Separation Processes – I (CHE F244)

Total Marks – 12

Due date & Time: 5/05/2015, 5:00 PM

Assignment

1. A feed of ethanol-water containing 60 wt % ethanol is to be distilled at 101.32 kPa pressure to give a distillate containing 85 % ethanol and a bottoms containing 2 wt % ethanol. The feed rate is 10000kg/h and its enthalpy is 116.3 kJ/kg (50 btu/lb_m). Use consistent units of kg/h, weight fraction, and kJ/kg.
   a) Calculate the amount of distillate and bottoms.
   b) Determine the minimum reflux ratio using enthalpy-concentration data from data given.
   c) Using 2.0 times the minimum reflux ratio, determine the theoretical number of trays needed.
   d) Calculate the condenser and reboiler heat loads.
   e) Determine the minimum number of theoretical plates at total reflux.
   Equilibrium data for ethanol-water system at 101.325 kPa is as follows:

x_A	0	0.020	0.050	0.100	0.200	0.300	0.400	0.500
y_A	0	0.192	0.377	0.527	0.656	0.713	0.746	0.771

x_A	0.600	0.700	0.800	0.900	0.940	0.960	0.980	1.00
y_A	0.794	0.822	0.858	0.912	0.942	0.959	0.978	1.00

(X_A and Y_A are mass fractions of ethanol in liquid and vapor state respectively)

Enthalpy-concentration data for ethanol-water system 101.325 kPa is as follows:

Mass fraction		0	0.1	0.3	0.5	0.7	0.9	1.0
Enthalpy (kJ/kg of mixture)	Liquid	418.9	371.7	314.0	285.9	258.4	224.7	207.0
	Vapor	2675	2517	2193	1870	1544	1223	1064

2. A total feed of 200 mol/h having an overall composition of 42 mol% heptane and 58 mol% ethyl benzene is to be fractionated at 101.3 kPa pressure to give a distillate containing 97 mol % heptane and a bottoms containing 1.1 mol %heptane. The feed enters the tower partially vaporised so that 40 mol % is liquid and 60 mol % is vapour. Equilibrium data are given below. Calculate the following
   a) Moles/h of distillate and bottoms

b) Minimum reflux ratio Rm
c) Minimum steps and theoretical trays at total reflux
d) Theoretical number of trays required for an operating reflux ratio 2.5:1

temperature		X_H	y_H	temperature		x_H	y_H
K	^0C			K	^0C		
409.3	136.1	0	0	383.8	110.6	0.485	0.73
402.6	129.4	0.08	0.23	376	102.8	0.79	0.904
392.6	119.4	0.25	0.514	371.5	98.3	1	1

3. 1000 kg moles/h of ethanol propanol mixture containing 65 mol% ethanol is to be separated in a continuous plate column operating at 1 atm total pressure. The desired terminal compositions in units of mole fraction of ethanol are
   xD=0.92 and xW=0.07
   The feed is saturated vapour and total condenser is used. When the reflux flow rate is 4 times the amount of the top product, find the number of theoretical plates required for separation.
   The relative volatility of the ethanol propanol system may be taken as 2.10
4. Gas from a petroleum distillation column has its concentration of H_2S reduced from 0.03 kmol H_2S per kmol inert hydrocarbon gas to 1% of this value by scrubbing with triethanolamine-water mixture in a counter current tower of height 7.79m operating at 300K and 1 atm pressure. The equilibrium relation is given by y=2x, where y = kmol H_2S per mol inert gas and x=kmol H_2S per kmol solvent. Pure solvent enters the tower and leaves it containing 0.013 kmol H_2S per kmol of solvent. If the flow rate of gas is 0.015kmolm^{-2}s^{-1} and gas phase resistance controls the process, calculate the overall gas absorption coefficient K_ga.
5. A tray tower is to be designed to absorb SO_2 from an air stream by using pure water at 293K (68^{0}F). The entering gas contains 20 mol% SO_2 and that leaving 2 % at total pressure of 101.3kPa. The inert air flowrate is 150kg air /h.m^2, and the entering water flowrate is 6000kg water / h.m^2. Assuming an overall tray efficiency of 25%, how many theoretical and actual trays are needed? Assume that the tower operates at 293K (20^{0}C).

Mol fraction of SO_2 in liquid, x_A	**Mol fraction of SO_2 in vapor, y_A (20^{0}C)**	**Mol fraction of SO_2 in vapor, Y_A (30^{0}C)**
0	0	0
0.0000562	0.000658	0.00079
0.0001403	0.00158	0.00223
0.00028	0.00421	0.00619
0.000422	0.00763	0.01061
0.000564	0.01120	0.0155
0.000842	0.01855	0.0259
0.001403	0.0342	0.0473
0.001965	0.0513	0.0685
0.00279	0.0755	0.1040
0.0042	0.121	0.1645
0.00698	0.212	0.284
0.01385	0.443	0.594

0.0206	0.682	0.905
0.027	0.917	-

6. An aqueous feed solution of 1000kg/h of acetic acid-water solution contains 30 wt% acetic acid and is to be extracted in a counter current multi-stage process with pure isopropyl ether to reduce the acid concentration to 2 wt% acid in final raffinate. If 2500kg/h of ether solvent is used, determine the number of theoretical stages required.
7. Oil is to be extracted from meal by means of benzene, using a continuous counter-current extractor. The unit is to treat 2000 lb of meal (based on completely exhausted solid) per hour. The untreated meal contains 800 lb of oil and 50 lb of benzene. The fresh wash solution consists of 20 lb of oil dissolved in 1310 lb of benzene. The exhausted solids are to contain 120 lb of unexhausted oil. Experiments carried out under conditions identical with those of the projected battery, show that the solution retained depends on the concentration of the solution as given in the table below. Find:
   a) The composition of the strong solution
   b) The composition of the solution adhering to the extracted solids
   c) The weight of solution leaving with the extracted meal
   d) The weight of the strong solution
   e) The number of units required

Experimental data		Underflow composition				
		Per lb of oil free meal			Weight fraction	
Solution composition, y_A	$\frac{Lb\ solution\ retained}{Lb\ oil\ free\ meal}$	Lb of oil	Lb of benzene	Lb of underflow stream	$\frac{Lb\ oil}{Lb\ \text{Underflow}}$ x_A	$\frac{Lb\ benzene}{Lb\ \text{Underflow}}$ X_B
0.0	0.5	0	0.5	1.5	0	0.333
0.1	0.505	0.0505	0.4545	1.505	0.0336	0.302
0.2	0.515	0.1030	0.412	1.515	0.0680	0.272
0.3	0.530	0.1590	0.371	1.530	0.1039	0.242
0.4	0.550	0.220	0.330	1.550	0.1419	0.213
0.5	0.571	0.2855	0.2855	1.571	0.1817	0.1817
0.6	0.595	0.357	0.238	1.595	0.224	0.1492
0.7	0.620	0.434	0.186	1.620	0.268	0.1148

8. In a continuous counter-current train of mixer-settler, 100 kg/h of a 40:60 acetone-water solution is to be reduced to 10% acetone by extraction with pure 1,1,2-trichloroethane at 25°C. If the solvent flow rate is 46.63 kg/h, find the number of stages required. Also find the mass flow rates of other streams.

Data:

Weight % in water layer			**Weight % in trichloroethane layer**		
$C_2H_3Cl_3$	**Water**	**Acetone**	**$C_2H_3Cl_3$**	**Water**	**Acetone**
0.52	93.52	5.96	90.93	0.32	8.75
0.73	82.23	17.04	73.76	1.10	25.14
1.02	72.06	26.92	59.21	2.27	38.52

1.17	67.95	30.88	53.92	3.11	42.97
1.60	62.67	35.73	47.53	4.26	48.21
2.10	57.00	40.90	40.00	6.05	53.95
3.75	50.2	46.05	33.70	8.90	57.40

9. A plant distill a mixture containing 75 mol % methanol and 25 mol % water. The overhead product contains 99.99 % methanol and the bottom product 0.0002 mol %. The feed is cold, and for each mol % of feed 0.15 mol of vapour is condensed at the feed plate. The reflux ratio at the top of the column is 1.4 and the reflux is at its bubble point. Calculate:
   a) The minimum number of plates
   b) The minimum reflux ratio
   c) The number of plates using a total condenser and a reboiler, assuming an average Murphree plate efficiency of 72 %

   Equilibrium data for ethanol-water system:

x	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Y	0.417	0.579	0.669	0.729	0.780	0.825	0.871	0.915	0.959	1.0

10. Oil is to be extracted from halibut livers by means of ether in a counter-current extraction battery. The entrainment of solution by the granulated liver mass was found by experiment to be as shown in table below. In the extraction battery, the charger per cell is to be 100 lb, based on completely exhausted livers. The unextracted livers contain 0.043 gal of oil per pound of exhausted material. A 95 percent recovery of oil is desired .The final extract is to contain 0.65 gal of oil per gallon of extract. The ether is fed to the system is oil free.(a) How many gallons of ether are needed per charge of livers?(b) How many extractors are needed ?

Solution retained by 1lb exhausted livers, gal	Solution concentration , gal oil/gal solution
0.035	0
0.042	0.1
0.050	0.2
0.058	0.3
0.068	0.4
0.081	0.5
0.099	0.6
0.120	0.68