]

recovery information:

\[D x_D + (150)(0.44)(0.763) = 45.78\]

\[96.75 = 45.78 + 0.54 B\]

\[B = 94.4 \text{ kmol/hr}\]

\[D = 150 - 94.4 \Rightarrow D = 55.6 \text{ kmol/hr}\]

(3) flow rate

\[D x_D = 45.78 \Rightarrow x_D = 0.823\]

Component overall balance:

\[(150)(0.44)(0.823) + 94.4 x_D\]

\[x_B = 0.151\]

(3-5) see plot

3 or 4 stages, depending on your drawing

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slope operating line:

\[\frac{R}{R+1} = 0.63\]

arbitrary point extend plot x_B value

draw from (0.82, 0.82) to (0.2, 0.43)
Equilibrium Data for Ethanol-Water at 101.43 kPa
Problem 4) 10 points (answer each question briefly)

a) When carrying out a multicomponent bubble point calculation, if a selected temperature and pressure results in the bubble point criteria being greater than 1, how should you modify your pressure estimate for the next iteration assuming that the temperature remains constant and why?

\[ \text{increase the pressure to decrease the } k \text{-values} \]

b) For a non-ideal binary equilibrium system with attractive interactions between molecules, construct a representative y-x equilibrium curve for this system.

\[ \text{also ok if form azeotrope here} \]