5E3203

Roll No. _____ Total No of Pages: 8

5E3203

B. Tech. V Sem. (Main / Back) Exam., Dec. 2014
Chemical Engineering
5CH3 Mass Transfer - I

Time: 3 Hours **Maximum Marks: 80**

Min. Passing Marks: 24

Instructions to Candidates:

*Attempt any **five questions,** selecting **one question** from **each unit.** All questions carry **equal** marks. Schematic diagrams must be shown wherever necessary. Any data you feel missing suitably be assumed and stated clearly.*

Units of quantities used/calculated must be stated clearly.

Use of following supporting material is permitted during examination.

(Mentioned in form No. 205)

1. NIL 2. NIL

UNIT – I

Q. 1 (a) For mass transfer across a phase interface, what is the difference between the film penetration and surface – renewal theories, particularly with respect to the dependence on diffusivity? [16]

(b) Calculate the rate of diffusion (kmd/m^2.s) of acetic acid across a film of non-diffusing water solution of 2mm thickness at 290k. The concentrations on opposite sides of the film are 8% and 4% by weight of acid respectively. The diffusivity of acetic acid in the solution is 0.95×10^{-9} m^2/s. The densities of 8%

and 4% by weight acetic acid solutions are 1.01 gm/cm^3 and 1.004 gm/cm^3 respectively. Molecular weight of acetic acid and water is 60 and 18 respectively.

OR

Q. 1 (a) For a binary mixture (A and B), derive the expression for molar flux of A and B in case of equimolar diffusion. Also show that $D_{AB} = D_{BA}$ [16]

(b) Carbon dioxide is stripped from water by air in a wetted-wall tube. At a location where pressure is 10 atm and temperature 25°C the flux of CO_2 is 0.00022 mol/s-cm^2. The partial pressure of CO_2 is 8.2 atm at the interface and 0.1 atm in the bulk gas. The diffusivity of CO_2 in air at these conditions is 1.6×10^{-2} cm^2/s. Assuming turbulent flow, calculate by film theory the mass- transfer co-efficient kc for the gas phase and the film thickness, if the bulk flow effect is not negligible.

UNIT-II

Q. 2 (a) Derive an expression of overall mass transfer co–efficient based on mole fraction (K_x and K_y) for the gas-liquid mass transfer. (Write all steps clearly) [16]

(b) In a mass transfer apparatus operating at 1 atm pressure, the individual mass transfer co–efficients are k_x = 22 k $mol/m^2.h$ and k_y = 1.07k $mol/m^2.h$. The

equilibrium composition of the gas and liquid phases are characterized by Henry's law:

$P_A = 0.08 \times 10^6 \, x_A$ mm Hg

Where P_A is the partial pressure of the solute in the gas phase and x_A is the mole fraction of the solute in the liquid phase. Determine the overall mass transfer coefficient based on gas and liquid phases. By how many times does the diffusion resistance of the liquid phase differ from that of the gas phase?

OR

Q. 2 (a) What is the difference between on operating line and an equilibrium curve? Explain briefly, how to calculate the data for drawing these two lines? [16]

(b) Component A is being transferred from the liquid phase to the gas phase in a mass transfer apparatus. The equilibrium relation is given by Y= 0.75x. At one point in the apparatus, the liquid contains 90 mol % A and the gas in contact with the liquid contains 40 mol% A. The gas film co-efficient at the above point is 2 k mol m^{-2} $h^{-1}(\Delta y_A)^{-1}$ and 72% of the total resistance to mass transfer lies in the gas phase. Determine the molar flux of A, the interface concentration of A in both phases and the overall mass transfer coefficient based on the gas phase.

UNIT-III

Q. 3 A mixture of air and acetone vapor containing 85% air by volume is stripped of 95% of its acetone content by counter current contact with a stream of water in a bubble plate column operating at 298k and 1 atm. An overall plate efficiency of 30% can be assumed. If 1.25 times the minimum liquid rate is used. Find the actual number of plates required. [16]

Equilibrium Data:

Mole% of acetone in liquid	3.33	7.20	11.7	17.10
Partial Pressure of acetone in gas (mm Hg)	3.0	29.6	61.8	103

OR

Q. 3 (a) Under what conditions, mechanical entrainment phenomena occurred in trayed absorption column. [16]

(b) In a trayed tower, what is meant by flooding and weeping?

(c) Air concentrated with solute P is brought in contact with water. It steady state, the bulk concentration of P in air and water are 0.3 and 0.02 respectively. The equilibrium equation relating the interface compositions is $Y_{P,i} = 0.25x_{p,i}$ Assume that the mass transfer coefficient k_G and K_L are identical. Calculate the gas phase mole fraction of P at the interface ($y_{p,i}$).

UNIT-IV

Q. 4 The following experimental data for the adsorption of water vapor from nitrogen in a fixed- bed of 4A molecular sieves:

Bed depth = 0.88ft, temperature = 83°F (negligible temperature change), pressure = 86 psia (negligible pressure drop), entering gas molar velocity = 29.6lb md/ h-ft^2 entering water content = 1440 ppm (by volume), initial adsorbent loading = 1lb/100 lb siever and bulk density of bed = 44.5 lb/ft^3. For the entering gas moisture content, the equilibrium loading = 0.186 lb H_2O/ lb solid

C_{exit}, PPM (by Volume)	Time, h
< 1	0-9.0
1	9.0
4	9.2
9	9.4
33	9.6
80	9.8
142	10.0
238	10.2
365	10.4
498	10.6
650	10.8
808	11.0
980	11.25
1115	11.50
1235	11.75
1330	12.0
1410	12.5
1440	12.8
1440	13.0

Determine the bed height required for a commercial unit to be operated at the same temperature, pressure and entering gas mass velocity and water content to obtain an existing gas with no more than 9 ppm (by volume) of water vapor with a breakthrough time of 20h. [16]

OR

Q. 4 A waste stream of alcohol vapor in air from a process was absorbed by activated carbon particles in a packed bed having a diameter of 4cm and length of 14 cm containing 79.2g of carbon. The inlet gas stream having a concentration co of 600 ppm and a density of 0.00115 g/cm^3 entered the bed at a flow rate of 754 cm^3/s. Data in Table -1 give the concentrations of the breakthrough curve. The break-point concentration is set at C/co= 0.01. Do as follows: [16]

(a) Determine the break-point time, the fraction of total capacity used up to the break- point and the length of the unused bed. Also determine the saturation loading capacity of the carbon.

(b) If the break- point time required for a new column is 6.0h, what is the new total length of the column required?

Time, h	0	3	3.5	4	4.5	5	5.5	6.0	6.2	6.5	6.8
C/Co	0	0	0.002	0.030	0.155	0.396	0.658	0.903	0.933	0.975	0.993

UNIT-V

Q. 5 (a) Draw the drying curve for non-process solids and explain the nature of the curve with proper justification. [16]

(b) A batch of solid is dried from 28% to 8% moisture, wet basis. The initial weight of the solid is 380 kg and the drying surface is 0.15m^2/40kg of dry weight. The

critical moisture content is 28% dry basis and the content drying rate is 0.32kg/hrm^2. For the falling rate period, the following data are available.

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

Determine the drying time.

OR

Q. 5 (a) Derive the expression for total drying time. [16]

(b) Experimental data for the surface drying of a 3.18cm thick × 6.6cm^2 cross-sectional area slab of a thick paste of $CaCO_3$ (Whiting) from both sides by air at T_d = 39.8°C and T_w = 23.5°C and a cross- circulation velocity of 1 m/s exhibit the complex type of drying rate curve (porous solid):

Data given:

Constant rate period: X_o =10.8% (dry basis)

X_{c2} = 8.3% (dry basis), R_{c1} = 0.053g H_2O/h-cm^2

First falling rate period: X_{c2} = 3.7% (dry basis),

$$R_{c2} = 0.038 \text{ g } H_2O/\text{h-cm}^2$$

Second falling rate period to X = 2.2% (dry basis): $R = 29.03X^2 - 0.048X$

Determine the time to dry a slab of the same dimension at the same drying conditions, but from Xo=0.14 (dry basis) to X = 0.022 (dry basis), ignoring the preheat period. Assume that the initial weight of the slab is 46.4g and drying is from both sides.
