BACHELOR OF ENGINEERING IN CHEMICAL ENGINEERING EXAMINATION, 2018

(3rd Year, 2nd Semester)

SEPARATION PROCESSES - II

Time : Three hours Full Marks : 100

(50 marks for each Part)

Use a separate Answer-script for each Part

PART - I (50 MARKS)

1. A binary mixture of 60 mole% A and 40 mole% B is to be separated into a top product having 90 mole% A and a bottom product with 6 mole% A. The feed is a two phase mixture containing 72% liquid. Determine the minimum reflux ratio for the separation. The equilibrium data for the system at the operating conditions of the column are given below: [20]

x	0	0.05	0.07	0.1	0.15	0.2	0.25	0.4	0.5	0.6	0.7	0.8	0.9	1.0
y	0	0.07	0.1	0.14	0.205	0.29	0.39	0.75	0.86	0.93	0.96	0.98	0.99	1.0

Or

Vinyl chloride is a bulk organic chemical required for the production of polyvinyl chloride (PVC), a widely used polymer. Since vinyl chloride is a toxic and carcinogenic volatile organic compound (VOC), it must be removed from any waste gas stream containing this compound. Adsorption in a packed bed of activated carbon is a practical method of its removal from an emission. The following experimental breakthrough data for adsorption of vinyl chloride on granular activated carbon (GAC) at 20^{0}C and essentially atmospheric pressure were given below:

Time. Min	141	154	166.7	189.7	205	225.6	246	261
y/y_i	0	0	0.018	0.144	0.223	0.411	0.587	0.692

Time. Min	282	297	318	338	350
y/y_i	0.807	0.894	0.996	0.99	1.0

Details of the experimental parameters are: bed length, L=15.2 cm, bed diameter, d = 2.3 cm, gas flow arte 80cm^3/s at 1 atm and 20^{0}C, bed porosity, 0.36, interstitial gas velocity 0.54 m/s, vinyl chloride concentration in the feed 190 ppm (by volume), y_i is mole fraction of solute in feed gas and y is that in the effluent.

a) Calculate the length of the mass transfer zone, the velocity of the stoichiometric front and the saturation capacity of the bed at the influent gas concentration.

b) A waste gas stream containing 190 ppm (volume) vinyl chloride is to be treated with activated carbon in a packed bed reactor at a rate of 20 m^3/min to reduce its concentration by 98%. Using the above breakthrough data, determine the bed diameter, height and pressure drop if an adsorption period of 10 h is allowed. The specific gas velocity to be used is the same as that of experimental study.

[Turn over

Breakthrough time in the experimental column t_b is 165 min (when effluent concentration is almost 0.02). Stoichiometric time t_s is 238 min. [20]

2. A hot solution containing 2000 kg of $MgSO_4$ and water at 330 K and with a concentration of 30 wt% $MgSO_4$ is cooled at 293 K and $MgSO_4 .7H_2O$ crystals are removed. The solubility at 293K is 35.5 kg $MgSO_4$ /100 kg of water. The average heat capacity of the feed solution is 2.93 kJ/kg K. The heat of solution at 293 K is -13.31 x 10^3 kJ/kg mole $MgSO_4 . 7H_2O$. Calculate the yield of crystals and make a heat balance. Assume that no water is vaporized. Molecular weight of $MgSO_4$: 120.35, $MgSO_4 .7H_2O$: 246.49 [15]

Or

1000 kg of an aqueous solution containing 50% acetone is contacted with 800 kg of chlorobenzene containing 0.5 mass % of acetone in a mixer-settler unit, followed by separation of the extract and the raffinate phases. Determine the composition of the extract and the raffinate phases and the fraction of acetone extracted. Data given: $x_{C, R}$ (solite concentration in raffinate) = 0.24, $y_{C,E}$ = 0.3 (solute concentration in extract phase) [15]

3. Briefly describe Circulating-liquid evaporated-crystallizer or Bollman bucket-type extractor and its application. [5]

4. Prove that: $$\frac{C_e}{x} = \frac{1}{K_L x_m} + \frac{C_e}{x_m}$$

where x and X_m are the amount of the adsorbent adsorbed at equilibrium concentration C_e and maximum amount of adsorbate for the formation of monolayer, respectively [10]

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SEPARATION PROCESSES II

PART II (50 Marks)

Assume any **missing** data

1. Answer any ***one***:
   a) Show that cold reflux in a continuous distillation operation ensures lower number of tray requirement for a particular separation duty?
   b) In case of liquid-liquid extraction, discuss the effect of change of temperature and pressure on binodal solubility curve of the system having three liquids with one pair partially soluble. What is the plait point concentration in LLE diagram?
   c) What is HPLC? How it differs from normal Liquid Chromatography?

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2. Answer any ***one***
   a) Under what conditions, can adsorption isotherms be represented by Freundlich equation? Show that the Langmuir isotherm is essentially linear at low solution concentrations.
   b) What is the Matsuoka-Garside number and what is its physical significance?
   c) Derive Fenske's equation for calculation of minimum number of stages in fractionators and state its limitation.

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3. 1000 kg of crushed oil seeds (19.5% oil and 80.5% meal) is extracted using three-stage cross-current unit with 500 kg pure hexane in each vessel. Calculate the fraction of oil that can be extracted.

   Equilibrium data: A: seed meal, B: hexane, C: oil

Overflow			Underflow		
W_A(kg)	W_B(kg)	W_C(kg)	W_A(kg)	W_B(kg)	W_C(kg)
0.3	99.7	0	67.2	32.8	0
0.45	90.6	8.95	67.1	29.94	2.96
0.54	84.54	14.92	66.93	28.11	4.96
0.7	74.47	24.83	66.58	25.06	8.36
0.77	69.46	29.77	66.26	23.62	10.12
0.91	60.44	38.65	65.75	20.9	13.35
0.99	54.45	38.65	65.33	19.07	15.6
1.19	44.46	54.35	64.39	16.02	19.59
1.28	38.5	60.22	63.77	14.13	22.1
1.48	24.63	73.89	61.54	9.61	28.85

OR

[Turn over

100 kg/hr of fresh fish liver containing 25% oil has to be extracted with ethyl-ether in a continuous counter-current leaching unit. 95% of the oil has to be extracted and the strong solution should contain 0.7 mass fraction oil.

Determine:

i) The quantity and composition of discharged solids
ii) Kilograms of oil-free ether required per hour
iii) Number of stages required

Laboratory experiments have furnished the following equilibrium data:

x	0.1	0.2	0.3	0.4	0.5	0.65	0.7	0.7
S	4.13	3.50	2.95	2.47	2.04	1.67	1.49	1.31

Where, x = kg oil in leached solid/$kg\ solution$; S = $kg\ oil - free\ liver/kg\ solution$

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4. The vapour-liquid equilibrium data for a binary mixture A-B is given below:

x_A	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
y_A	0	0.18	0.33	0.46	0.57	0.67	0.75	0.82	0.89	0.95	1.0

The feed mixture (saturated liquid) contains 50 mol% A. it is fractioned into product streams containing 95 mol% A and other 5 mol%. The feed flow rate is 100 moles/sec. A partial condenser is being used. Use Ponchon-Savarit technique to determine

a) Minimum reflux ratio
b) Number of stages in the column, if actual reflux ratio is 1.5 times of minimum
c) Feed stage
d) Reboiler and condenser heat load

The enthalpy of liquid and vapour may be assumed to be constant at 10,000 KJ/mol and 20,000 KJ/mol, respectively for all concentrations.

OR

A pyridine-water solution containing 50% pyridine, is to be continuously and counter-currently extracted at the rate of 2.25 Kg/s with chlorobenzene to reduce the pyridine concentration to 2%.

a) Determine the minimum solvent rate required;
b) If 2.3 Kg/s solvent rate is used, what are the number of theoretical stages and the weights of final extract and raffinate?

The equilibrium tie line data at 25°C, in weight percent are:

Pyridine	Chlorobenzene	Water	Pyridine	Chlorobenzene	Water
0	99.95	0.05	0	0.08	99.92
11.05	88.28	0.67	5.02	0.16	94.82
18.95	79.9	1.15	11.05	0.24	88.71
24.1	74.28	1.62	18.9	0.38	80.72
28.6	69.15	2.25	25.5	0.58	73.92
31.55	65.58	2.87	36.10	1.85	62.05
35.05	61.0	3.95	44.95	4.18	50.87
40.6	53.0	6.4	53.2	8.9	37.9
49.0	37.8	13.2	49.0	37.8	13.2