Reg.No.									

INTERNATIONAL CENTRE FOR APPLIED SCIENCES

(Manipal University)

FOURTH SEMESTER B.S. DEGREE EXAMINATION – APRIL 2017

SUBJECT: INTRODUCTION TO MASS TRANSFER OPERATION (CHM 243)

(BRANCH: CHEMICAL ENGINEERING)

Friday, 21 April 2017

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

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

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

1B. The diffusivity of the gas pair oxygen-CCl_4 is determined by observing the steady state evaporation of CCl_4 into a cylindrical tube containing oxygen. The distance between the liquid level and the top of the tube is 17.1 cm. The total pressure of the system is 755 mm Hg and the temperature is 273 K, the vapour pressure of CCl_4 at 273 K is 33 mm Hg and density is 1.59 g/cc. The cross sectional area of the diffusion tube is 0.82 cm^2. It is found that 0.0208 cc of CCl_4 evaporates in 10 hr period after steady state has been attained. What is the diffusivity of oxygen-CCl_4? Assume that the vapour pressure exerted for the compound compare with atmospheric pressure is negligible. (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) in a steady state co-current mass transfer operation.

2B. Pure gas 'A' is absorbed in a laminar liquid jet (circular pipe). The volumetric flow rate of the liquid was 4 cm^3/sec and the diameter and the length of the jet were 1 mm and 30 mm respectively. The rate of absorption of 'A' at 1 atmosphere pressure was 0.12 cm^3/sec at 30˚C. The equilibrium solubility of gas at 30˚C is 0.0001 gmole/cc. Estimate the diffusivity of gas. If the diameter of the jet is reduced to 0.9 mm, under the same conditions, how would it affect the rate of evaporations? Assume the validity of Higbie's penetration theory. (10+10)

3A. Derive an expression to determine the height of packed bed absorption tower (Z) with the suitable assumption.

3B. A Packed tower is designed to recover 98% CO_2 from a gas mixture containing 10% CO_2 and 90% by volume air using water. A relation Y = 14X can be used for equilibrium conditions where Y is kg CO_2/kg dry air and X is kg CO_2/kg water. The water to gas rate is kept 30% more than the minimum value. Calculate the actual mole ratio of water to solute free gas. (14+06)

4A. (i) List out the names of industrial important adsorbents.

(ii) Derive an equation to calculate the minimum total adsorbent required by considering two stage cross current adsorption operation and also draw its graphical representation.

4B. 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.

(i) Calculate the percentage of original colour removed in single stage cross current operation using 32 kg of fresh adsorbent.

(ii) Calculate the quantity of fresh adsorbent required to reduce the colour to 10% of its original value in a four stage counter current adsorbent operation. Assuming that colour concentration in the solution stream leaving from first stage is 4.6 times the final colour of the solution. (12+8)

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) Compare and contrast between Knudsen flow and poiseuille's flow with necessary flux equation.

5B. An unglazed porcelain plate 5 mm thickness have a average pore diameter of 0.002 μm. Pure oxygen gas at a partial pressure of 20 mm Hg, 373˚K on one side of the plate passes through a flux of 7.99×10^{-8} gmole/(cm^2.sec),when the partial pressure on the downstream side was so low as to be considered negligible. Estimate the flux of diffusion of hydrogen at 298˚K at 10 mm Hg with negligible downstream partial pressure. The viscosity of oxygen at 373˚K, 20 mm Hg is 0.02 cp and viscosity of hydrogen at 298˚K, 10 mm Hg is 0.0085 cp respectively. Assume that the pore length is constant for both oxygen and hydrogen diffusing. (10+10)

6A. Obtain an expression to find the relationship between overall and individual phase mass transfer coefficient for a gas-liquid phase mass transfer with its various cases.

6. In an experimental study of absorption of NH_3 by water in a wetted wall column. The value of overall mass transfer coefficient K_G was found to be 1 kmole/(hr. m^2. atm.) at 1 point of the column the gas contains 8% of the NH_3 and liquid phase concentration was 0.064 kmole/m^3 of the solution. The temperature was 20°C and total pressure was 1 atm. 85% of total resistance to ass transfer was found to be in gas phase. If Henry's law constant at 20°C is 9.364×10^{-3} atm. m^3/kgmole NH_3. Calculate the interfacial and equilibrium composition of the gas and liquid phase. (10+10)

7A. Compare and contrast between packed column and plate column with eight different criterion.

7B. The CS_2 vapour−Nitrogen mixture is scrubbed with an absorbent hydrocarbon oil to recover CS_2. CS_2-N_2 mixture has a partial pressure of CS_2 equal to 50 mm Hg at 24˚C and is to be blown into the absorber at essentially standard atmospheric pressure at the rate of 0.4 m^3/sec. The hydrocarbon oil enters at the top of the absorption column and it has an average molecular weight 180 g/gmole and specific gravity 0.81 at 24˚C. For a liquid/gas ratio of 1.5 times the minimum. Determine the number of theoretical trays required for a multistage countercurrent absorption by both graphically and analytically. Follow Raoult's law should hold for the system, the vapour pressure of CS_2 at 24˚C is 340 mm Hg. Assume isothermal operation and 95% of CS_2 gas is absorbed. (08+12)

8A. (i) Define HETP.

(ii) What are the nature of adsorbents? State the difference between physical and chemical adsorption with six different criterion.

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)