Code No: RR310804 **Set No. 1**

III B.Tech I Semester Regular Examinations, November 2006
MASS TRANSFER OPERATIONS-I
(Chemical Engineering)

Time: 3 hours **Max Marks: 80**

Answer any FIVE Questions
All Questions carry equal marks

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1. (a) Differentiate between J_A and N_A with relevant equations.
   (b) Oxygen is diffusing through carbon dioxide under steady state conditions, with carbon dioxide non-diffusing. The temperature and total pressure of the system are respectively 273 K and $101.3 \times 10^3\, N/m^2$. The partial pressure of oxygen at two parallel, vertical planes 2 mm apart is 14000 N/m^2 and $7000\, N/m^2$. Determine the rate of diffusion of oxygen through per m^2 of the two planes.[Diffusivity of gas mixture $= 1.39 \times 10^{-5}\, m^2/sec$] [6+10]

2. (a) Explain the mass transfer mechanism using Higbie theory.
   (b) A stream of air is flowing at 30m/sec over a $2.25m^2$ thin square plate of solid naphthalene. Determine the rate of sublimakon try from the plate. The air is at 25^0C and the plate is at 25^0C. The diffusivity of naphthalene in air at 0^0C and 1 atm is $5.14 \times 10^{-6} m^2$/sec. The vapour pressure of naphthalene at 25^0C is 25 P. The viscosity of air is 1.85×10^{-8} kg/m sec. [8+8]

3. A gas mixture A-air is fed into an absorption tower where absorption of the component A in water is taking place at 298 K and 2 std atm. Given that $k_L = 0.122$ k mol A / (hr.m^2)(mol A/m^3). $k_G = 1.32$ k mol A / hr.m^2.atm the equilibrium partial pressure of gas A over dilute solution of A in the water is given $p_{A,i}$= 0.28 ($c_{A,i}$), where $p_{A,i}$ is in atm while $c_{A,i}$ is expressed in terms of mol A/m^3. determine the values of the following mass transfer coefficients.
   (a) $\mathbf{k}_y$
   (b) $\mathbf{k}_c$ for gas film
   (c) $\mathbf{K}_L$ [16]

4. (a) Write short note on 'Sparged Vessels'.
   (b) Classify gas-liquid contact devices. [8+8]

5. (a) Define absorption factor and discuss its importance for the design of tray absorber.
   (b) It is desired to eliminate traces of H_2S from effluent gases of a toppling still, so that they can be conveniently used as a fuel. The original concentration of 2.5% by volume of H_2S is to be reduced to 0.2% by volume, by scrubbing the gas mixture with hot nonvolatile hydrocarbon oil in multistage continuous counter current equipment. Determine the number of ideal stages required if the plant is operated using 1.5 times the minimum liquid rate. Henry's law

is applicable for this system and the constant is 0.25 atmospheres per mole fraction can be taken. [6+10]

6. (a) Briefly explain wet bulb depression, wet bulb approach and dehumidification.
   (b) Derive the following equation for wet bulb temperature. Y'_w-Y'_g=$h_g(t_g$-$t_w)/k_y\lambda_w$ [8+8]

7. (a) A batch of solids is dried from 28% to 6% moisture, wet basis. The initial weight of the solid is 380 kg and drying surface is 0.15 m^2/40 kg dry weight. The critical moisture content is 28% dry basis and the constant drying rate is 0.32 kg/hr m^2. For the falling rate period, the following data are available:

Moisture content (% dry basis):	25	21.9	19	16	13.6	11	8.2	7.5	6.4
Rate of drying: (kg/hr m^2)	0.3	0.27	0.24	0.21	0.18	0.15	0.07	0.044	0.025

   (b) Define moisture content on wet and dry basics [12+4]

8. (a) Explain how it is possible to cool water in a counter current cooling tower to a temperature lower than the cooling air dry bulb temp.
   (b) How the drying equipments are classified and explain. [6+10]

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Time: 3 hours **Max Marks: 80**

Answer any FIVE Questions
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1. (a) Write the expression for flux in steady-state equimolar counter-current diffusion of molecular diffusion in liquids.
   (b) Estimate the diffusivity of mannitol, $CH_2OH(CHOH)_4CH_2OH$, (A) in dilute solution in water at 20^0C. Compare with the observed value, $0.56 \times 10^{-9} m^2/s$. Mannitol molal volume at normal boiling point is 0.185 , association factor for water is 2.26 and solution viscosity is $1.005 \times 10^{-3}\, kg/m - s$. Viscosity of water is 1.005×10^{-3} kg/m sec. [8+8]

2. A canvas bag commonly used for storing water in the deserts holds some quantity of water a small quantity of which continually seeps through the canvas pores and diffuses in the ambient air with the effect that evaporation of the water cools the bag.
   The surface temperature of the bag is 291^0K. Determine the ambient temperature of air on the basis of the following parameters at the film temperature:
   Prandtl number = 0.72
   Schmidt number = 0.61
   Density of air = 1.1532 kg/m^3
   Specific heat of air = 1.0048 kJ/kg.^{o}K
   Latent heat of vaporization of water = 2456 kJ/kg
   Partial pressure of water in ambient air = 1066.64 Pa. [16]

3. (a) Write short note on "Two-resistance theory".
   (b) Write the basic concept of equilibrium between two phases. [8+8]

4. (a) Write short note on:
      i. Packing restrainers
      ii. Entrainment eliminators.
   (b) Define and explain volumetric overall mass transfer coefficients in packed tower. [8+8]

5. The equilibrium partial pressures (p. p) of carbon dioxide over solutions of mono ethanolamine are as follows:

X	0.058	0.060	0.062	0.064	0.066	0.068	0.070
Partial pressure of CO_2 (mmHg)	5.6	13	29	56	99	155	232

A plant for manufacturing dry ice will burn coke in air to produce a flue gas which

when cooled will contain 20% CO_2,and 80% N_2. The gas will be blown into a bubble tray scrubber at 1.2 atm and 25^0C to be scrubbed with mono ethanolamine solution entering at 25^0C. The scrubbing liquid which is recycled from a stripper will contain 0.058 mol CO_2/mole of solution. The gas leaving the scrubber is to contain 2% CO_2. Assume isothermal operation. Determine the number of theoretical trays required for an L/G ratio of 1.2 times the minimum. [16]

6. (a) Explain the concept of wet bulb temperature with neat sketch.

   (b) Moist air at 300 K has wet bulb temperature of 290 K. If the latent heat of vaporization of water at 290 K is 2458 kJ/kg, estimate the humidity of the air and the percentage relative humidity. The total pressure is 101.3 kN/m^2 and h_c/k_y= 1.09x10^3. Further, the Antoine's equation for water is: $\log p^{sat} = 8.07 - \frac{1730.63}{T-39.58}$, where p is in mmHg and T is in K [8+8]

7. (a) Explain the typical rate drying curve

   (b) A porous solid is dried in a batch dryer under constant drying conditions. Six hours are required to reduce the moisture content from 3% to 10%. The critical moisture content was found to be 16% and equilibrium moisture 2%. All moisture contents are on the dry basis. Assuming that the rate of drying during the falling rate period is proportional to the free moisture content, how long should it take to dry a sample of the same solid from 35% to 6% under the same drying conditions? [8+8]

8. (a) The effective diffusivities for passage of hydrogen and nitrogen at 20^0C through a 2 mm thick piece of unglazed porcelain were measured by determining the counter current diffusion fluxes at 1.0 and 0.01 std atm pressure. $D_{H2-N2,eff}$= 5.3×10^{-6} m^2/sec at std atm and $D_{k,H2,eff} = 1.17 \times 10^{-5}$ m^2/sec. estimate (a). the equivalent pore diameter of the solid and (b) the diffusion fluxes for O_2-N_2 mixtures at a total pressures of 0.1 std atm, 20^0C with mole fractions of O_2 =0.8 and 0.2 on either side of the porcelain.

   (b) Write the briefly the principles of spray drier and with neat sketch. [8+8]

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Code No: RR310804 **Set No. 3**

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Time: 3 hours **Max Marks: 80**

Answer any FIVE Questions
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1. (a) Derive the expression for the molar flux of A for the steady state diffusion of A through nondiffusing B for molecular diffusion of gases.
   (b) Calculate the rate of diffusion of hydrogen (A) through nondiffusing methane (B) at 25^oC and 101 kN/m^2 pressure ($D_{AB} = 6.6 \times 10^{-5}\, m^2/s$). The diffusion path is 5 mm long and the concentration of hydrogen at the two ends of the path in terms of partial pressure is 12 kN/m^2 and 8.4 kN/m^2 respectively.

   [8+8]

2. (a) A large volume of pure water at 26.1^{o}C is flowing parallel to a flat plate of solid benzoic acid, where L= 0.244 m in the direction of flow. The velocity is 0.061m/s. The solubility of benzoic acid is 1.245x10^{-9}m^2/s. Calculate the mass transfer coefficient k'_c and flux N_a.
   (b) Describe the wetted wall tower with neat sketch. [8+8]

3. (a) Write short note on "Two-resistance theory".
   (b) Write the basic concept of equilibrium between two phases. [8+8]

4. (a) Discuss the relative merits and demerits of plate and packed towers for mass transfer.
   (b) Write a brief note on tower packing and their characteristics to be used as an industrial packing material. [10+6]

5. An acetone-air mixture containing 0.025-mole fraction acetone has its acetone reduced to 1% of this value by counter current absorption in a packed tower by pure water. Gas flow rate of pure air is 1kg/m^2 sec and water is1.6 kg/m^2s. For this system the equilibrium diagram is given by Y=1.75X/(1-0.75X) where Y is kg moles of acetone /kg mole of air in gas phase and X is kg moles of acetone per kg mole of water in liquid phase. What is the tower height required if height of overall transfer unit is H_{toG} =50 cm.(solve graphically). [16]

6. Derive the equation to calculate the height of cooling tower and mention the assumption involved in it. [16]

7. (a) It is desired to dry a batch of 500 kg of wet solid from 30% to 6% moisture. The rate of drying may be assumed to be linear in the falling rate zone. Calculate the time required for drying. The critical and equilibrium moisture contents are 0.2 and 0.05 kg/kg of dry solids. The constant rate period drying rate is 1.5 kg/hr m^2 and the drying surface is 0.026 m^2 per kg of dry soild.

(b) Derive the relationship between surface humidity and surface temperature during constant rate drying. Consider all modes of heat transfer. [8+8]

8. (a) Write about mechanisms of heat and mass transfer in coling towers.

(b) Suggest the type of drier you would recommend for drying of ceramic materials on a large scale. Indicate the reasons for your choice. Further, give a brief description of the driver and draw the sketch of the same. [6+10]

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Code No: RR310804 **Set No. 4**

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MASS TRANSFER OPERATIONS-I
(Chemical Engineering)

Time: 3 hours **Max Marks: 80**

Answer any FIVE Questions
All Questions carry equal marks

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1. Estimate the diffusivity of n-Butanol vapor (A) ($C_2H_5CH_2CH_2OH$) through air at 1 atm pressure and 59^0C. Data: Molecular weight n-Butanol = 74 Molecular weight of air = 29 For air $\epsilon_B/k = 97$, $r_B = 0.3617$ nm Group contribution of atomic volume (m^3/K. atom) C = 0.0148 O = 0.0074 H = 0.0037 $r_A = 1.18\,v^{1/3}$ Normal boiling point of n-Butanol = 117^0C. Collision function data: [16]

KT/ϵ	f(KT/ ϵ)
1	0.72
1.5	0.6
2	0.54

2. (a) Explain Reynolds analogy, and also find a relation between mass transfer coefficient and friction factor.
   (b) Write short notes on surface-removal theory of mass transfer. [8+8]

3. With the help of figure explain what do you mean gas phase controlled mass transfer coefficient and liquid phase controlled mass transfer coefficient. What is their relation to local overall mass transfer coeffect. Further, what is the significance overall mass transfer coefficient. [16]

4. (a) Explain the phenomena of liquid distribution and redistribution in packed towers.
   (b) What are the factors to be considered for choice between tray-towers and packed towers? [6+10]

5. A tower 20 cm in diameter filled to a height 126 cm with 2.5 cm diameter spheres, reduced the ammonia concentration from 5 to 1.2% by volume of the gas mixture fed at the rate of 65 kg/hr, by means of water supplied at the rate of 55 kg/hr. Find the strength of the ammonia solution obtained. The temperature is 25^0C at which the equilibrium relationship may be taken as y=0.99x where y and x are in mole fraction. Calculate the height for transfer unit, H_{toG} and the overall gas phase mass transfer coefficient K_Ga. The total pressure was 1 atm. [16]

6. (a) 30000m^3 of coal gas (measured at 289 K and 101.3kN/m^2 saturated with water vapor is compressed to 340kN/m^2 pressure, cooled to 289k and the condensed water is drained off. Subsequently the pressure is reduced to 170kN/m^2 and the gas is distributed at this pressure and 289K.What is the percentage humidity after this treatment? Vapor pressure of water at 289 K is1.N/m^2.

(b) Distinguish between adiabatic saturation and wet bulb temperature and explain briefly both. [8+8]

7. (a) A drying test conducted at constant drying conditions (air velocity 6.096 m/s; air dry bulb temperature 71.1^{o}C; air wet bulb temperature 32.2^{o}C) gave a drying rate for the constant rate period of 3.0759 kg/m^2 hr. Determine the corresponding rate at the same air velocity and wet bulb temperature if the air dry bulb temperature is 51.67^{o}C. Radiation and conduction to the wetted surface may be considered negligible.

   (b) Write minimum two ways for the movement of moisture within the solid. [8+8]

8. (a) A mixture of nitrogen and hydrogen diffuses at std atm and 293 K through a 25 mm thick unglazed porcelain membrane. Calculate pore diameter of solid.
   $D_{H2-N2} = 74.3 \times 10^{-6}$ m^2/sec at 288 K and 1 std atm
   $D_{H2-N2,eff} = 5.3 \times 10^{-6}$ m^2/sec at 293 K and 1 std atm
   $D_{k,H2,eff} = 11.7 \times 10^{-6}$ m^2/sec.

   (b) Describe vaccum drum drier with neat sketch. [8+8]

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