SEPARATION PROCESS - I
(CHEN 2202)

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) In physical terms, Schmidt number means
(a) thermal diffusivity/ momentum diffusivity
(b) thermal diffusivity/ mass diffusivity
(c) momentum diffusivity / mass diffusivity
(d) mass diffusivity/ thermal diffusivity.

(ii) Chemisorption is
(a) generally irreversible
(b) readily reversible
(c) reversible in some cases but irreversible in other cases
(d) equilibrium.

(iii) Penetration theory relates average mass transfer coefficient (k) with diffusivity (D_{AB}) as
(a) $K \alpha D$ (b) $K \alpha D^{0.5}$ (c) $K \alpha D^{1.5}$ (d) $K \alpha D^{2}$

(iv) Gas A diffuses through non diffusing B from point 1 to point 2. Total pressure is 2 atm and $y_{A1} = 0.1$; then find the ratio of $\frac{(\delta p/\delta z)_1}{(\delta p/\delta z)_2}$.
(a) 1 (b) 10 (c) 1.11 (d) 0.9.

(v) In which of the following cases would you choose a packed column?
(a) Liquid is corrosive (b) Gas flow rate fluctuates too much
(c) Heat of solution is high (d) The liquid has a fouling tendency.

(vi) Extractive distillation works by
(a) change of relative volatility
(b) formation of an azeotrope
(c) increase in mass transfer coefficient
(d) alteration of activity coefficients.

(vii) Wetted wall tower experiment determines
(a) molar diffusivity (b) mass transfer co-efficient
(c) volumetric coefficient (d) mass flux.

(viii) The length of unused bed is more when mass transfer zone is
(a) wide (b) narrow (c) asymmetric (d) symmetric.

(ix) The value of q for a feed which is a saturated vapour is
(a) <1 (b) 1 (c) 0 (d) >1.

(x) For a tray where appreciable back-mixing takes place, the relation between local efficiency (E_{loc}) and Murphree efficiency (E_M) is
(a) $E_{loc} > E_M$ (b) $E_{loc} < E_M$ (c) $E_{loc} = 0.5\ E_M$ (d) $E_{loc} = E_M$

Group – B

2. (a) Show that according to Film theory mass transfer co-efficient is proportional to the diffusivity.

(b) Ammonia is diffusing through a neoprene rubber of 200 micron thickness at 343K and at 10kpa partial pressure. The pressure of ammonia on the sweep side of the rubber is assumed as zero. The solubility of ammonia in the neoprene membrane is 0.007 m^2 (STP of 0^oC and 1 atm) and the diffusivity is 5×10^{-10} m^2/s. Calculate the steady state flux of ammonia.

(c) Derive the relation between liquid phase convective mass transfer co-efficient with diffusivity, for
(i) diffusion of A through non diffusing B
(ii) equimolar counter diffusion of A and B.

4 + 4 + 4 = 12

3. (a) Calculate the rate of diffusion of acetic acid across a film of non-diffusing water solution 3 mm thick at 17^oC when the concentration (by weight) on opposite sides of the film are 15% and 6% acid. The diffusivity of acetic acid in the solution is 0.95×10^{-9} m^2/s. Density of 15% and 6% acid (by weight) are 1013 kg/m^3 and 1004 kg/m^3 respectively.

(b) What are F-type mass transfer coefficients?

(c) Prove that for ideal binary gas mixture the diffusivity of A through B is equal to the diffusivity of B through A.

6 + 2 + 4 = 12

Group – C

4. (a) Deduce the expression for separation factor for a binary distillation operation.

   (b) A mixture containing 50 mol% n-heptane and 50 mol% n-octane is differentially distilled at atmospheric pressure. The residue composition is found to be 0.33 mol fraction n-heptane. Calculate the moles of distillate and residue as well as the composited distillate composition. Equilibrium data is given below:

x	0.5	0.46	0.42	0.38	0.34	0.32
y^*	0.689	0.648	0.608	0.567	0.523	0.497

   (c) Write down a few characteristics of an ideal solution.

3 + 6 + 3 = 12

5. (a) What is the significance of the difference point in the H-x,y diagram in the Ponchon-Savarit method?

   (b) What is the significance of "q" in the McCabe-Thiele method?

   (c) A plant must distil a mixture containing 75 mol% methanol and 25 mol% water. The distillate specification is 99.99 mol% methanol and bottoms specification is 0.002 mol% methanol. The feed is cold and for each mole of feed, 0.15 mol of vapour is condensed at the feed plate. Calculate the minimum reflux ratio and the number of plates if 1.2 times the minimum reflux ratio is used. Assume overall efficiency of the column to be 72%. Equilibrium data for the system is given as:

x	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
y	0.417	0.579	0.669	0.729	0.78	0.825	0.871	0.915	0.959	1

3 + 2 + 7 = 12

Group – D

6. (a) In the absorption of NH_3 in water for an air-NH_3 mixture in a certain apparatus at 2 atm pressure at 15°C, the value of k_y is estimated to be 1.957 kg mol/hour.m^2.mole fraction, and that of k_l to be 0.3353 kg mol/{hour.m^2.(kg mol/m^3)}. For dilute solutions of NH_3 in water at 15°C the equilibrium partial pressure of NH_3 is given by P = 645x, where P is in mm Hg, and x is the mole fraction of NH_3 in water.
   (i) Calculate the overall gas phase mass transfer coefficient in kg mol/hour.m^2.atm.
   (ii) Determine the percentages of the total resistance to mass transfer in the gas film and liquid film.
   (iii) Determine which resistance is controlling.

   (b) What are the physical significances of HTU and NTU in case of a packed absorption column?

7 + 5 = 12

7. (a) The operating line for absorption lies above the equilibrium curve while that for stripping lies below the equilibrium curve. Explain.

   (b) In your plant, SO_2 is to be removed from a gas mixture by scrubbing with ammoniacal liquor. The flow rate of the gas mixture has been found to vary from 4 kg/s to 15 kg/s due to faulty operation, whereas normally the flow rate fluctuation is within 4-6 kg/s. The temperature of the gas mixture also varies from 60°C to 80°C at times. You have ordered your newly recruited design engineer to design an absorption column for the system. He / She has designed a packed absorption tower and the design is absolutely correct mathematically. Will you keep him / her in your employment or fire him / her immediately? Justify.

   (c) "Absorption is a gas-film controlled operation". Justify the statement.

3 + 5 + 4 = 12

Group – E

8. (a) Derive the equation of Langmuir isotherm with clearly mentioning the assumptions.

   (b) There are two systems: (i) Benzene-Toluene and (ii) Methanol-Acetone. The first system employs ordinary distillation while the second system employs extractive distillation for separation. On increasing the reflux ratio from 4 to 8, it is seen that the purity of the distillate increases for case (i) while distillate purity decreases in case (ii). Explain this paradox.

4 + 8 = 12

9. (a) Write short notes on "mass transfer zone" and LUB.

   (b) What are the three main industrial techniques for azeotropic distillation? Which one is generally most favourable and why? What is the function of the weir on trays in a tray column?

(3 + 2) + (3 + 3 + 1) = 12