Question Paper

Exam Date & Time: 06-Jun-2019 (09:30 AM - 12:30 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]

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) 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. (10)

B) Oxygen is diffused into a non-diffusing gas mixture consisting of 1/3rd of methane and 2/3rd of hydrogen by volume. The total pressure is 2.05 atm. and the temperature is 55˚C. Calculate the rate of diffusion of oxygen through a gas film 0.5 mm thickness when the concentrations across the film are 10% and 5% by volume respectively. Diffusivity of O_2 in CH_4 and O_2 in H_2 at 20˚C and 1 atm. pressure are 0.69 and 0.194 cm^2/sec, respectively. Assume that 1 m^2 area is involved for diffusion. (10)

2) A) 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 write the significance of stripping factor (S). (10)

B) For dissolution of copper sulphate crystals of soluble salt in water, in an agitated vessel, the following equation holds good. (10)

$$\frac{K_C\, T}{D_{AB}} = 0.052\,(N_{Re})^{0.833}\,(N_{Sc})^{0.5}$$

where T is the diameter of the tank. A 1 m diameter cylindrical tank contains 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 (i) rate of dissolution of all the crystals (ii) total time required to dissolve all the crystals. Assume that equimolar counter diffusion prevails. The diffusivity of $CuSO_4$ solution in water at 20˚C is 0.73 x 10^{-5} cm^2/sec. The density and molecular weight of $CuSO_4$ is 2400 kg/m^3 and 159.5 g/gmole, respectively. The mole fraction of $CuSO_4$ in one phase is 0.0229 and the other phase is considered as negligible. The density and viscosity of the solution in other phase can be assumed to be that of water.

3) A) Derive an entire expression to determine the height of packed bed absorption tower (Z) with the suitable assumption. (14)

B) Discuss about the following terms (i) Henry's law (ii) Channeling (ii) HETP (6)

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

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˚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. (5)

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

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˚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˚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) i) Obtain an expression to determine the various relationship between mass transfer coefficient for gases and liquids for the case (a) Diffusing compound 'A' through non diffusing compound 'B'(b) Equimolar counter diffusion. (8)

ii) Write the various assumptions and importance for Chilton-Colburn's analogy with necessary equations. (4)

B) Calculate the rate of sublimation from a cylinder of naphthalene 0.075 m inner diameter by 0.6 m long into a stream of pure air flowing at a velocity of 6 m/sec at 1 atm. pressure and 100˚C using Reynolds and Taylor-Prandtl analogy. The vapour pressure of naphthalene in the given operating condition may be taken as 10 mm Hg and the other stream it vapour pressure may be considered as negligible. Diffusivity of naphthalene in air at 1 atm. pressure and 100˚C is 5.18 x 10^{-6} m^2/sec. The density and viscosity of air 0.946 kg/m^3 and 0.021 cp respectively. Assume that the air is considered as stagnant. (8)

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

A)

B) 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 superheated steam is passed. The temperature is held constant at 423 K by internal heating in the tower at 1 atmospheric pressure and superheated steam enters at bottom of the tower. Steam can be considered as an inert gas and will not condense. 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 number of theoretical trays 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 (12)

$\frac{\text{Moles of benzene}}{\text{Moles of benzene free oil}}$	0.02	0.04	0.06	0.08	0.10	0.12	0.13

Moles of benzene / Moles of steam	0.07	0.135	0.215	0.305	0.4	0.51	0.58

8) List out the various assumptions for Langmuir adsorption isotherm. (2)

A) i)

ii) Write the various steps involved for adsorption of solute from liquid to porous adsorbent particle. (3)

iii) An aqueous solution containing valuable solute is colored by small amount of an impurity. Decolorization 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 four stage 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. (5)

C) Define the following terms (i) Dry bulb temperature (ii) Wet bulb temperature (iii) Relative humidity (iv) Dew point temperature (v) Psychrometric volume. (10)

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