Code No: 09A50803 **R09** **Set No. 2**

III B.Tech I Semester Examinations,December 2011
MASS TRANSFER OPERATIONS-I
Chemical Engineering

Time: 3 hours **Max Marks: 75**

Answer any FIVE Questions
All Questions carry equal marks

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1. (a) Define point efficiency and Murphree tray efficiency. How are they related for different flow conditions? Explain.
   (b) Explain the counter current flow cascades with neat diagram. [8+7]
2. (a) Explain the significance of 'Schmidt Number' and j_D - factor.
   (b) Explain briefly for mass transfer from a gas into a falling liquid film. [6+9]
3. (a) Derive an equation to estimate the required time to dry a solid material under falling rate period. Make suitable assumptions and state them.
   (b) A granular insoluble solid material wet with water is being dried in the constant-rate period in a pan 0.61 m X 0.61 m and the depth of material is 25.4 mm. The sides and bottom are insulated. Air flows parallel to the top drying surface at a velocity of 3.005 m/s and has a dry bulb temperature of 60^0C and wet bulb temperature of 29.4^0C. The pan contains 11.34 kg of dry solid having a free moisture content of 0.35 kg H_2O per kg dry solid, and the material is to be dried in the constant rate period to 0.22 kg H_2O per kg dry solid. Calculate the drying rate and the time in hours needed. [6+9]
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+7]
5. (a) Draw the concentration profiles in terms of pressure verses distance for the following two cases:
      i. Steady state diffusion of A through non diffusing B and
      ii. The steady state equimolar counter diffusion.

      Also write the equation for both cases.
   (b) Oxygen (A) is diffusing through carbon monoxide (B) under steady state conditions, with the carbon monoxide non-diffusing. The total pressure is 1×10^5N/m^2 and the temperature is 0^0C. The partial pressure of oxygen at two planes 2 mm apart is, respectively, 13,332 and 6,666 N/m^2.The diffusivity for the mixtures is 1.87×10^{-5}m^2/s. Calculate the rate of diffusion of oxygen in k mol/s through each square meter of two planes. [6+9]

6. (a) Benzene is used a solvent in a process. It is evaporated into dry nitrogen. At 297 K and 1 atm pressure, the resulting mixture has a percentage relative saturation of 60. It is required to recover 80% of the benzene present by cooling to 283 K and compressing to suitable pressure. What should be this pressure? Vapor pressures of benzene at 297 K and 283 K are 0.122 atm and 0.06 atm respectively.

   (b) Describe the working of a forced draft cooling tower. [8+7]

7. (a) Develop an equation for diffusion in a Flat Plate with negligible surface resistance.

   (b) A window of SiO_2, 2 mm thick and 1.0×10^{-4} m^2 in area, is used to view the contents in a metal vessel at 20^0C. Helium gas at 202.6 kPa is contained in the vessel. The diffusivity is 5.5×10^{-14} m^2/s at 20^0C and 202.6 kPa. Calculate the Permeability an the loss of He in kg.mol/hr at steady state. [8+7]

8. (a) How the solubility of gaseous solute changes with temperature explain with respective to Henry's Law?

   (b) A solvent is to be recovered from a solvent-air mixture by scrubbing with water in a packed tower at a pressure of 101.3 kN/m^2 and at a temperature of 300K. The solvent vapour enters the tower at a rate of 0.1kg/s and has a concentration of 2% by volume. It is necessary to recover 99.9% of the solvent; for the packing selected the optimum gas and water flow rates are known to be 1.3 and 2.0 kg/m^2s respectively. Calculate the height and diameter of the tower. The data required is as follows:
   Overall mass transfer coefficient K_{Ga} = 0.0389 kg/s $m^2(kN/m^2)$
   Equilibrium data: $P_e = 0.02$ x; where P_e equilibrium pressure of the solvent kN/m^2 and x the mole fraction of the solvent in water.
   The molecular weight of the solvent and air are 70 and 29 kg/kmol, respectively. [3+12]

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MASS TRANSFER OPERATIONS-I
Chemical Engineering

Time: 3 hours **Max Marks: 75**

Answer any FIVE Questions
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1. (a) Write short notes on 'Tray towers' with neat sketch.
   (b) Explain the factors influencing the efficiency of trays. [8+7]

2. (a) Show the Reynolds analogy for mass transfer gives J_D=f/2.
   (b) A sphere of naphthalene ball having a radius of 10 mm is suspended in a large volume of still air at 318 K and 1 atm absolute pressure. The vapor pressure of naphthalene is 0.56 mm Hg at 318 K and the D_{AB} of naphthalene in air at 318 K is 6.92×10^{-6} m^2/s. Calculate the rate of evaporation of naphthalene from the surface in k.moles/m^2.s. [6+9]

3. (a) Define the terms Bound Moisture Content and Unbound Moisture Content in the wet solid. Explain the mechanism of batch drying during constant rate period.
   (b) Explain different regions of drying in a rotary drier and sketch the temperature profiles in these zones of drying. [7+8]

4. (a) Explain principle of wet bulb temperature. What is meant by wet bulb depression?
   (b) Air having a dry bulb temperature of 37.8^0C and a wet bulb temperature of 26.7^0C is to be dried by first cooling to 15.6^0C to condense water vapor and then heating to 23.9^0C. Calculate the initial and final humidity of the air. Also determine the amount of heat given or removed from the air. What is the amount of water condensed per kg dry air? (Use humidity Chart). [6+9]

5. (a) Discuss about steady state molecular diffusion in porous solids that depends on structure and derive related equations.
   (b) A sintered solid of silica 2.0 mm thick is porous with a void fraction of 0.30 and a tortuosity of 4.0. The pores are filled with water at 298K. At one face the concentration of KCl is held at 0.10 g.mole/liter and fresh water flows rapidly past the other face. Neglecting any other resistance but that in the porous solid, calculate the diffusion of KCl at steady state. The diffusivity of KCl in water at 298K is 1.87×10^{-9} m^2/s. [7+8]

6. (a) Define HTU and HETP. Distinguish between them.
   (b) Exit gas from a chlorinator consists of a mixture of 5 mol% chlorine in air. This concentration is to be reduced to 1% chlorine by water absorption in a packed column to operate isothermally at 20^0C and atmospheric pressure.

Using the following equilibrium x-y data, calculate for 100 k mole/hr of feed gas.

i. The minimum water rate in kilograms per hour

ii. Number of overall gas phase transfer units (N_{toG}) for twice the minimum water rate.

Pure water is used. Assume dilute solutions. Solve the problem graphically. Data for x-y at 20^0C (in chlorine mole fraction) [3+12]

x:	0.0001	0.00015	0.0002	0.00025	0.0003
y:	0.006	0.012	0.024	0.04	0.06

7. Absorption of oxygen from an air bubble occurs in 'pure' water. Calculate the overall coefficients K_y and K_x for the following cases:

   (a) The two-film model is applicable. The air-film thickness is 2 mm, and the water-film thickness is 0.02 mm.

   (b) The film model is applicable for the gas-phase. The contact time of a liquid element with the gas is 1s.

   Given: diffusivity of O_2 in air = 0.176 cm^2/s, in water = 2.1×10^{-9} m^2/s; the equilibrium relation is p = 4.36×10^4x, p = partial pressure of O_2 in atm; temperature = 298 K; total pressure = 1 atm. [15]

8. (a) Differentiate between rate governed and equilibrium governed separation process with suitable examples.

   (b) Briefly explain the importance of molecular properties for selection of separation process. [10+5]

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Code No: 09A50803 **R09** **Set No. 1**

III B.Tech I Semester Examinations,December 2011
MASS TRANSFER OPERATIONS-I
Chemical Engineering

Time: 3 hours **Max Marks: 75**

Answer any FIVE Questions
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1. (a) Explain the cross flow cascades with neat diagram.
   (b) In mass exchange apparatus operating at a pressure of 3.1×10^5 N/m^2 the individual mass transfer coefficients are k_y = 1.07 k.mole/m^{2}hrΔy and k_x = 22 k.moles/m^{2}hrΔx. The partial pressure of gas at equilibrium, p* with liquid mole fraction, x is given by p* = 8 x 10^6 x. Calculate the overall mass transfer coefficients K_x, K_y and percentage of resistance in each phase. [7+8]

2. (a) Explain and define the terms humidity, humid heat and humid volume.
   (b) Discuss the theoretical principles and inter phase heat and mass transfer involved in the cooling of water in a cooling tower.
   (c) Give a general classification of the cooling towers used in commercial practice.
   (d) With a neat sketch, explain the working of any one type of cooling tower. [4+4+2+5]

3. (a) Under what conditions are the mass average velocity and the molar average velocity of the components of a mixture equal?
   (b) Ammonia is diffusing through an inert air film thick at a temperature of 20^0C and a pressure of 1 atm. The concentration of NH_3 is 10% by volume on one side of the film and zero on the other side. Estimate the effect on the rate of diffusion of raising the total pressure to 10 atm. The diffusivity of NH_3 in air at 0^0C and 1 atm is 0.198 cm^2/s. [7+8]

4. Discuss the correlation between Sherwood, Schmidt and Reynolds for flow insides pipes, flow outside tubes parallel to axis, flow normal to cylinders, flow normal to tube bundle and flow past single spheres. [15]

5. Write short note on the following
   (a) BubbleCap plate
   (b) Design features of tray tower. [8+7]

6. (a) Derive basic equation for unsteady state diffusion and state the assumption made.
   (b) Cellophane is being used to keep food moist at 38^0C. Calculate the loss of water vapor in grams per day at steady state for a wrapping 0.10 mm thick and an area of 0.2 m^2 when the vapor pressure of water vapor inside is 10 mm Hg and the air outside contains water vapor at a pressure of 5 mm Hg. The permeability of water vapor in Cellophane at 38^0C is 1.82×10^{-10} m^3 solute (STP) (s.m^2.atm/m). [7+8]

7. (a) Discuss the batch drying operation and development of drying rate curve.

   (b) To determine the drying characteristics of s fiber board sheet, a sample piece of 0.3X0.3m with edges sealed (drying takes place from two large faces only) was suspended in a cbinet drier and exposed to hot dry air. The following data was recorded.
   Initial moisture content = 75%
   Critical moisture content = 60%
   Equilibrium moisture content = 10%
   Dry mass of the sample = 0.9 kg
   Rate of drying under constant rate period = 1×10^{-4} kg/m^{2}sec
   Determine the time of drying from 75% to 20% moisture removal. [5+10]

8. A stripping tower with four ideal plates is being used to remove ammonia from waste water using air. The inlet air is pure air, and the inlet water contains 0.02 mole fraction ammonia. The column operates at L/G ratio of 0.65. Equilibrium data in mole fractions are given as $y = 1.414x$, where y and x are mole fractions of ammonia in air and water respectively.

   (a) Find the outlet concentrations.

   (b) If plate column is replaced with packed column having 6.5m height, determine number of overall liquid phase transfer units required for the same operation

   (c) Determine HETP and Height of overall liquid phase transfer unit. [15]

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Code No: 09A50803 **R09** **Set No. 3**

III B.Tech I Semester Examinations,December 2011
MASS TRANSFER OPERATIONS-I
Chemical Engineering

Time: 3 hours **Max Marks: 75**

Answer any FIVE Questions
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1. (a) Define permeability for solid diffusion and relate it with diffusivity and solubility.
   (b) The gas hydrogen at 17^0C and 0.010 atm partial pressure is diffusing through a membrane of vulcanized neoprene rubber 0.5 mm thick. The pressure of H_2 on the other side of the neoprene is zero. Calculate the steady- state flux, assuming that the only resistance to diffusion is in the membrane. The solubility of H_2 gas in neoprene at 17^0C is 0.051 m^3 (at STP of 0^0C and 1 atm)/m^3 solid. atm and the diffusivity of H_2 gas in the solid at 17^0C is 1.03×10^{-10} m^2/s. [6+9]

2. (a) What is Lewis relation? Can it be applied for the organic liquid vapor- gas mixture? Explain.
   (b) Wet air is having a dew point of 35^0C and it is heated to 50^0C. Determine the wet bulb temperature, absolute humidity, percentage of saturation, humid volume and humid heat by using humidity chart.
   (c) Write about mechanisms of heat and mass transfer in cooling towers. [3+6+6]

3. (a) Draw the drying curve and identify various regions of drying with proper explanation. Define Critical Moisture Content and Equilibrium Moisture Content.
   (b) What do you mean by saturated surface drying? How is the rate of drying affected by various parameters during the constant rate period? [7+8]

4. (a) Distinguish between N_p & N_{toG} and HETP & H_{toG}. State under what conditions they are equal.
   (b) Ammonia gas stream from a reactor contains 25% by volume of ammonia and 75% by volume of air. Pure water is used to absorb ammonia in an absorption tower at 30^0C and 1 atm. The total gas flow rate is 1000 k moles.hr. It is desired to reduce the concentration of ammonia to 2 % by volume in the outlet. What is the minimum liquid rate (if counter current flow is used)? If 2.0 times the minimum liquid is used, what will be the number of theoretical plates required? Equilibrium relation is given as $y^*= 2.0$ x, where y is mole fraction of ammonia in gas and x is mole fraction of ammonia in liquid. [5+10]

5. In an absorption tower SO_2 was removed from an air-SO_2 mixture by water. At one point in the tower the bulk gas contained 10% by volume SO_2 was in contact with liquid containing 0.4% by volume SO_2 (density is 990kg/m^3) the temperature was 50^0C and pressure at 1 std atm.the overall mass transfer coefficient based on the

gas concentration was $K_G = 7.36 \times 10^{-10}$ Kmol m^2.s (kN/m^2) of the total diffusional resistance 47% lay in the gas phase and the rest in the liquid phase. Calculate

(a) the overall coefficient based on liquid concentration in terms of mol/vol.

(b) the individual mass transfer coefficients for gas k_y, mole/(area)(time)(mole fraction) and for liquid k_x, mole/(area)(time)(mole fraction). [15]

6. (a) Write short notes on surface- removal theory of mass transfer.

   (b) 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 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 temperature.
   Prandtl number = 0.72
   Schmidt number = 0.61
   Density of air = 1.11532 kg/m^3
   Specific heat of air = 1.0048 kJ/kg.^{0}K
   Latent heat of vaporization of water = 2456 kJ/kg
   Partial pressure of water in ambient air = 1066.64 Pa. [6+9]

7. Larson using an Arnold cell measured the diffusivity of chloroform in air at 25^0C and 760 mmHg. The liquid density of chloroform at 25^0C is 1485 kg/m^3 and its vapor pressure at 25^0C is 200mmHg. At time t = 0, the liquid chloroform surface was 74 cm from top of the tube and after 10 hours the liquid surface had dropped by 0.44cm .If the concentration of chloroform is zero at the top of the tube, what would be the gas diffusion coefficient of chloroform in air. [15]

8. Write short notes on

   (a) Sparged vessels

   (b) Terminal velocity of single bubbles and bubble diameter. [8+7]

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