Separation Processes, ChE 4M3, 2012

Assignment 5

Kevin Dunn, kevin.dunn@mcmaster.ca **Due date: 30 November 2012**

Objectives: Confirming your understanding of liquid-liquid extraction and adsorption.

Question 1

2.5 m^3 of wastewater solution with 0.25 kg phenol.m^{-3} is mixed in a batch reactor with 3.0 kg granular activated carbon until equilibrium is reached. Use the following values determined in the lab, calculate the final equilibrium values of phenol extracted and percent recovery.

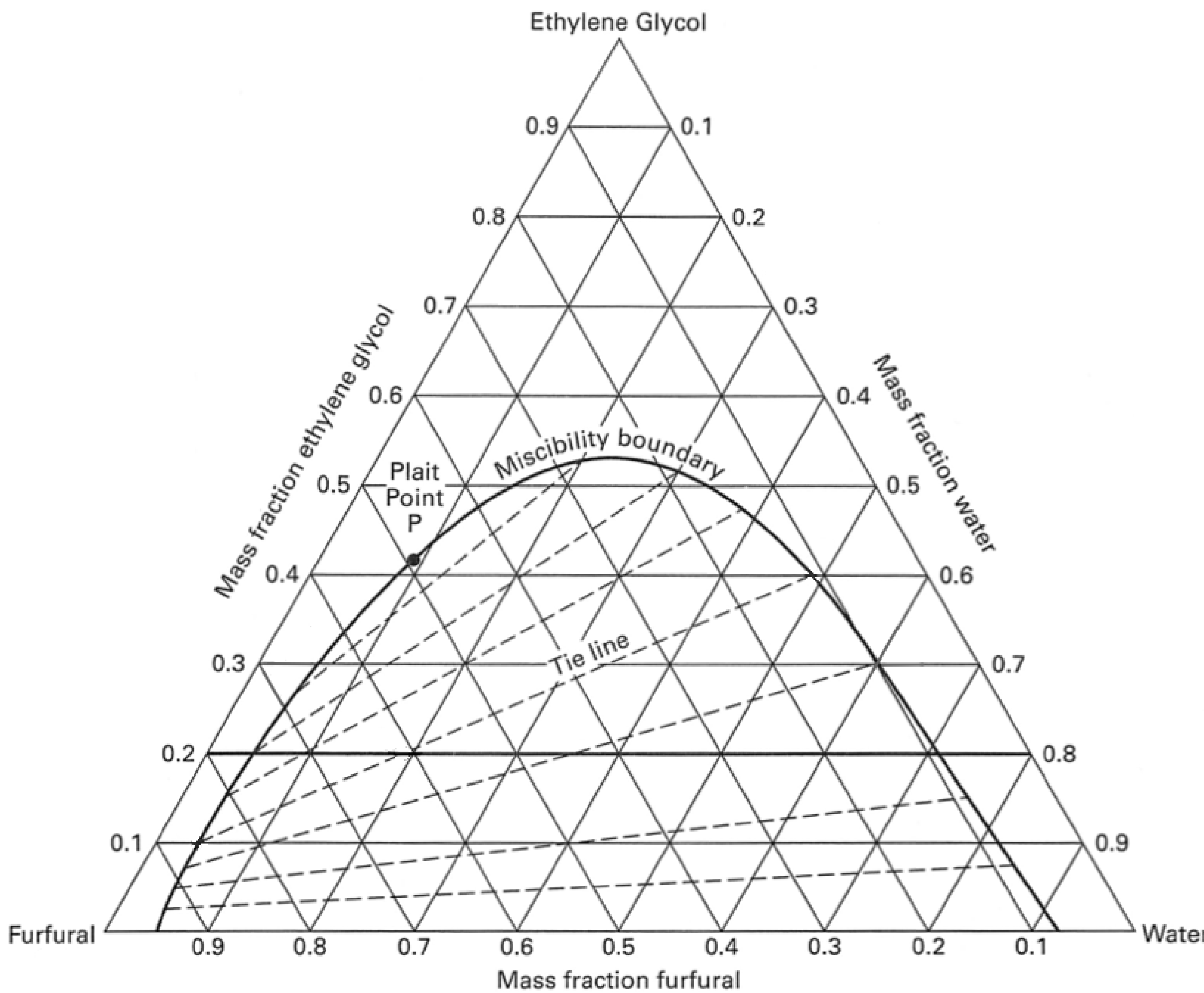
$C_{\mathbf{A}}$	$C_{\mathbf{A,S}}$
0.004	0.026
0.0087	0.053
0.019	0.075
0.027	0.082
0.094	0.123
0.195	0.129

1. Plot the isotherm.
2. Determine the isotherm type.
3. Calculate the isotherm parameters.
4. Calculate the steady-state conditions in the batch reactor for C_{A} in g.cm^{-3} and for $C_{\text{A,S}}$ in grams solute per gram of activated carbon.
5. Calculate the percentage amount of phenol that is recovered by the adsorbent.

Question 2

The aim is to recover ethylene glycol from water using furfural as solvent (the ternary diagram for furfural, ethylene glycol and water at the unit's operating temperature is provided).

1. Calculate the equilibrium compositions leaving a single mixer-settler unit operated at:
   - the recycled solvent stream: 105 kg.hr^{-1} with a composition of 84% furfural, and unrecovered ethylene glycol at 5%, with the rest being water.
   - the feed stream contains 42% ethylene glycol and 58% water at a rate of 200 kg.hr^{-1}.
2. Calculate the flow rates of the extract and raffinate streams.
3. What is the distribution (partition) coefficient, D_{A}, for A = ethylene glycol (see course notes for definition)?
4. What is the distribution (partition) coefficient, D_{C}, for C = water, using this same definition?


Ethylene Glycol
0.9
0.1
0.8
0.2
0.7
0.3
0.6
0.4
0.5
0.5
0.4
0.6
0.3
0.7
0.2
0.8
0.1
0.9
Mass fraction ethylene glycol
Mass fraction water
Plait Point P
Miscibility boundary
Tie line
Furfural
Water
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Mass fraction furfural

5. What is the separation factor for i = ethylene glycol from j = water in the 1=extract and 2=raffinate streams? Also show the relationship between the separation factor and the previous two distribution coefficients.
6. What will happen to the separation factor when operating at a lower feed flow rate; show a construction on your diagram to demonstrate it.

Question 3

Consider a system for which you have been given the ternary diagram (see next page). A = solute, S = solvent, C = carrier. The feed, F, enters at 112 kg/hr with composition of 25 wt% solute and 75 wt% carrier, shown as point F.

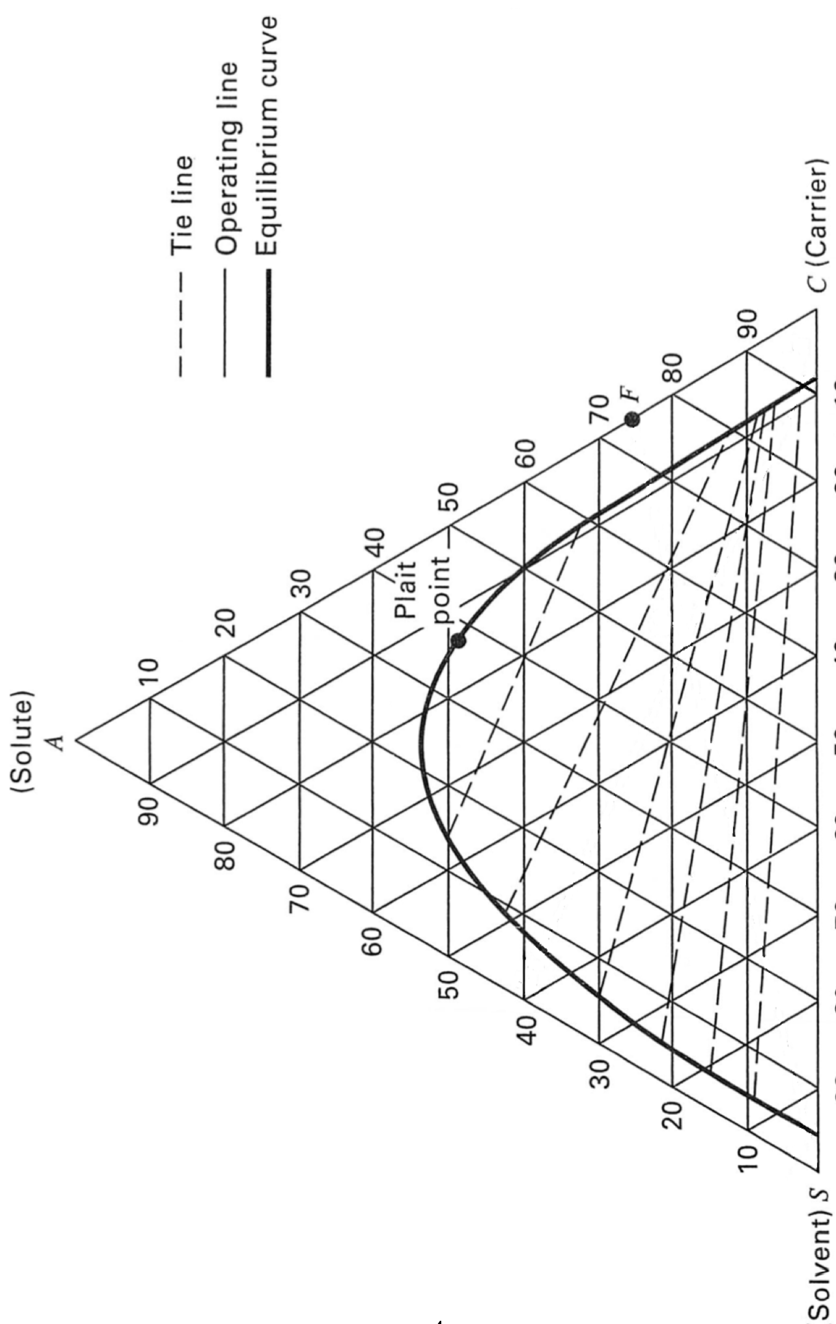
1. Calculate the flow and composition of the extract and raffinate from (*covered in class*):
   (a) 1st co-current stage, using a pure solvent flow of 50 kg/hr.
   (b) 2nd co-current stage, which is few with an a fresh solvent flow of 50 kg/hr.
2. For the overall 2-stage system, find the (*covered in class*):
   (a) overall recovery, defined using the mass flows of $\dfrac{\text{Feed} - R_2}{\text{Feed}}$
   (b) overall concentration [kg/kg] of combined extract streams, E_1 and E_2 combined concentration.
3. *New*: The objective now is to have a counter-current system so the raffinate leaving in the N^{th} stage, R_N has $y_{R_N} = 0.025$.
   (a) What is the *maximum allowable solvent flow* to achieve $y_{R_N} = 0.025$?
   (b) Explain whether it's possible to achieve a final extract stream of concentration $y_{E_1} = 0.20$.
   (c) Show the construction on the ternary diagram for the number of equilibrium stages to achieve $y_{R_N} = 0.025$, given a solvent flow of 15 kg/hr.
   (d) Plot, on the same axes, the concentrations in the extract and raffinate streams from each stage.
   (e) Calculate the distribution (partition) coefficient for the solute in each stage, $D_{\text{A},i} = \dfrac{y_{\text{E}_i,\text{A}}}{x_{\text{R}_i,\text{A}}}$

Submit the single ternary diagram for part (1 and 2), and another ternary diagram for part (3).

Be sure to make a copy of your filled in diagrams, because you might not be able to pick up your graded assignment 5 before the final exam.

Questions 4 and 5 will be posted soon.

END


(Solute) A
(Solvent) S
C (Carrier)
Tie line
Operating line
Equilibrium curve
Plait point
F
10
20
30
40
50
60
70
80
90