# Question Paper

Exam Date & Time: 24-Apr-2018 (09:30 AM - 12:30 PM)

## MANIPAL ACADEMY OF HIGHER EDUCATION

**INTERNATIONAL CENTRE FOR APPLIED SCIENCES**
**IV SEMESTER B.S. (ENGG.)**
**END - SEMESTER THEORY EXAMINATIONS APRIL - 2018**
**DATE: 24 APRIL 2018**
**TIME: 9:30 AM TO 12:30 PM**

**Introduction To Mass Transfer Operations [CHM 243]**

**Marks: 100** **Duration: 180 mins.**

## Answer 5 out of 8 questions.

## Missing data, if any, may be suitably assumed
## Write specific and precise answers, usual notations shall apply.

1) A) 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) The nitrogen is non-diffusing (ii) There is equimolar counter diffusion of the two gases. (10)

B) A crystal of $CuSO_4.5H_2O$ falls through a large tank of pure water of density 1 g/cc. Estimate the flux of diffusion of $CuSO_4$ solution across a film of non-diffusing water of 0.003 cm thickness at $20^0$C when the concentration on opposite sides of the film are 17.196 and 0 wt.% respectively. Density for 17.196 wt% solution is 1193 kg/$m^3$. The diffusivity of $CuSO_4$ solution in water at $20^0$C is 0.729 x $10^{-5}$ $cm^2$/sec. (Molecular weight of CuSO4 is 159.5 g/gmole) (10)

2) A) Derive the operating line expression in a multistage cross current operation for transfer of solute from liquid phase (R) to gas phase (E) with its graphical representation. Determine the Murphree stage efficiency with respect to each phase and percentage recovery of solute in a multistage cross current operation. (10)

B) Pure $CO_2$ (carbon dioxide) gas is absorbed in a laminar liquid flow circular pipe. The volumetric flow rate of the liquid was (10)

4 $cm^3$/sec and the diameter and the length of the circular pipe were 1 mm and 30 mm respectively. The rate of absorption of $CO_2$ at 1 atmospheric pressure was 0.12 $cm^3$/sec at $30^0$C. The equilibrium solubility of gas at $30^0$C is 0.0001 gmole/cc. Estimate the diffusivity of $CO_2$ gas. If the diameter of the pipe is reduced to 0.9 mm, under the same conditions, how would it affect the rate of diffusion? Assume the validity of Higbie's penetration theory.

3) 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 $\neq 1$ (show all the steps with neat figure). (10)

A)

B) The absorption tower is to recover 95% ethylene oxide from 3 mole% of ethylene oxide- air mixture. There is evidence to believe that the gas film offers the controlling resistance. The gas rate is 610.5 kgmole/hr and the liquid rate to be used is twice the theoretical minimum. Maximum mass velocity of water is 3901 kg/hr $m^2$. The tower will operate at $20^0$C, employing that water as the liquor for absorption. The tower is packed with raschig rings for which the absorption coefficient is 298 kgmoles/(hr.$m^3$). Total pressure of the system is 1 atmosphere. The solubility of ethylene oxide in water solution at $20^0$C may be represented by the equation p* = 200 x mm Hg. Determine the height of the packed bed absorption tower. (10)

4) Write the nature of adsorbent? Briefly describe about of any four industrial important adsorbents with its uses. (10)

A)

B) 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 mixture 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 $25^0$C and 1 standard atmospheric pressure. The entering silica gel will be free of nitrogen dioxide. The equilibrium adsorption isotherm at this temperature is given by the following data (10)

| 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.

5) A) (i) Hydrogen gas is kept in a sphere with inner and outer diameters are '$d_1$'and '$d_2$' respectively and the sphere is made of unvulcanised neoprene rubber. Develop an expression to determine the mass transfer rate of loss of $H_2$ by diffusion through the sphere. (10)

(ii) Explain the types of flow in structure sensitive diffusion of gases in solids with necessary flux equation.

B) 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$^0$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 a 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$^0$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. (10)

6) A) Obtain an expression to determine the various relationship between mass transfer coefficient for gases for the case (i) Diffusing compound 'A' through non diffusing compound 'B'(ii) Equimolar counter diffusion (iii) F type mass transfer coefficient for both the cases. (12)

B) On the basis of Chilton - Colburn analogy, estimate the value of mass transfer coefficient for the absorption of ammonia by the wet surface of a cylinder placed in a turbulent air stream flowing across the cylinder at 4.6 m/sec. No data on mass transfer exists for this process, but heat transfer tests for the same geometry and air velocity give heat transfer coefficient as 1.357 x 10$^{-4}$ cal/(cm$^2$.sec K). Following data is given for air: Prandtl number ($N_{Pr}$) = 0.74; $C_P$ = 0.49 x 10$^{-3}$ cal/(gm K) ; density($\rho$) = 0.0012gm/cc ; and for dilute ammonia - air mixture Schmidt number ($N_{Sc}$) is 0.61. (8)

7) A) Compare and contrast between packed column and plate column with 8 different criterion. (8)

B) $NH_3$ is to be recovered from 10% NH3 - air mixture by counter current absorption with water at 1 atmospheric pressure. The tower will be provided with adequate cooling so that the entire operation may be carried at $20^0$C .The tower is to be designed to recovered 95% of the $NH_3$ in the inlet gas, and the gas enters at the rate of 200 Kg/hr. Calculate the number of theoretical stages required for a multistage countercurrent absorption by both graphically and analytically. If water rate is 20% higher than the minimum is employed. The equilibrium partial pressure for $NH_3$ solutions at $20^0$C is given below (12)

| Partial pressure of $NH_3$ (mm Hg) | 12 | 18 | 32 | 50 | 70 | 166 |
|---|---|---|---|---|---|---|
| $\frac{\text{gm } NH_3}{\text{100 gm } H_2O}$ | 2 | 3 | 5 | 7.5 | 10 | 20 |

8) A) Define HETP. Derive an equation to determine the height of adsorbent column in a continuous counter current adsorber. (10)

B) The equilibrium water adsorbed by a silica-gel in contact with moist air varies linearly with the humidity of Y= 3.4435 x $10^{-2}$ X, Where X = kg water adsorbed/ kg dry silica gel, Y= humidity of air, kg moisture/kg dry air. 0.5 kg of silica gel containing 5 %(dry basis) adsorbed water is placed in a collapsible vessel in which there are 10 $m^3$ of moist air, the partial pressure of water vapour being 15 mm Hg. The total pressure and temperature were kept constant at 1 atm. and $25^0$C respectively. For gas mixtures following Ideal gas law. What is the amount of water picked up from the moist air in the vessel by the silica gel in terms of kg?. Also calculate the final partial pressure of water vapour in the vessel. (10)

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