Ref. No. : Ex/ChE/T/323/2017

Bachelor of Engineering in Chemical Engineering 3rd year 2nd Semester Examination, 2017
Separation Process II

Time: 3 hours **Total Marks:100**

Answer any five questions.

Use graph paper if required. Assume any missing data

1. a. The following data have been collected on equilibrium adsorption of nitrogen on an oxidation catalyst at 77.5 K, the normal boiling point of nitrogen, determine the specific surface area of the catalyst by the BET technique. **[15]**

P (pressure of N_2 mm Hg)	v (volume of N_2 adsorbed, cm^3 at NTP/100 g solid)
10	71.3
20	142.3
40	387.3
100	679.4
150	1025
200	1053
250	1175
300	1316
350	1996
400	3451
500	5283

For liquid nitrogen, density is 0.0808 g/cm^3, M=28, N=6.023 x 10^{23}
Specific surface area $S_g = q_m N\alpha$, where α is the projected area.

b. Prove that LUB = $(1-w_2/w_1)L$, where w is the total uptake of the adsorbent in the bed till the equilibrium time. **[5]**

2. 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°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

[Turn over

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.
LUB = $L_s[1-(t_b/t_s)$. Breakthrough time in the experimental column t_b is 165 min (when effluent concentration is almost 0.02). **[20]**

3. Oil is to be extracted from meal by means of benzene using a continuous countercurrent extractor. The unit is to treat 1000 kg of meal (based on completely exhausted solid) per hour. The untreated meal contains 400 kg of oil and is contaminated with 25 kg of benzene, the fresh solvent mixture contains 10 kg of oil and 655 kg of benzene. The exhausted solids are to contain 60 kg of unextracted 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 shown in table:
Calculate

a) the concentration of the strong solution or extract; b) the concentration of the solution adhering to the extracted solids; c) the mass of solution leaving with the extracted meal; d) the mass of extract. **[16]**

Briefly describe Dorr agitator for leaching process. **[4]**

4. Derive the expression for single stage extraction process. **[4]**
Briefly describe centrifugal extractor and rotating disk contactor for extraction process. **[10]**
What is the significance of power number, weber number and Galileo number in mass transfer. **[6]**

5. (a) Explain with the help of McCabe – Thiele diagram in which case (i) or (ii) the product purity will be higher for continuous distillation with total condenser:

(i) reflux returned to the column at bubble point
(ii) reflux cooled below its bubble point (cold reflux)

The number of stages and other conditions are same.

(b) A binary mixture containing 40% benzene and remaining toluene enters in to a flash column at 1 atm to give 70% vaporization. Find the composition of the liquid and vapor streams thus produced. Also calculate the yield of benzene in the vapour product.

Given: Relative volatility of benzene with respect to toluene = 2.1

[10+10]

6. A distillation column receives two feeds: (i) 250kmol/h, 70% liquid and 30% vapour, with 43 mole % methanol on average, (ii) 100 kmol/h, saturated liquid, with 18 mole % methanol. The top product must have a purity of 96 mole % and bottom must not have more than 3 mole % of alcohol. A liquid sidestream having 67 mole % methanol is to be withdrawn at the rate of 35 kmol/h. The reflux is returned to the top tray as saturated liquid.

   i) Find the minimum reflux ratio.
   ii) Find the number of ideal stages required for separation considering an operating reflux ratio to be 1.5 times the minimum.
   iii) Locate the feed trays, and also the tray from which the side stream should be withdrawn.

[20]

The equilibrium and bubble point data for the methanol–water system at 101.3 kPa are given below.

x	0	0.02	0.04	0.06	0.08	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	0.95	1.0
y	0	0.134	0.23	0.304	0.365	0.418	0.579	0.665	0.729	0.779	0.825	0.87	0.915	0.958	0.979	1.0
Temp.	100	96.4	93.5	91.2	89.3	87.7	84.4	78.0	75.3	73.1	71.2	69.3	67.6	66	65	64.5

OR

(a) A mixture of benzene and toluene containing 40 mole per cent benzene is to be separated to give a product containing 90 mole per cent benzene at the top, and a bottom product containing not more than 10 mole per cent benzene. The feed enters the column at its boiling point, and the vapour leaving the column which is condensed but not cooled, provides reflux and product. It is proposed to operate the unit with a reflux ratio of 3 kmol/kmol product. It is required to find the the position of entry for the feed. Assume, the relative volatility of benzene with respect to toluene is 2.2 at the operating condition. **Use Lewis- Sorel method to solve the problem.**

(b) A solution consisting of 30% $MgSO_4$ & 70% water is cooled to 60F. During cooling, 5% of the total water in the system evaporates. How many kilograms of the crystals are obtained per 1,000kg of original mixture? (It is given that crystals of $MgSO_4.7H_2O$ will be formed & concentration of mother liquor is 24.5% anhydrous $MgSO_4$ and 75.5% water.)

[10+10]