AE 335

Separation Processes

Problem Set 7

(Liquid-Liquid Extraction)

1. We wish to extract a dilute solution of the enzyme *alcohol dehydrogenase* from an aqueous solution of 5 wt% poly ethylene glycol (PEG) with an aqueous solution of 10 wt% dextran. The entering dextran phase contains no enzyme (*alcohol dehydrogenase*). The entering PEG + enzyme phase has the flow rate of 20 kg/h. Calculate the total recovery fraction of enzyme *dehydrogenase* [or (the amount of enzyme extracted)/(the initial amount of enzyme)] when 20 kg/h of the dextran phase is added to a two (2)-stage, cross-flow extractor. Given the distribution of enzyme as

$$\frac{\text{Weight fraction of enzyme in PEG, } x}{\text{Weight fraction of enzyme in dextran, } y} = 0.12$$

2. We have a mixture of acetic acid in water and wish to extract this mixture with heptanol at 25 °C, in which the distribution of acetic acid is

$$\frac{\text{Weight fraction of acetic acid in the heptanol phase}}{\text{Weight fraction of acetic acid in the water phase}} = 0.828$$

   The inlet water solution flows at 550 kg/h and is 0.0097 weight fraction of acetic acid. We desire that an outlet water has a concentration of acetic acid of 0.00046 weight fraction. The heptanol phase contains acetic acid with the concentration of 0.0003 weight fraction. Assume that this system is dilute and immiscible. Find the weight fraction of acetic acid in the outlet heptanol phase and the number of equilibrium stages required.

3. We are extracting acetic acid (the solute) from benzene (the diluent) using water (the solvent) at 25 °C and 1 atm. The feed of 100 kg/h of the mixture of acetic acid and benzene with the weight fraction of acetic acid of 0.00092 is fed to a

extraction column. The inlet water is pure and flows at 25 kg/h. If the extraction column has 2 equilibrium stages. Find

3.1) the outlet weight fraction of acetic acid in benzene

3.2) the outlet weight fraction in water

The distribution of acetic acid is

$$\frac{\text{Weight fraction of acetic acid in water}}{\text{Weight fraction of acetic acid benzene}} = 30.5$$

Even though we can use a McCabe-Thiele diagram to solve this problem, it may be easier if we apply the ***Kremser*** technique as *per* the problem of absorption and stripping to this Question.

4. We have a feed of 30 wt% acetic acid and 70 wt% water with the amount of 15 kg.

   4.1) If the solvent of pure isopropyl ether with the amount of 10 kg is mixed with the feed in a mixer, find the final compositions of the raffinate and extract phases.

   4.2) If the concentration of acetic acid in the final raffinate phase is 0.1 weight fraction, how much (in kg) solvent is needed?

   The equilibrium data of the water-acetic acid-isopropyl ether system is as follows

Water Layer (wt%) (Raffinate Phase)			Isopropyl Ether Layer (wt%) (Extract Phase)		
Acetic acid	Water	Isopropyl ether	Acetic acid	Water	Isopropyl ether
0.69	98.1	1.2	0.17	0.50	99.3
1.41	97.1	1.5	0.37	0.70	98.9
2.89	95.5	1.6	0.79	0.80	98.4
6.42	91.7	1.9	1.93	1.0	97.1
13.3	84.4	2.3	4.82	1.9	93.3
25.5	71.1	3.4	11.4	3.9	84.7
36.7	58.9	4.4	21.6	6.9	71.5
44.3	45.1	10.6	31.1	10.8	58.1
46.4	37.1	16.5	36.2	15.1	48.7

5. A 100 kg/h feed contains 50 wt% M and 50 wt% H is mixed with the solvent, which comprises 15 wt% M and 85 wt% A in a single-stage counter-current extractor. We obtain the extract phase that contains 10 wt% M and the raffinate

that contains 61% M. What flow rate (in kg/h) of the solvent is used? The equilibrium data is as follows

H Phase (wt%) Raffinate Phase		A Phase (wt%) Extract Phase	
M	H	M	H
0	92.6	0	6.2
9.2	83.1	0.8	6.0
18.6	73.4	2.7	5.3
22.0	69.8	3.0	5.1
33.8	57.6	4.6	4.5
40.9	50.4	6.0	4.0
46.0	45.0	7.4	3.6
59.0	30.7	9.2	2.8
67.2	22.8	11.3	2.1
71.6	18.2	12.7	1.6
73.6	16.0	13.1	1.4
83.3	5.4	15.6	0.6
88.1	0	16.9	0

6. We wish to remove acetic acid from water using isopropyl ether as a solvent. The equilibrium data is as same as that in Question 4. Feed is 0.45 wt. fraction acetic acid and 0.55 wt. fraction water, with the flow rate of 2,000 kg/h. A counter-current extraction system is used. Pure isopropyl ether is used as a solvent. We desire to obtain an extract phase with 0.20 wt. fraction acetic acid and a raffinate phase with 0.20 wt. fraction acetic acid.
   6.1) How much solvent is needed (in kg/h)?
   6.2) How many equilibrium stages are required?
7. A counter-current extraction system with 3 equilibrium stages is used for water-acetic acid-isopropyl ether extraction. The equilibrium data is as same as that in Question 4. Feed is 40 wt% acetic acid and 60 wt% water. Feed flow rate is 2,000 kg/h. The isopropyl ether with 1 wt% acetic acid but no water is used as a solvent. We wish to get a raffinate phase that is 5 wt% acetic acid.
   7.1) What solvent flow rate is required?

7.2) What are the flow rates of outlet extract phase $\left(E_1\right)$ and outlet raffinate phase $\left(R_N\right)$?

8. The feed is 100 kg/h, containing 40 wt% acetic acid and 60 wt% water. The entering isopropyl ether is pure and has a flow rate of 111.2 kg/h. We want to have a raffinate phase with 20 wt% acetic acid.

   8.1) Find the weight faction of acetic acid in the outlet extract phase

   8.2) Determine the flow rates of the outlet extract phase $\left(E_1\right)$ and outlet raffinate phase $\left(R_N\right)$

   8.3) Find the number of equilibrium stages

   The equilibrium data is as same as that in Question 4.

9. Use the equilibrium data in Question 5 for this question. We have 100 kg/h of feed that is 60 wt% M and 40 wt% H. and another feed of 50 kg/h that is 20 wt% M and 80 wt% H are mixed with 200 kg/h of pure A (the solvent) in single-stage extractor.

   9.1) What are the compositions of the extract and raffinate phases leaving the extractor?

   9.2) Calculate the flow rate of the extract phase leaving the extractor