INTERNATIONAL CENTRE FOR APPLIED SCIENCES
MAHE, MANIPAL
B.Sc. (Applied Sciences) in Engg.
End – Semester Theory Examinations – MAY 2021
IV SEMESTER - MASS TRANSFER-I (ICHM 243)
(BRANCH: CHEMICAL ENGINEERING)

Time: 3 Hours **Date: 19 May 2021** **Max. Marks: 50**

- ✓ **Answer all the questions**
- ✓ **Each question carries equal marks (5 X 10 = 50)**
- ✓ **Missing data, if any, may be suitably assumed**
- ✓ **Write specific and precise answers, usual notations shall apply.**

1A. Ammonia 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 ammonia at two planes are P_{A1}, P_{A2} and mole fraction of ammonia at two planes are y_{A1}, y_{A2} respectively. Derive an expression to determine the flux of mass transfer of ammonia for the case (i) The nitrogen is non-diffusing (ii) There is equimolar counter diffusion of the two gases. **(5)**

1B. Porous alumina spheres 5 mm diameter, 20 % voids were thoroughly impregnated with an impregnated with an aqueous Potassium chloride solution, Concentration 0.35 g/cm^3, when immersed in pure running water, the spheres lost 85% of their salt content in 6 hrs. The surface concentration of KCl on porous alumina spheres is 0.012 g/cc. The temperature was 30°C. At this temperature the diffusivity of potassium chloride in water is 1.84 X 10^{-9} m^2/sec. Estimate the time required for removal of 98% 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 surface concentration of K_2CrO_4 on porous alumina spheres is negligible. 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 $^{-2.3}$. **(5)**

2A. (i) 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) in a steady state co-current mass transfer operation. Also, to write the significance of absorption factor (A). **(4)**

(ii) How to calculate the % recovery of solute in a multi stage counter flow cascade operation for the transfer of solute from phase E (gas phase) to phase R (liquid phase) with a neat schematic representation? **(1)**

2B. A crystal of spherical shape of copper sulphate falls through a large tank of pure water at 20°C. For dissolution of crystals of soluble salt in water in an agitated tank, the following equation holds good

$$\frac{K_C' T}{D_{AB}} = 0.052\,(N_{Re})^{0.833}\,(N_{Sc})^{0.5,}$$

Where T is the diameter of the tank, K_C' is the mass transfer coefficient. A 1 m diameter cylindrical tank containing 550 kg of pure water is kept well agitated using N_{Re} = 80,000. A 100 kg $CuSO_4.5H_2O$ crystals in the form of uniform spheres of 6 mm diameter are suddenly dropped into the tank. Estimate the rate of dissolution of all the crystals. Also, calculate the

total time required to dissolve all the crystals. Assume that the equimolar counter diffusion take place

Data: Diffusion coefficient of $CuSO_4$ in water is 0.73×10^{-5} cm^2/sec; The density of pure $CuSO_4$ is 2400 kg/m^3. The solubility of $CuSO_4$ in H_2O at 293 K can be taken as 0.0229 mole fraction in one side. In other side, the mole fraction of $CuSO_4$ in water is negligible. Density and viscosity of the solution in other side can be assumed to be that of water. Molecular weight of Cu = 63.5 kg/kgmole and Molecular weight of S = 32 kg/kgmole. **(5)**

3A. Compare and contrast between packed column and plate column with 6 different criterions. Explain the significance of HETP. **(4)**

3B. An absorption oil containing 0.12 mole of benzene per mole of benzene free oil is stripped by running the oil down the column, up with pure superheated steam at 121˚C and 1 atm. pressure is passed. The oil leaving the stripper contains 0.005 mole of benzene per mole of benzene free oil. If twice the minimum amount of steam is used. How many theoretical stages are required for the above operation by graphically and analytically. The vapor liquid equilibrium data at 423 K and 1 atmospheric pressure is given below

1	0.02	0.04	0.06	0.08	0.10	0.12	0.13
II	0.07	0.1354	0.215	0.305	0.40	0.51	0.58

Where I = moles of benzene/moles of benzene free oil, II = moles of benzene/moles of steam **(6)**

4A Derive an equation to calculate the minimum total adsorbent required by considering two stage cross current adsorption operation with its graphical representation. Write the significance of Freundlich isotherm constants. **(5)**

4B. (i) Write the nature of adsorbent? Describe in detail about any four industrial important adsorbents with its uses. **(2.5)**

(ii) An aqueous solution containing valuable solute is colored by small amount of an impurity. Decolourisation experiments of an aqueous solution yielded the following equilibrium relationship $Y^* = 8.91 \times 10^{-5} X^{1.66}$. 1000 Kg of Initial solution with colour concentration of 9.6 colour units/ kg solution is to be treated with an adsorbent. Calculate the quantity of fresh adsorbent required to reduce the colour to 10% of its original value in a fourstage counter current adsorbent operation. Assuming that colour concentration in the solution stream leaving first stage is 4.6 times the final colour of the solution. **(2.5)**

5. (a) Explain the types of flow in structure sensitive diffusion of gases in solids with necessary flux equation. **(2.5)**

(b) Write the various steps involved for adsorption of solute from liquid to porous adsorbent particle with neat sketch. **(2.5)**

(c) Explain the concept of minimum Liquid-gas ratio with its graphical representation. **(2.5)**

(d) Write the various assumption and importance for Chilton - Colburn's analogy with necessary equation. **(2.5)**