MASS TRANSFER I
(CHEN 3103)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) The diffusivity (D) in a binary gas mixture is related to pressure (P) as

(a) $D \alpha P^{0.5}$ (b) $D \alpha \frac{1}{P^{0.5}}$

(c) $D \alpha \frac{1}{P}$ (d) $D \alpha \frac{1}{P^{1.5}}$

(ii) In case of distillation, as the reflux ratio is decreased, the intersection of both the operating lines

(a) moves towards the diagonal (b) moves away from the diagonal

(c) does not at all move (d) none of these.

(iii) Penetration theory relates average mass transfer co-efficient (k) with diffusivity (D) as

(a) $k \alpha D$ (b) $k \alpha D^{0.5}$

(c) $k \alpha D^{1.5}$ (d) $k \alpha D^2$.

(iv) Corresponding to Prandtl number in heat transfer, the dimensionless group in mass transfer is the _____ Number.

(a) Sherwood (b) Schmidt

(c) Peclet (d) Stanton

(v) In the absorption of ammonia in water, the main resistance to absorption is by the _____phase.

(a) liquid (b) gas

(c) both liquid and gas (d) neither liquid nor gas

(vi) Operating velocity in a packed tower is usually_____ the flooding velocity

(a) half (b) twice

(c) equal to (d) more than

(vii) In case of an absorber, the operating
(a) line always lie above the equilibrium curve
(b) line always lie below the equilibrium curve
(c) line can be either above or below the equilibrium curve
(d) none of these.

(viii) When the feed to a distillation column is a subcooled liquid, the slope of the feed line is
(a) positive (b) negative
(c) 1 (d) none of these.

(ix) In a distillation column, with increase in the reflux ratio, the heat removed in the condenser
(a) increases
(b) decreases
(c) remains unaffected
(d) and the heat required in reboiler decreases.

(x) Azeotropic distillation is employed to separate
(a) constant boiling mixture
(b) high boiling mixture
(c) mixture with very high relative volatility
(d) none of these.

Group – B

2. (a) In case of binary diffusion of A (density ρ_A) and B (density ρ_B), express the relation between mass average velocity to individual mass velocity.

(b) Calculate the rate of diffusion of acetic acid (A) (Mol.wt. 60) across a film of non-diffusing water (B) solution 2 mm thick at 20^0C when the concentrations on opposite sides of the film are 9 and 3 wt% acid respectively. The diffusivity of acetic acid in the solution is 0.95×10^{-9} m^2/s. Given : density of 9 wt% and 2 wt% acid solutions are 1010 kg/m^3 and 1002 kg/m^3 respectively.

(c) Define Sherwood no.

(d) Discuss film theory related to mass transfer.

2 + 6 + 1 + 3 = 12

3. (a) Two large vessels are connected by a tube of 6 cm in diameter and 20 cm in length. Vessel 1 contains 75% N_2(A) and rest O_2(B). Vessel 2 contains 75% O_2 and rest N_2. The temperature is 25^0C and pressure is 1.8 atm. Diffusivity $D_{N2\text{-}O2}$ at 316 K and 1 atm. pr. is 0.23 cm^2/sec. Calculate the following:
(i) Steady state flux and rate of transport of A from vessel 1 to 2.
(ii) The partial pressure of N_2 in the tube at a distance 12 cm from vessel 1.
(iii) The net mass flux w.r.t a stationary observer.

(b) Prove that $D_{AB} = D_{BA}$..

9 + 3 = 12

Group – C

4. (a) Name two equipments used in mass transfer operations with liquid continuous and gas dispersed mode.

(b) Discuss the operating characteristics in a sieve tray tower based on variation of liquid rate and gas rate.

2 + 10 = 12

5. (a) Give two examples of gas absorption with chemical reaction.

(b) Discuss the interface behaviour for instantaneous reaction and extremely slow reaction in case of gas absorption with chemical reaction.

(c) Gaseous A absorbs and reacts with B in liquid according to
A (g→l) + B (l) →R (l) $-r_A = kC_AC_B$
in a packed bed under conditions where
$k_{AG}a$= 0.1 mol/hr. m^3 of reactor. Pa, $k_{Al}a$= 100 m^3 of liquid/ m^3 of reactor. hr.
a=100 m^2/ m^3 of reactor, $D_{Al}=D_{Bl}=10^{-6}$ m^2/hr.
f_l=0.1 m^3 of liquid/ m^3 of reactor, k= 10 m^3 of liquid/mol.hr.
Henry's Law constant, H_A= 10^5 Pa. m^3 liquid/mol.

At a point in the reactor where p_A= 100 Pa and C_B = 100 mol/ m^3 liquid,
(i) Calculate the rate of reaction in mol/hr. m^3 of reactor
(ii) Location of major resistance.

2 + 4 + 6 = 12

Group – D

6. (a) Using Kremser equation determine the number of theoretical stages required for absorption of 90% acetone in a gas containing 6 mol% acetone in air in a counter current stage tower. The total inlet gas flow rate to the tower is 34 kg mol/ h and the total inlet pure water flow to be used to absorb the acetone is 105 kg mol /h. The process is to operate isothermally at 300K and a total pressure of 101.3kPa.
Equilibrium relation is given by : $y_a = 2.5\ x_a$.

(b) Mention the limitations of using Kremser Equation.

(c) What do you understand by *packing factor*?

8 + 2 + 2 = 12

7. (a) A binary gas mixture containing 7% of a solute A is to be scrubbed with the solvent B in a packed tower. Based on flooding calculations, a tower diameter of 1.2 m has been selected. The total gas rate at the bottom is 62 kmol/h. The

exit gas must not contain more than 0.2% of the solute. Pure solvent B enters the tower at a rate of 40 kmol/h. The gas phase and liquid phase mass transfer coefficients (based on mole ratio) are k_X= 2.05 kmol/(m^2)(h)(ΔX), and k_Y= 1.75 kmol/(m^2)(h)(ΔY). Equilibrium line equation is Y=0.63X. The specific interfacial area of gas-liquid contact is 71 m^2/m^3. Calculate the height of packing necessary for the separation.

[mm graph paper is required].

(b) Mention the desirable properties of solvent for gas absorption.

10 + 2 = 12

Group – E

8. A mixture of benzene and toluene having 38% benzene is to be separated at a rate of 200 kmol/ hr. into a top product containing 96% benzene and a bottom product with 5% of it. The average relative volatility of benzene in the mixture is 2.5. A reflux ratio of 3 is suggested. The feed is a 50% liquid and 50% vapour.
Find the following:
(i) Rate of distillate and bottom product.
(ii) Equation of rectifying section operating line.
(iii) Equation of feed line.
(iv) Vapour flow rate in rectifying section and stripping section.

(3 × 4) = 12

9. (a) A mixture of 46 mole percent benzene (A) and rest toluene (B) is subjected to flash distillation at a separator pressure of 1 atm. The relative volatility α_{AB} is 2.5. Find the composition of the vapour and liquid leaving the separator for following cases:
(i) fraction of feed vaporized =0.5 , (ii) fraction of feed vaporized =1.

(b) What do you understand by *minimum boiling azeotrope*? Give example.

8 + 4 = 12

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CHE	https://classroom.google.com/c/MTIyMzkyNzQzNzI1/a/MjcxNDAyMTc4NTcy/details