Question Paper

Exam Date & Time: 29-Apr-2019 (02:00 PM - 05:00 PM)

MANIPAL ACADEMY OF HIGHER EDUCATION

INTERNATIONAL CENTRE FOR APPLIED SCIENES
IV SEMESTER B.Sc.(Applied Sciences) IN ENGINEERING END SEMESTER THEORY EXAMINATION- APRIL/MAY 2019

MASS TRANSFER - I [ICHM 243 - S2]

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) Methanol 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 methanol at two planes are x_{A1}, x_{A2} respectively. Derive an expression to determine the flux of mass transfer of methanol for the case (i) The water is non-diffusing (ii) There is equimolar counter diffusion of the two liquids. (10)

B) A cylindrical tank of 4 m diameter was filled with organic liquid xylene ($C_6H_4(CH_3)_2$) to a depth of 2.4 cm from the top storage and is exposed to ambient temperature of 24˚C in a gentle current of air for 10 hrs. Vapour pressure of xylene at 24˚C is 87 mm Hg; barometric pressure is 760 mm Hg; density of xylene is 0.861 g/cc; If the solute molal voume of air at normal boiling point is 0.0201 m^3/kgmole. Calculate the loss of organic liquid in rupees, if xylene is worth Rs. 20/liter. Assume that the theoretical diffusivity of xylene-air is almost close to experimental value. (10)

2) A) i) Derive the operating line expression in a multistage cross current operation for transfer of solute from gas phase (E) to liquid phase (R) with its graphical representation. Determine percentage recovery of solute in a multistage cross current operation. (7)

ii) Write the significance of Absorption factor (A). How to calculate the stage efficiency during the operation? (3)

B) A tube of 6 cm diameter is coated with naphthalene on the inside and air at 318 K, 1 atm. pressure flows through the tube at 4 m/sec. The diffusivity of naphthalene in air at 318 K is 6.92 x 10^{-6} m^2/sec. The viscosity and density of air at 318 K are 1.932 x 10^5 pa.sec and 1.114 kg/m^3, respectively. Calculate the mass transfer coefficient using Reynolds, Chilton-Colburn Taylor Prandtl and Von-Karman analogies. (10)

3) A) 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). (12)

B) 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 molecular 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. (8)

4) i) Write the selection criteria for choosing an adsorbent in adsorption operation. Write the short (8)

notes on adsorption hysteresis.

A) ii) List out the names of any four industrial important adsorbent. Write the significance of Freundlich adsorption isotherm constant.

B) An aqueous solution containing a valuable soluble is colored by small amounts of an impurity. Before crystallization, the impurity is to be removed by adsorption on a decolorizing carbon which adsorb only insignificant amounts of the principal solute. A series of laboratory test was made by stirring various amounts of the adsorbent into batches of the original solution until equilibrium was established, yielding the following data at constant temperature: (12)

Equilibrium color, $\frac{\text{Color units}}{\text{Kg solution}}$	9.6	8.6	6.3	4.3	1.7	0.7
$\frac{\text{Kg carbon}}{\text{Kg Solution}}$	0	0.001	0.004	0.008	0.02	0.04

The color intensity was measured on an arbitrary scale, proportional to the concentration of the colored substance. It is desired to reduce the color to 10% of its original value, 9.6. Determine the quantity of fresh carbon required per 1000 kg of solution for a single stage and two stage cross current operation.

5) Carbon dioxide gas (CO_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 CO_2 by diffusion through the pipe. (6)

A) i)

ii) Compare and contrast between Knudsen and Poiseuille's flow of diffusion of gases in porous solids with necessary flux equation. (4)

B) 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. Also write the importance of E factor. (10)

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

6) 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. (12)

A)

B) In a wetted wall column CO_2 is being absorbed from air by water flowing at 1 atmosphere pressure and 25˚C. The mass transfer coefficient k_y' has been estimated to be 6.78×10^5 kgmole/(m^2.sec. mole fraction). The diffusivity of CO_2 to water at 25˚C is 1.39×10^5 m^2/sec. Calculate the flux of absorption and film thickness, if the partial pressure of CO_2 at one phase is 0.2 atmosphere and the air is pure. Assume that the air is considered as stagnant. (8)

7) Discuss about the following terms (i) Flooding (ii) Relative merits of packed and plate columns (iii) HETP. (8)

A)

B) The carbon disulphide (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 (12)

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.

8) Compare and contrast between physical and chemical adsorption with 4 different criterion. (4)

A) i)

ii) Experiments on decolourisation of oil yielded the following equilibrium relationship: (10)
$y = 0.5\ x^{0.5}$ 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
a) All 25 kg of fresh adsorbent is used in one step.
b) 12.5 kg of fresh adsorbent is used initially, followed by another 12.5 kg of fresh adsorbent.

B) Define the following terms (i) Molal humidity (ii) Percentage saturation (iii) humid heat. (6)

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