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INTERNATIONAL CENTRE FOR APPLIED SCIENCES

(Manipal University)

IV SEMESTER B.S. DEGREE EXAMINATION - OCT. / NOV. 2017

SUBJECT: INTRODUCTION TO MASS TRANSFER OPERATION (CHM 243)

(BRANCH: CHEMICAL)

Tuesday, 31 October 2017

Time: 3 Hours **Max. Marks: 100**

- ✓ **Answer ANY FIVE Questions.**
- ✓ **Missing data, if any, may be assumed suitably.**

1A. Oxygen is diffusing through nitrogen under steady state conditions. The total pressure of the system is P_T ,Temperature is T, diffusion path is Z, partial pressure of oxygen at two planes are P_{A1}, P_{A2} and mole fraction of oxygen at two planes are y_{A1}, y_{A2} respectively. Derive an expression to determine the flux of mass transfer of oxygen for the case (i) Nitrogen is non-diffusing (ii) There is an equimolar counter diffusion of the two gases.

1B. Ammonia is diffusing through a stagnant gas mixture consisting of $1/3^{rd}$ of nitrogen and $2/3^{rd}$ of hydrogen by volume. The total pressure of the system is 2.05 atm. and the temperature is 55˚C. Calculate the rate of diffusion (N_A) of ammonia through a gas film of 0.5 mm thickness when the concentrations across the film are 10% and 5% by volume respectively. The diffusivity of NH_3 in N_2 and NH_3 in H_2 at 20˚C and 1 atm. pressure are 0.69 cm^2/sec and 0.194 cm^2/sec respectively. Assume that 1m^2 area is involved for diffusion.

(10+10)

2A. Define Murphree stage efficiency. Derive the relationship between Murphree stage efficiency with respect to phase 'E' and phase 'R' for transfer of solute from liquid phase (R) to gas phase (E) under co-current mass transfer operation process.

2B. Give a brief account of Higbie's Penetration theory of mass transfer with its assumption.

(10+10)

3A. Derive an expression to determine the Number of Theoretical plates (N_P) required for an multistage counter current absorption operation with an Absorption factor A ≠1 (show all the steps with neat figure).

3B. 1000 m^3/hr of an air- benzene mixture at 26.6˚C and 1atm pressure containing 5% of benzene vapour is being scrubbed with 1800 Kg/hr of benzene free hydrocarbon oil with an average mol.wt. of 260 g/gmole in a packed tower under these operating condition. The 90% of the incoming benzene vapour is absorbed(removed). Assuming that all the conditions remain unchanged. How much fraction to increase in height should be to absorb 96% of the benzene. Assume that Raoult's law could be hold for the system and vapour pressure of benzene at 26.6˚C is 100 mm Hg.

(12+8)

4A. What are the nature of adsorbents? Briefly explain any six industrial important adsorbent.

4B. Nitrogen dioxide (NO_2) is produced by a thermal process for fixation of nitrogen is to be removed from a dilute mixture with air by adsorption on silica gel in a continuous counter current adsorber. The gas entering the adsorber at the rate of 0.126 kg/sec contains 1.5% NO_2 by volume, and 90% of the nitrogen dioxide is to be removed. Operation is to be isothermal at 25˚C, 1 standard atmosphere. The entering silica gel will be free of nitrogen dioxide. The equilibrium adsorption isotherm at this temperature is given by the following data

Partial pressure of NO_2 (mm Hg)	0	2	4	6	8	10	12
$\frac{\text{Kg } NO_2}{\text{100 Kg Silica gel}}$	0	0.4	0.9	1.65	2.60	3.65	4.85

(a) Determine the minimum weight of gel required per hour?

(b) If twice the minimum gel rate, calculate the number of ideal stages required by graphically.

(8+12)

5A. (i) Hydrogen gas (H_2) is flowing through the circular pipe with inner and outer diameters are 'd_1'and 'd_2' respectively and the pipe is made of unvulcanised neoprene rubber. Develop an expression to determine the mass transfer rate of loss of H_2 by diffusion through the pipe.

(ii) Explain the types of flow in structure sensitive diffusion of gases in solids.

5B. Porous alumina spheres 10 mm diameter, 35% voids were thoroughly impregnated with an aqueous potassium chloride solution, concentration 0.25 g/cm^3, when immersed in pure running water, the spheres lost 90 % of their salt content in 4.75 hrs. The temperature was 25˚C. At this temperature the average diffusivity of potassium chloride in water is 1.84 x 10^{-9} m^2/sec. Estimate the time required for removal of 90% of the dissolved solute if the spheres had been impregnated with potassium chromate solution at an concentration 0.28 g/cm^3, when immersed in a running stream of water containing 0.02 gm K_2CrO_4/cm^3. The average diffusivity of K_2CrO_4 in water at 25˚C is 1.14 x 10^{-9} m^2/sec. The following relationship can be used $E = 0.0019\ X^{-2.3}$. Where E = Unaccomplished change; X = Relative time.

(6+4+10)

6A. Obtain an expression to determine the various relationship between mass transfer coefficient for liquids for the case (i) Diffusing compound 'A' through non diffusing compound 'B'(ii) Equimolar counter diffusion (iii) F type for both the cases

6B. In a packed bed mass transfer apparatus operating at 1 atm. pressure the individual mass transfer coefficient have the following values. k_{La} = 22 kgmole/(m^3.hr), k_{Ga} = 1.07 kgmole/(m^3.hr).The equilibrium compositions of the gaseous and liquid phases are characterized by Henry's law $P^* = 0.08\ X\ 10^6$ x mm Hg. How many times the overall diffusion resistance of the liquid phase differs from that of gaseous phase?

(14+6)

7A. Describe in detail about the selection criteria for choosing a solvent in gas absorption operation.

7B. Water at the rate of 3000 kg/hr is used for scrubbing acetone from air−acetone mixture. The mixture contains 6% acetone by volume. Air flow rate free from acetone is 1500 m^3/hr at 20˚C, 850 mm Hg pressure and 98 percentage of acetone is scrubbed with water. The Equilibrium relationship for acetone-water system is given by $y^* = 1.68\ x$. where y^* and x are mole fraction of acetone in vapour and liquid phase respectively. Absorption of acetone takes place in a tower packed with ceramic rings of the size 25 x 25 x 3 mms. Assuming that the entering gas mixture is to be dilute. Determine the diameter of the tower and height of the packing required. The mass transfer coefficient is 0.46 kgmoles acetone/(m^2. hr). The interfacial surface area of packing is 204 m^2/m^3. The operating velocity of gas mixture is 25% less than the flooding velocity which is equal to 1.56 m/sec.

(8+12)

8A. Define HETP. Derive an equation to determine the height of adsorbent column in a continuous counter current adsorber.

8B. Experiments on decolourisation of oil yielded the following equilibrium relationship: $y = 0.5\ x^{0.5}$ where y = gm colour removed/gm adsorbent; x = colour in oil, gm colour per 1000 gm colour free oil. 100 kg oil containing 1 part of colour to 3 parts of oil is agitated with 25 kg of adsorbent. Calculate the percentage colour removal if

(i) All 25 kg of fresh adsorbent is used in one step.

(ii) 12.5 kg of fresh adsorbent is used initially, followed by another 12.5 kg of fresh adsorbent.

(10+10)