32430: Chemical Engineering Separations
EXAM 1, Fall 2008

Closed Book/Notes

Please put all answers in boxes and write as clearly as possible. (Thanks)
Problem 1) (35 points)

100 kg moles/hr of a saturated vapor containing a binary mixture of propane and butane is introduced into a system consisting of three unit operations. The feed (which contains 80% butane) is first fed into a partial condenser (unit op 1). The vapor stream exiting from the partial condenser is then sent to a second partial condenser (unit op 2) and the liquid stream exiting from the second partial condenser is then sent to a flash chamber (unit op 3). The percent condensed in the first partial condenser is 62.6 %. In addition, 28.1 % of the feed to the flash chamber is vaporized. There is no recycle in this system. The liquid leaving the flash chamber contains 81.5 % butane. Calculate the following after constructing a flow chart of this process.

1) The compositions and flow rates of all liquid and vapor streams in this system

2) The percent "condensed in the second partial condenser (unit op 2)\[72.6\%\]

3) Make a brief comment about the design of this particular process.

The overall process does not seem very efficient given \(y_2\) and \(y_3\). Also, since \(x_3\) is about the same as \(F\), a reflux loop could be put in.

**Note:** The equilibrium curve for the propane/butane system is given in Figure 1.
Equilibrium Data for Propane-Butane at 101.43 kPa

\[ \Delta Y = 1.159 \]
\[ \Delta x = 0.60 \]

\[ \text{Slope } Z = \frac{y_2 - 1}{y_2} = \frac{1.159}{0.60} \]
\[ y_2 = 1.274 \]

\[ \Delta Y \]
\[ \Delta x = -1.674 \]
\[ \Delta Y = -1.674(1) \]
\[ = -1.674 \]

\[ \Delta Y \]
\[ \Delta x = -2.559 \]
\[ \Delta Y = -2.559(1) \]
\[ = -2.559 \]
Problem 2) (25 points)

A two stage extraction system is designed to recover ethylene glycol from water using furfural as the solvent. 150 kg moles/hr of a feed containing 55% ethylene glycol in water is contacted with a stream of pure furfural solvent in the first extraction stage. Using the accompanying figure, calculate the following (note: you can use approximate tie lines using your eye).

1) Find the minimum and maximum amounts of solvent that could be employed to effect some separation in this system.

2) Using a solvent flow rate that is 4 times the minimum solvent value, determine the extract and raffinate compositions and flow rates leaving the first stage.

The raffinate from the first stage is then contacted with 120 kg moles/hr of pure furfural solvent in the second stage.

3) Determine the mixing point for the second stage.
Problem 3) 30 points

100 lbmoles of a liquid mixture containing 65 mol % n-butane and 35 mol % n-pentane is charged to a still pot where a Raleigh distillation is carried out at 100 PSIA pressure. The vapor from the still is then condensed and collected in a distillate holding tank. At the end of the batch distillation process the instantaneous vapor leaving the still contains 60.2 mol % n-pentane. Although the temperature changes during the process, use an intermediate temperature of 200 °F to determine the following:

1) The equilibrium constants for n-butane and n-pentane.
2) The separation factor (or relative volatility) at this temperature and pressure.
3) Assuming that the separation factor obtained in part 2 is constant for the process, determine the liquid composition remaining in the still at the end of the batch process.
4) The amount of liquid that is boiled away during the process.
5) The concentration of the distillate product that is collected in the distillate holding tank when this process is completed.

(note: The VLE data is given in figure 2.8 on the next page)

\[
\frac{K_{n\text{-butane}}}{K_{n\text{-pentane}}} = \frac{1.775}{.76} \quad \alpha = \frac{1.775}{.76} = 2.336
\]

\[
K_{n\text{-pentane}} = \frac{X_n\text{-pentane}}{X_n\text{-pentane}^\prime}
\]

\[
\ln \left( \frac{W_0}{W} \right) = \frac{1}{\alpha - 1} \left[ \ln \left( \frac{X_0}{X} \right) + \alpha \ln \left( \frac{1 - X}{1 - X_0} \right) \right]
\]

\[
\ln \left( \frac{100}{W} \right) = \frac{1}{1.536} \left[ \ln \left( \frac{.65}{.208} \right) + 2.336 \ln \left( \frac{1 - .208}{1 - .65} \right) \right]
\]

\[
\ln \left( \frac{100}{W} \right) = 2.2807
\]

SOLVING GRAPHICALLY

\[
W = 10.221 \text{ lb mole}
\]

\[
Y_D = \frac{W_0 X_0 - W X}{W_0 - W} = \frac{100(.65) - 10.221(.208)}{89.779} = 7.002 = Y_D
\]

AMOUNT BOILED AWAY: 100 - 10.221 = 89.779 lb mole

MATERIALS BOILED AWAY: 89.779 lb mole
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?

You should decrease your pressure estimate.

\[ \sum_{i=1}^{n} k_i = 1 \Rightarrow \text{If you have a calculation that} \]

is greater than 1, you need smaller

\[ k_i \]'s. This can be done by decreasing

pressure or temperature. Since temperature

is fixed, pressure should be decreased.

b) Explain briefly in words why countercurrent operation is more efficient than cocurrent and crosscurrent systems.

Countercurrent is most efficient because it allows

for the largest driving force. The concentration

differences between the two streams are

greater throughout the countercurrent process.