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INTERNATIONAL CENTRE FOR APPLIED SCIENCES

(Manipal University)

IV SEMESTER B.S. DEGREE EXAMINATION – MAY 2016

SUBJECT: INTRODUCTION TO MASS TRANSFER OPERATION (CHM 243)

16TH MAY, 2016

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

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

1A. Acetic acid is diffusing through water under steady state conditions. The total concentration of the system is 'C', Temperature is 'T', diffusion path is 'Z' and mole fraction of acetic acid at two planes are x_{A1}, x_{A2} respectively. Derive an expression to determine the flux of mass transfer of acetic acid for the case (i) The water is non-diffusing (ii) There is equimolar counter diffusion of the two liquids.

1B. Through the accidental opening of a valve, water has been spilt on the floor of an industrial plant in a remote area which is difficult to reach. Determine the time required to evaporate the water in the surrounding air. The height of water layer is 15 mm thickness. It may be assumed that constant temperature of 25˚C and 1 atmospheric pressure with an absolute humidity of 0.002 kg H_2O/kg dry air (after diffusion). Evaporation is assumed to take place by molecular diffusion through a gas film of 10 cm thickness, air is considered as stagnant. The mass diffusivity of water vapour in air is 2.6 x 10^{-5} m^2/sec and vapour pressure of water at 25˚C is 24 mm Hg. Assume that 1m^2 area is required for evaporation.

(10+10 = 20 marks)

2A. 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. How do you calculate stage efficiency and percentage recovery of solute in a multistage cross current operation?

2B. (i) Write the various assumption and importance for Chilton - Colburn's analogy with necessary equation.

(ii) In a wetted wall column CO_2 is being absorbed from air by water flowing at 2 atmosphere pressure and 25˚C. The mass transfer coefficient k_y' has been estimated to be 6.78 x 10^{-5} kgmole/(m^2.sec. mole fraction). Calculate the flux of absorption, if the partial pressure of CO_2 at one phase is 0.2 atmosphere and the air is pure. Assume that air is considered as stagnant.

(10+05+05 = 20 marks)

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 = 20 marks)

4A. 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. The equilibrium adsorption of acetone vapour on activated carbon at 30˚C is given by the following data.

gm Acetone adsorbed / gm carbon	0	0.1	0.2	0.3	0.35
Partial pressure of Acetone (mm Hg)	0	2	12	42	92

The vapour pressure of acetone at 30˚C is 283 mm Hg. A 1 liter flask containing air and acetone vapour at 1 std atm. and 30˚C, with a relative saturation of vapour of 35%. After 2 gm fresh adsorbent carbon is introduced into the flask containing the mixture and the flask is sealed. Compute the final relative saturation of air after adsorption. The gas mixture follows ideal gas law and neglect the adsorption of air.

(10+10 = 20 marks)

5A. The given organic liquid 'A' is taken in a Stephen glass tube. Consider the case of diffusion through a stagnant gas film. Liquid 'A' is evaporated into air 'B' and the initial liquid level is maintained at $z = z_1$. Derive an expression to find the diffusivity of the species 'A' and 'B'. Write the theoretical correlation for determination of diffusivity of organic vapour into air.

5B. A wet rectangular brick of clay of length 20 cm, breadth 12 cm and thickness 5 cm is being dried by exposure to warm air on both sides. The following observations are made when the narrow sides are sealed. The initial average moisture content is 20% by wt. The constant surface moisture content is 7% by wt. Moisture content after 2 hrs of drying is 15% by wt. Estimate the effective diffusion coefficient of water in wet clay. The following standard data for this geometry was available.

Unaccomplished change (E)	Relative time (X)
0.7	0.07
0.3	0.395

(10+10 = 20 marks)

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.

6B. In an apparatus used for the absorption of SO_2 in water, at1 point in the column the concentration of SO_2 in gas phase was 10% SO_2 by volume and was in contact with a liquid containing 0.4% SO_2

by weight (after diffusion). Pressure and temperature are 1 atm. and 50˚C respectively. The overall gas phase mass transfer coefficient is 7.36 x 10^{-10} kgmole/(m^2.sec.(N/m^2)). Of the total resistance 45% lies in gas phase and 55% in the liquid phase. The Equilibrium data at 50˚C is given below

kg SO_2/100 kg water	0.2	0.3	0.5	0.7
Partial pressure of SO_2 (mm Hg)	29	46	83	119

Estimate the interfacial and equilibrium concentration, individual film coefficients and overall mass transfer coefficient expressed in terms of mole fraction for both gaseous and liquid phase.

(10+10 = 20 marks)

7A. Compare and contrast between packed column and plate column with 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 = 20 marks)

8A. List out the names of industrial important adsorbent and write the significance of Freundlich constant. Briefly explain the Langmuir adsorption isotherm.

8B. 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.

(10+10 = 20 marks)