INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR

Mid-Autumn Semester Examination, 2018-2019

Subject : **Mass Transfer - I** *Subject No.*: **CH31001**
Department: Chemical Engineering *Duration: 2 hrs* *Full Marks*: **30**

Instructions : **(1)** ***Answer ALL Questions.***
(2)No queries will be entertained during the exam.
(3)Any missing data may be assumed suitably giving proper justification.
(4) Use relevant equations and diagrams, wherever necessary

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1. (a) In an experimental study of the absorption of ammonia by water in a wetted-wall column, the value of overall mass transfer coefficient, K_G, found to be $2.75X10^{-6}$ kmol/m^2-s-kPa. At one point in the column, the composition of the gas and liquid phases were 8.0 and 0.115 mole% NH3, respectively. The temperature was 30^0K and the total pressure was 1 atm. Eighty five % of the total resistance to mass transfer was found to be in the gas phase. At 30 ^{0}K, Ammonia –water solutions follows Henry's law upto 5 mole% ammonia in the liquid, with m = 1.64 when concentrations in both phases are expressed in mole fractions. Calculate the individual mas transfer coefficients and the interfacial gas and liquid phase concentrations. (5)

(b) A very thin polymeric coating of thickness 0.1 mm uniformly coats a rectangular surface. The rectangular surface has a length of 20 cm and a width of 10 cm. The coating contains a solvent that must be evaporated away from the coating in order to cure the coating. Initially, there is 0.001 mole of solvent per cm^3 of coating loaded in the coating. A heated plate just beneath the surface maintains the coating at a uniform temperature of 30 °C, and the vapour pressure exerted by the solvent is 0.05 atm at 30 °C. Air gently flows parallel to the surface at a velocity of 5.0 cm/s. The surrounding air at 1.0 atm total system pressure and 40 °C represents an "infinite sink" for mass transfer. You may neglect any molecular diffusion of the solvent through the very thin polymeric film and focus only on the convection aspects of the problem. (5)

a) What is the average mass transfer coefficient, k_c?

b) How long will it take for the solvent to completely evaporate from the coating?

Given: The physical properties at 30 ^{0}C are:
Kinematic viscosity ν=0.158 cm^2/s
Density ρ=1.17×10−3g/cm^3
The diffusion coefficient of species in air at 30 ^{0}C is 1.025 cm^2/s
Boundary Layer theory can be used to estimate the mass transfer coefficient.

2. An experiment is conducted using a Stefan tube to determine the gas diffusivity of benzene in air at 308 K and 1.0 atm. The 20-cm-long tube, with an inner diameter of 1.0 cm, is initially loaded with liquid benzene to a depth of 1.0 cm from the bottom of the tube. The tube and the liquid are maintained at a constant temperature of 308 K. At this temperature, benzene exerts a vapor pressure of 0.195 atm. Air is continually blown over the top of the tube, removing any of the vaporized benzene vapor; the gas space within the tube is

essentially stagnant. At 308 K, liquid benzene's density is 0.85 g/cm^3. It was determined that 72.0 h were required to completely evaporate the benzene initially loaded into the tube.

(5+3+2)

(i) Derive an expression for the total Flux N_A.

(ii) Derive an expression to determine the time for complete depletion of benzene in the tube

(iii) Estimate the binary gas-phase diffusion coefficient for benzene in air.

3. Answer the following questions: (5x2)
   a. Write the expression for Mass transfer coefficients as per (i) Film theory (ii) Penetration theory. How will you justify the fact that mass transfer rate increases with the increase in velocity according to the film theory and penetration theory?
   b. List the factors which affect the (i) gas phase diffusivity and (ii) liquid phase diffusivity
   c. What is Knudsen number? For what value of Knudsen number, Knudsen diffusivity will occur?
   d. What is the relationship of the overall mass transfer coefficient based on liquid phase driving force with the individual gas and liquid phase mass transfer coefficients if Henrys law is applicable? If the solute is highly soluble in the liquid phase, mass transfer resistance of which phase will control the mass transfer rate?
   e. Define (i) Sherwood number, (ii) Schmidt number and (iii) Chilton-Colburn J factor