Name : ....

Roll No. : ....

Invigilator's Signature : ....

CS/M.Tech (CHE)/SEM-2/CHE-904/2010

2010

ADVANCED MASS TRANSFER

Time Allotted : 3 Hours   Full Marks : 70

The figures in the margin indicate full marks.

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

Answer any *five* questions.   5 × 14 = 70

1. In the ultrafiltration of a protein solution of concentration $0{\cdot}01$ kg/ m^3, analysis of data on gel growth rate and wall concentration C_w yields the second order relationship :

$$\frac{dl}{dt} = K_r C_w^2$$

where l is gel thickness, and K_r is a constant, $9{\cdot}2 \times 10^{-6}$ m7/kg 2s.

The water flux through the membrane may be described by :

$$j = \frac{|\Delta p|}{\mu_w R_m}$$

where | p | is pressure difference, R_m is membrane resistance and μ_w is the viscosity of water. This equation may be modified for protein solution to give :

$$j = \frac{|\Delta p|}{\mu_p \left(R_m + \frac{l}{P_g} \right)}$$

where p_g is gel permeability, and μ_p is the viscosity of permeate.

The gel permeability may be estimated from the Carmen – Kozeny equation :

$$P_g = \left(\frac{d^2}{180} \right) \left(\frac{e^3}{(1-e)^2} \right)$$

where d is particle diameter and e is the porosity of the gel.

Calculate the gel thickness after 30 minutes operation.

Data : Flux (mm/s)	0·02	0·04	0·06
Δp (kN/ m^2)	20	40	60

Viscosity of water = 1·3 mNs/ m^2

Viscosity of permeate = 1·5 mNs/ m^2

Diameter of protein molecule = 20 nm

Operating pressure = 10 kN/ m^2

Porosity of gel = 0·5

Mass transfer coefficient to gel h_D = $1 \cdot 26 \times 10^{-5}$ m/s

Calculate the gel thickness after 30 minutes operation. 14

2. a) Enumerate the four basic classifications of membrane. Write a technical note on any one of them.

   b) What are the available types of liquid membranes ? Discuss a suitable application of liquid membrane with a neat sketch. (4 + 4) + (2 + 4)

3. a) Explain the following :

   i) Ultrafiltration flux is not entirely dependent on operating pressure.

   ii) Membrane module configured as a single stage feed and bleed is characterized by low average flux than that in a batch mode.

   b) It is desired to use ultra filtration for 800 kg of a solution containing 0·05% wt% of a protein to obtain a solution of 1·10 wt%. The feed is recirculated by the membrane with a surface area of 9·90 sq.m. The permeability of the membrane is

   $A_W = 2 \cdot 5 \times 10^{-2}\,kg/s.m^2.atm.$ Neglecting the effects of concentration polarization, if any, calculate the final amount of solution and the time to perform this using a pressure difference of 0·50 atm. 4 + 10

4. a) Draw a flow diagram of a typical reverse osmosis plant for desalination of water and label its different parts.

b) Deduce the expression or rejection ratio $R = \frac{A_W(\Delta p - \Delta\pi)}{B_i\rho_W + A_W(\Delta p - \Delta\pi)}$ where symbols stand for usual notations. 8 + 6

5. a) What is Reversed Phase Chromatography ? How does it differ from Hydrophobic Interaction Chromatography ?

b) In a chromatographic separation column use for the adsorption of solute *A* onto an adsorbent solid *B*, the atmospheric isotherm is given by $C_s = k_1 C_L{}^3 = f(C_L)$, where the C_s is mg solute adsorbed/mg adsorbent C_L is the solute concentration in liquid medium (mg solute/ml liquid) and k_1 is constant and k_1 = 0·02 (mg solute adsorbed/mg adsorbent)/(mg solute/ml liquid)^3. The porosity (void fraction) of the packed column ε = 0·35. The cross-sectional area of the column is 10 cm^2 and M is 5 gm adsorbent per 100 ml column volume. If the volume of the liquid added is ΔV= 250 ml :

i) Determine the position (ΔX) of the solute band in the column when the solute concentration in the liquid phase at equilibrium is $C_L = 5 \times 10^{-2}$ mg/ml.

ii) Find the ratio of the travel distance of solute *A* (L_A) to that of solvent *B* in the column (Rf) when $C_L = 5 \times 10^{-2}$ mg/ml. (2 + 2) + 10

6. Write down a few applications of pervaporation process. What are the problems of pervaporation over other modern separation processes ? Deduce the model equations for mass transport of prevaporation for a pure liquid (ideal case).

3 + 2 + 9

7. a) A liquid containing dilute solute *A* at a concentration $c_1 = 3 \times 10^{-2}$ kg.mol/m^3 is flowing rapidly by a membrane of thickness $L = 3 \times 10^{-5}$ m. The distribution coefficient K' = 1·5 and $D_{AB} = 7 \times 10^{-11}$ m^2/s in the membrane. The solute diffuses through the membrane and its concentration on the other side is $c_2 = 0$Æ05×10^{-2} kg.mol/m^3. The mass transfer coefficient kc_1 is large and can be considered as infinite and $kc_2 = 2 \cdot 02 \times 10^{-5}$ m/s.

i) Derive the equation to calculate the steady-state flux N_A and make a sketch.

ii) Calculate the flux and concentrations at the membrane interfaces.

b) i) Explain the principle of haemodialysis in artificial kidney.

ii) Calculate the flux and the rate of removal of urea at steady state in g/h from blood in a cellophane membrane dialyzer at 37° C. The membrane is 0·025 mm thick and has an area of $2 \cdot 0 \, m^2$. The mass transfer coefficient on the blood side is estimated as $k_{c_1} = 1 \cdot 25 \times 10^{-5} \, m/s$ and that on the aqueous side is $3 \cdot 33 \times 10^{-5} \, m/s$. The permeability of the membrane is $8 \cdot 73 \times 10^{-6} \, m/s$. The concentration of urea in the blood is 0·02 g urea per 100 ml and that in the dialyzing fluid will be assumed to be zero. 8 + (3 + 3)

8. a) Deduce the expression for membrane area A_m for gas separation by membrane assuming complete mixing model.

b) A membrane is used to separate gaseous mixture of *A* and *B* whose feed flow rate $q_f = 1 \times 10^4 cm^3$ (STP)/s and feed composition of *A* is $x_f = 0 \cdot 50$ mole fraction. The desired composition of the reject is $x_0 = 0 \cdot 25$. The membrane thickness $t = 2 \cdot 54 \times 10^{-3} cm$, the pressure on the feed side is $p_h = 80cm$ Hg and on the permeate side is $p_l = 20cm$ Hg. The permeabilities are $P'_A = 50 \times 10^{-10} cm^3$ (STP). cm/(s.cm^2.cm Hg) and $P'_{1B} = 5 \times 10^{-10}$. Assuming the complete mixing model, calculate the permeate composition yp, the fractional permeated, θ and the membrane area, A_m. 7 + 7