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

III B.Tech I Semester Regular Examinations, November 2005
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) State the Fick's first law of diffusion.
   (b) Oxygen (A) is diffusing through carbon monoxide (B) under steady-state conditions, with the carbon monoxide non-diffusing. Total pressure is 1×10^5 N/m^2, and the temperature 0^0 C. the partial pressure of oxygen at two planes 2.0 mm apart is respectively, 13000 and 6500 N/m^2. The diffusivity for the mixture is 1.87×10^{-5} m^2/s. Calculate the rate of diffusion of oxygen in k mol/sec through each square meter of the two planes. [4+12]

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. (a) Explain the counter current flow cascades with neat diagram.
   (b) Equilibrium relation is y = mx. What is the relation between K_x, k_y and k_x? What will happen if the gas phase controlled? Explain. [8+8]

4. (a) Write short note on 'Tray towers'.
   (b) What are the factors influencing the efficiency of trays. [8+8]

5. An ammonia gas stream from a reactor contains 25% by volume of ammonia and 75% by volume of air. Pure water is added to absorb ammonia in an absorption tower at 30^0C and 1 atm. The total gas flow rate is 1000moles/h. It is desired to reduce the concentration of ammonia to 2% by volume in the inlet.
   (a) What is the minimum liquid rate (if counter current flow is used).
   (b) what will be the number of theoretical plates required, if two times the minimum liquid rate is used.

   Equilibrium relation ship is given by: y = 2x; where y = mole fraction of ammonia in the gas and x is the mole fraction of ammonia in the liquid. What is an absorption factor? [16]

6. A plant requires 2000kg/min of cooling water to flow through its distillation equipment condensers, thereby removing the heat from the condensers, the water will leave the condensers at 50^0C.It is planned to design a counter current cooling tower in order to cool this water to 30^0c from 50^0C for re use, by contact with air. Air is available at 30^0C dry bulb temperature and 24^0c wet bulb temperature. 30% excess air will be used and the make up water will enter at 15^0C.For the packing

to be used , the value of the mass transfer coefficient is expected to be 2500kg/hr m^3molefraction, provided the minimum liquid rate and gas rates are 12000 and 10000kg/hr m^2 respectively. Determine the height and the diameter of the cooling tower. DATA:

t_l^0c	25	30	35	40	45	50	55
H [kcal/kg dry air]	19.1	23.9	31.8	40.4	51.3	53.1	82.3

[16]

7. (a) Define:
   i. Equilibrium moisture,
   ii. Bound moisture,
   iii. Unbound moisture,
   iv. free moisture,
   v. moisture content on wet basis,
   vi. moisture content on dry basis

   (b) Explain drying hysteresis. [12+4]

8. (a) Enumerate different driers used for drying rigid or granular solids.
   (b) Describe the working of a forced draft cooling towers.
   (c) Give threes examples for mass transfer using energy as the separating agent and explain. [5+5+6]

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Code No: RR310804 **Set No. 2**

III B.Tech I Semester Regular Examinations, November 2005
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) Write the application of local mass transfer coefficients in detail.
   (b) Write short notes on penetration theory. [8+8]

3. (a) Derive an expression to find local overall gas phase mass Transfer coefficient?
   (b) What is the necessity of introducing the overall mass Transfer coefficient?
   [10+6]

4. (a) Write short note on 'Tray efficiencies' in plate column.
   (b) Write about "Gas hold-up" in plate tower.
   (c) Write sort notes on presure drop in packed column. [8+4+4]

5. For dilute mixtures and cases when Henry's law applies, prove that the number of overall transfer units for counter-current gas absorption in packed towers is given by $N_{toG} = \frac{\ln[\frac{y_1-mx_2}{y_2-mx_2}(1-\frac{1}{A})+\frac{1}{A}]}{1-1/A}$ Where subscript 1 indicates the bottom (where gas enters and liquid leaves) and subscript 2 indicates the top of the tower (where gas leaves and liquid enters). Write the ansumptions made the relation. [16]

6. A plant requires 2000kg/min of cooling water to flow through its distillation equipment condensers, thereby removing the heat from the condensers, the water will leave the condensers at 50^0C.It is planned to design a counter current cooling tower in order to cool this water to 30^0c from 50^0C for re use, by contact with air. Air is available at 30^0C dry bulb temperature and 24^0c wet bulb temperature. 30% excess air will be used and the make up water will enter at 15^0C.For the packing to be used , the value of the mass transfer coefficient is expected to be 2500kg/hr

t_l^0c	25	30	35	40	45	50	55
H [kcal/kg dry air]	19.1	23.9	31.8	40.4	51.3	53.1	82.3

[16]

m^3molefraction, provided the minimum liquid rate and gas rates are 12000 and 10000kg/hr m^2 respectively. Determine the height and the diameter of the cooling tower. DATA:

7. (a) Explain the following terms in drying
   i. Critical moisture content,
   ii. Constant rate period,
   iii. Falling rate period
   iv. Initial adjustment. [4x2]

   (b) A batch of solids is dried from 25 to 6% moisture under conditions identical to those for which the following applies. The initial weight of the wet solid is 160 kg and the drying surface is 1 m^2/40 kg dry weight. Determine the time for drying in the constant rate period.
   Data: Xc = 0.2kg moisture/1kg dry solid
   N_c=0.3×10^{-3} rate of drying. [8]

8. (a) Describe various types of cooling towers.
   (b) Describe in detail the construct on and operation of a direct heating drier with neat sketch.
   (c) Give three examples for mass transfer using barrier as separating agent and explain them. [5+5+6]

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

III B.Tech I Semester Regular Examinations, November 2005
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) Write the expression for flux in steady-state diffusion of A through non-diffusing B of molecular diffusion in liquids.
   (b) Calculate the rate of diffusion of acetic acid (A) across a film of non-diffusing water (B) solution 1 mm thick at 17^0C when the concentrations on opposite sides of the film are, respectively, 9 and 3 wt% acid. The diffusivity of acetic acid in the solution is $0.95 \times 10^{-9} m^2/s$. The density of 9 wt% acitic acid 3 wt% actic acid solution are 1012 kg/ms and 1003 kg/m^3 respectively. [8+8]

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 5.14×10^{-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) What do you mean by "Gas phase controlled" mass transfer
   (b) Discuss about equilibrium when a substance is distributed between two insoluble phases. [8+8]

4. Explain the following undesirable operations in Sieve-tray tower?
   (a) Coning
   (b) Dumping
   (c) Entrainment
   (d) Flooding [4x4]

5. Carbon disulfide vapor - nitrogen mixture is to be scrubbed with absorbent hydrocarbon oil. The CS_2-N_2 mixture has a partial pressure of CS_2 is 50 mmHg at 24^0C and is blown into the absorber at atmospheric pressure at the rate of 1400 m^3/hr. The vapor content of the gas is to be reduced to 0.5%. The absorbent oil has mol wt. of 180, viscosity 2×10^{-3} Pa S and specific gravity 0.81. The oil enters the absorber essentially stripped off all CS_2 and solutions of oil and CS_2 are ideal. The vapor pressure of CS_2 at 24^0C is 46 kN/m^2. Assume an isothermal operation and determine:
   (a) Minimum L/G ratio
   (b) For twice the minimum L/G ratio calculate the number of stages

(c) The exit oil concentration. [16]

6. It is planned to cool water from 45^0C to 27^0C in a packed counter current cooling tower using air entering at 24^0C with a wet bulb temperature of 20.5^0C. The water flow rate is 10000kg/hr.m^2. The overall mass transfer coefficient is K_G a = 105 kmol/hrm^9 atm.

(a) Calculate the minimum air rate that can be used.

(b) Calculate the tower height needed if the air flow is 7000kg.air/hr.m^2.

Data:

Temperature of air ^{o}C	15.6	18.3	21.1	23.9	26.7	29.4	32.2
Enthalpy of Moist air Kcal/kg dry air	14.7	16.7	18.9	21.5	24.3	27.5	31.1

[16]

7. (a) A wet cake with a weight of 5 kg originally contains 50% moisture content on wet basis. The slab is 0.6mx1mx7.5cm thick. The equilibrium moisture content is 5%. When in contact with air of 40^0C and 20% humidity, the drying rate is given in the table below. For contact with air of the above quality and same velocity, how long will it take to dry the slab to 15% moisture content on wet basis? Drying is from one face.

Wet slab weight, kg:	5	4	3.6	3.5	3.4	3.06	2.85
Drying rate, kg/m^{2}hr:	5	5	4.5	4.0	3.5	2.0	1.04

(b) Write short note on aplications drying operation. [10+6]

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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III B.Tech I Semester Regular Examinations, November 2005
MASS TRANSFER OPERATIONS-I
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Time: 3 hours **Max Marks: 80**

Answer any FIVE Questions
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1. (a) Draw the concentration profiles in terms of pressure versus distance for the following two cases:
   i. steady state diffusion of A through nondiffusing B and
   ii. the steady state equimolar counter diffusion. Also write the equations for both the cases.
   (b) Oxygen (A) is diffusing through carbon monoxide (B) under steady state conditions, with the carbon monoxide nondiffusing. The total pressure is $1 \times 10^5\, N/m^2$ and the temperature is 0^oC. 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 mixture is $1.87 \times 10^{-5}\, m^2/s$. Calculate the rate of diffusion of oxygen in k mol /s through each square meter of the two planes. [8+8]

2. (a) List various forms of expressing mass transfer coefficient with their units.
   (b) List the assumptions involved for the derivation to estimate rate of mass transfer of gas into filling liquid film. [10+6]

3. (a) Explain the cross flow cascades with neat diagram.
   (b) At certain level in the wetted wall column the ammonia concentration in gas and liquid phases 0.6 and 0.35 by mole fractions. Equilibrium relation is y=0.58x, k_y=2 and 65 % controlled by gas phase resistance. Find the interfacial concentrations? [8+8]

4. (a) Write short note on 'Downspouts' and tray spacing in tray columns.
   (b) Discuss about geometric similarity, kinematic similarity and dynamic similarity in gas-liquid equipment. [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. It is planned to cool water from 45^0C to 27^0C in a packed counter current cooling tower using air entering at 24^0C with a wet bulb temperature of 20.5^0C. The water flow rate is 10000kg/hr.m^2. The overall mass transfer coefficient is K_G a = 105 kmol/hrm^9 atm.

   (a) Calculate the minimum air rate that can be used.

   (b) Calculate the tower height needed if the air flow is 7000kg.air/hr.m^2.

   Data:

Temperature of air ^{o}C	15.6	18.3	21.1	23.9	26.7	29.4	32.2
Enthalpy of Moist air Kcal/kg dry air	14.7	16.7	18.9	21.5	24.3	27.5	31.1

[16]

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) Enumerate different driers used for drying rigid or granular solids.

   (b) Describe the working of a forced draft cooling towers.

   (c) Give threes examples for mass transfer using energy as the separating agent and explain. [5+5+6]

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