

JK LAKSHMIPAT UNIVERSITY, JAIPUR

INSTITUTE OF ENGINEERING AND TECHNOLOGY

End Term Examination (Regular/Backlog), April-May 2016

B. Tech in Chemical Engineering, Semester IV

Roll No.....

CHE402: MASS TRANSFER OPERATIONS

Time: 3 hours

Max. Marks: 100

Instructions to students:

1. Do not write anything other than your roll number on question paper.
2. Assume suitable data wherever required and mention it clearly.
3. Writing appropriate units, nomenclature, and drawing neat sketches/schematics/ flow chart wherever, required are an integral part of the answer.

Q.1A Objective type multiple choice questions (10 questions @ 1 mark)

10

- i. Penetration theory relates average mass transfer co-efficient (K) with Diffusivity (D) as:

(a) $K \propto D$ (b) $K \propto \sqrt{D}$ (c) $K \propto D^{1.5}$ (d) $K \propto D^2$

- ii. Corresponding to Prandtl number in heat transfer, the dimensionless group in mass transfer is:

(i) Schmidt number
(ii) Sherwood number
(iii) Peclet number
(iv) none of these

- iii. In the McCabe-Thiele diagram for binary distillation, vertical feed line represent feed and horizontal feed line represent Feed.

(i) saturated vapour, saturated liquid
(ii) saturated liquid, saturated vapour
(iii) saturated feed, saturated vapour
(iv) none of these

- iv. Henry's law state that

(i) Partial pressure of a component over a solution is proportional to its mole fraction in the liquid.
(ii) Partial pressure of a component over a solution is proportional to its mole fraction in the vapour.
(iii) Vapour pressure is equal to the product of the mole fraction and total pressure.
(iv) Partial pressure is equal to the product of the mole fraction and total pressure.

- v. Most important to separate a mixture of two volatile liquids by distillation is

(i) solubility
(ii) relative volatility



- (iii) density difference
- (iv) selectivity

vi. Match List I with List II, and select the correct answer from the codes given below the lists,

	List I	List II
(i)	$\frac{y^*(1-y)}{x(1-x)}$	1. Reflux ratio
(ii)	$\frac{L}{D}$	2. q
(iii)	$\frac{H_V - H_F}{H_V - H_L}$	3. Relative volatility

vii. In a countercurrent gas absorber, both the operating and equilibrium relations are linear. The inlet liquid composition and the exit gas composition are maintained constant. In order to increase the absorption factor:

- (a) the liquid flowrate should decrease
- (b) the gas flowrate should increase
- (c) the slope of equilibrium line should increase
- (d) the slope of equilibrium line should decrease

viii. For steady state equimolar counter diffusion of two gases A and B, the ratio

$$\frac{N_A}{N_A + N_B} \text{ is}$$

- (i) 0
- (ii) 1
- (iii) $1/2$
- (iv) ∞

ix. For gas absorption the height of transfer unit, based on the gas phase, is given by (G: Superficial molar gas velocity, L: superficial molar liquid velocity, F_G = mass transfer coefficient, and a = interfacial area per unit volume of tower)

- (a) $\frac{G}{F_G a}$
- (b) $\frac{F_G}{G a}$
- (c) $\frac{G a}{F_G}$
- (d) $\frac{L}{F_G G}$

x. Define Molar average velocity and Mass average velocity

Q.2 Short answer type questions (4 questions @ 2.5 marks)

10

- (i) Explain the concept of 'weeping' and 'Entrainment' of the tray tower.
- (ii) Define q value. What it signifies.
- (iii) Determine the relation between the gas phase mass transfer coefficients, k_G and k_Y .
- (iv) A column for distillation of a mixture of A & B operates at total reflux. The liquid concentration of the fifth tray from the top is $x = 0.4$. If the relative volatility is $\alpha_{AB} = 1.8$, what are the concentration of vapor stream entering the tray.

Q.3A Explain Fick's law of molecular diffusion. Show that mutual diffusivity of two components A & B are same.

05

Q.3B Write short note on:

05

- (i) Film Theory
- (ii) Surface renewal theory

- Q.4A Derive an expression for steady state molecular diffusion through uniformly tapered equilateral triangle. 05
- Q.4B The CO_2 is diffusing through non-diffusing N_2 at steady state in a conduit of 2m long at 300K and a total pressure of 1 atmosphere. The partial pressure of CO_2 at the left end is 20 KPa and 5KPa at the other end. The cross section of the conduit is in the shape of an equilateral triangle being 0.025m at the left end and tapering uniformly to 0.05m at the right end. Calculate the rate of transport of CO_2 . The diffusivity is $D_{AB} = 2 \times 10^{-5} \text{ m}^2/\text{s}$. 05
- Q.5A One kmole of gas mixture at a total pressure of 250 kPa and 303 K contains 10% CH_4 , 30% C_2H_6 , and 60% H_2 by volume. The absolute velocities of each species are -10 m/s, -5 m/s, and 15 m/s, respectively, all in the direction of the z axis. 05
- (a) Determine the molar average velocity, U_{mol} for the mixture.
- (b) The molar flux of CH_4 with respect to an observer moving with the molar average velocity.
- Q.5B Carbon disulphide is to be absorbed from a dilute gas mixture of $\text{CS}_2\text{-N}_2$ into a pure nonvolatile oil at atmospheric pressure in a counter current absorber. The mole fraction of CS_2 in inlet gas stream is 0.05 and the flow rate of gas stream, G_s is 1500 kmol/hr. The equilibrium relation is given by $y = 0.5x$, Where x is the mole fraction of CS_2 in liquid stream. It is desired to reduce the mole fraction of CS_2 in the gas stream is 0.005. Calculate the minimum value of L_s/G_s , where L_s is the liquid flowrate in kmol/hr. 05
- Q.6A Explain Distillation by giving example of any three industrial processes. Differentiate between absorption and distillation. 03 + 02 = 05
- Q.6B A batch distillation operation is carried out to separate a feed containing 100 moles of a binary mixture of A and B. The mole fraction of A in the feed is 0.7. The distillation progresses until the mole fraction of A in the residue decreases to 0.6. The equilibrium curve in this composition range may be linearized to $y^* = 0.7353x + 0.3088$. Here x and y are the mole fractions of the more volatile component A in the liquid and vapor phases respectively. Calculate the number of moles of residue. 05
- OR
- Q.6B A Refinery off gas streams contains 10% undesirable component B. It is desire to remove 95% of component B. The feed gas streams enters at the bottom of a separation column at a flow rate of 5000 kg/h. The pure solvent is fed at the top of the column at a flow rate of 5000 kg/h. The equilibrium relation is linear $Y = 1.1X$. Obtain the equation of operating line and calculate the number of trays by using kremser equation. 05
- Q.7A The equilibrium distribution of a solute A between air and water at low concentration at a particular temperature is given below 05

$$y = 1.2x$$

At a certain point in mass transfer device, the concentration of solute A in the bulk air is 0.04 mole fraction and that in the bulk aqueous phase is 0.025. The local individual



mass transfer coefficients for the transport of A are, $k_y = 7.2 \text{ kmol/(h)(m}^2\text{)(}\Delta y\text{)}$ and $k_x = 4.6 \text{ kmol/(h)(m}^2\text{)(}\Delta y\text{)}$. Calculate (a) the interfacial concentrations in both the gas-phase and the liquid phase; (b) the Overall mass transfer coefficients, K_x and K_y .

Q.7B Derive material balance equations for steady state counter-current process. 05

OR

Q.7B Explain steam distillation column with neat diagram. How you will calculate the amount of steam required for a steam distillation process? 05

Q.8A A gas mixture containing 0.015 mole fraction of solute S at the inlet (and the rest inerts) is subjected to counter-current absorption with water in a packed tower. The outlet concentration of the solute is to be 1% of the inlet value. The total gas inlet flow rate is $1.0 \text{ kg/m}^2\text{s}$ (MW = 29) and the pure water entering is $1.6 \text{ kg/m}^2\text{s}$. The system can be considered as dilute. 10

The equilibrium condition can be described by Henry's Law and is given as $y = 1.75x$, where y and x are the mole fraction of solute S in the vapour and liquid respectively. The column uses a certain type of packings which provides an overall gas-phase mass transfer coefficient (K_Ya) of $0.06 \text{ kg-mole/(m}^3\text{s.mole fraction)}$. Determine the height of packings required for the separation

Given:

$$N_{OG} = \frac{y_1 - y_2}{(y - y^*)_{LM}} \quad (y - y^*)_{LM} = \frac{(y_1 - y_1^*) - (y_2 - y_2^*)}{\ln \left[\frac{(y_1 - y_1^*)}{(y_2 - y_2^*)} \right]}$$

$$H_{OG} = \frac{G}{K_Y a (1 - y)_{LM}^*} \quad (1 - y)_{LM}^* = \frac{(1 - y_1) - (1 - y_1^*)}{\ln \left[\frac{1 - y_1}{1 - y_1^*} \right]}$$

Q.9A Define HETP. Derive equation of height of a gas transfer unit for a continuous packed absorption tower. 10

Q.9B Derive an expression of operating line for rectifying and stripping section. How could you determine the number of trays and feed tray location of continuous multistage fractionation column of binary mixtures using the McCabe-Thiele method. 10

OR

Q.9B Derive material and energy balance equations for multistage fractionation column of binary mixtures. 10

***** GOOD LUCK *****