BACHELOR OF ENGINEERING IN CHEMICAL ENGINEERING EXAMINATION, 2019

(3rd Year, 2nd Semester)

SEPARATION PROCESSES - II

Time : Three hours | Full Marks : 100

Answer any four question
(Assume any missing data, giving proper justification)

1. 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 20^0C 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 20^0C, 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. 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. [25]

2. Briefly describe Hilderbrandtl extractor for leaching. [5]
Briefly describe the steps in leaching process. [5]
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. a) Determine the composition of the extract and the raffinate phases and the fraction of acetone extracted. b) Calculate the amount of solvent required if 90% of acetone is to be removed. Data given: $x_{C,R}$ = 0.24, $y_{C,E}$ = 0.3 (for Problem a), $x_{C,R}$ = 0.091, $y_{C,E}$ = 0.105 (for problem b). [15]

3. 500 kg of the inert solid containing 28 percent by mass of the water-soluble component (A), is agitated with 100 m^3 of water for 600 sec. After each decanting 25% of the solution produced remain in the residue. Water is saturated with the solute at a concentration of 2.5 kg/m^3. Find the concentration of the solute (A) in the solution after the leaching. In a pilot scale test using a vessel 1m^3 in volume, a solute was leached from an inert solid and the water was 75 percent saturated in 10 s. Assuming conditions

$$C = C_S\left[1 - e^{\frac{-K_L \cdot A}{V}t}\right]$$

are equivalent to those in the pilot scale vessel. [15]
Briefly describe Hildebrandt screw-conveyor extractor and Bollman bucket-type extractor [10]

[Turn over

4. (a) Prove that when the surface integration or accommodation of solutes in the growing layers of a crystal is assumed to be a 1st order step, the growth rate would be proportional to degree of super-saturation.
(b) What do you mean by invariant growth?
(c) Explain the phenomenon of Ostwald ripening.
(d) 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 = 2.4

7+5+5+8 = 25

5. (a) 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 under the given condition, crystals of $MgSO_4.7H_2O$ will be formed & concentration of mother liquor is 24.5% anhydrous $MgSO_4$ and 75.5% water).
(b) What are the methods for generation of super-saturation in case of crystallization?
(c) A MSMPR crystallizer of 5 m^3 working volume produces crystals of mass average particle size 1.0mm. If the product stream is withdrawn at the rate of 4 m^3/h, calculate the crystal growth rate and the rate of secondary nucleation, B^o. The magma density is 150 kg/m^3, and the true density of the crystals is 1900 kg/m^3. The volume shape factor is 0.6.

8 + 7 + 10 = 25

6. (a) What do you mean by nucleation in case of crystallization? What are the different types of nucleation? What are the important factors that influence the rate of nucleation?
(b) What is "McCabe Δ-law"? Explain its significance in deriving the population balance model of crystal size distribution (CSD).
(c) A continuous fractionating column is to be designed to separate 20,000 kg/hour of a binary mixture containing 36 %(by weight) of benzene and 64 %(by weight) of toluene. The top product contains 98 %(by weight) of benzene and the bottom product contains 94% (by weight) toluene. The feed is liquid entering the column at its boiling point. Design a suitable distillation column for this purpose operating at 1 atm pressure. Relative volatility of benzene –toluene system may be taken as 2.4. Take suitable reflux ratio with proper justification and find number of theoretical plates and feed-plate location.
(d) Do the crystals of a substance of 1mm have the same solubility in a solvent like 1μm particles? Can you give qualitative explanation of any difference?

5 + 5 + 10 + 5 = 25