TRANSFER OPERATIONS II
(BIOT 3104)

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) Relative volatility (α) for a binary mixture is a measure of separability by distillation. If α = 1, separation by distillation is
(a) Maximum possible (b) Least possible
(c) Impossible (d) Optimum possible.

(ii) Consequence of concentration polarization is
(a) solvent diffuses back from the membrane surface to the solution
(b) solute diffuses back from the membrane surface to the solution
(c) rate of diffusion increases
(d) none of the above.

(iii) The Freundlich adsorption isotherm can be used to model
(a) Multilayer adsorption (b) Monolayer adsorption
(c) Both (d) None of the above.

(iv) Which of the following is not an application of ultrafiltration?
(a) Concentration (b) Purification
(c) Diafiltration (d) Dialysis.

(v) Constant drying conditions includes
(a) Temperature constant (b) Humidity constant
(c) Velocity constant (d) All of the mentioned.

(vi) Molecular diffusion induced by temperature is
(a) eddy diffusion (b) thermal diffusion
(c) forced diffusion (d) none of the above.

(vii) In absorption the ratio of the slope of the operating line to that of the equilibrium line is called
(a) Distribution coefficient (b) Henry's law constant
(c) Absorption factor (d) Stripping factor

(viii) If the distribution coefficient less than unity,
(a) Separation by extraction is not possible
(b) Weight fraction of solute in the raffinate is greater than that in extract
(c) Selectivity will be less than unity
(d) Slope of the distribution curve will be negative.

(ix) Molecular weight cut-off is a measure of
(a) the permeability of membrane
(b) selectivity of membrane
(c) retention capabilities of membrane
(d) percent of feed separated as permeate.

(x) In physical adsorption, gas molecules are bounded on the solid surface by
(a) Chemical force (b) Electrostatic force
(c) Gravitational force (d) Van der Waal force

Group – B

2. (a) CO_2 and O_2 experience equimolal counter diffusion in a circular tube whose length and diameter are 1m and 50mm respectively. The total pressure is 10atm and temperature is 25°C. The ends of the tube are connected to large chambers in which the species concentration are maintained at fixed values. The partial pressure of CO_2 at one end is 190mm of Hg and at the other end 95mm of Hg.
(i) Estimate the rate of mass transfer.
(ii) Find the partial pressure of CO_2 at 0.75m from the end where the partial pressure is 190mm of Hg. $D_{AB} = 2.1 \times 10^{-5} m^2/s$.

(b) Derive a relationship between overall mass transfer coefficients and local mass transfer coefficients.

(c) What is the significance of varying the slope of the operating line in gas absorption?

7 + 3 + 2 = 12

3. (a) Diffusivity of chloroform at 298K and 100kPa is measured in an Arnold cell. Chloroform surface was initially at a height of 50mm from the top and after 10hrs the liquid surface dropped by 6.3mm. The concentration of chloroform at the surface of the tube is negligible and at the liquid surface, air is saturated with chloroform vapours. If the liquid density is 1485kg/m^3 and the vapour pressure at 298K is 26kPa, determine the diffusivity of chloroform in air.

(b) Ammonia is diffusing through a uniform tube 0.1m long containing nitrogen gas maintained at 298K and 100kPa pressure. At the one end of the tube, the partial pressures of ammonia is 10kPa and the other end 5kPa, respectively. The diffusivity of ammonia in nitrogen is $2.33 \times 10^{-5} m^2/s$. Calculate the molar flux of ammonia.

6 + 6 = 12

Group – C

4. (a) Derive the Raleigh equation for batch distillation.

   (b) Write short note on extractive distillation.

6 + 6 = 12

5. A feed mixture containing 40% benzene and 60% toluene (by wt) is fed to distillation column at a flow rate of 30,000 kg/hr. The overhead product contains 97% benzene (by wt) and bottom product contains 98% toluene (by wt). If the reflux ratio is maintained at 3.5, then
   (i) Calculate the moles of overhead product and bottom product produced per hr.
   (ii) Number of plated required when feed is liquid at temperature 20°C.
   Provided:
   Feed boiling point temperature is 95°C at 1 atm pressure
   Ave. Molecular weight of feed is 86.4
   Relative volatility of benzene with respect to toluene (α) is 2.5
   Molar latent heat of feed (λ) is 89.7 cal/gm
   Specific heat of feed (Cp) = 0.44 Cal/g^{o}C.

(4 + 8) = 12

Group – D

6. (a) Under the constant drying condition, a wet solid is dried from 30% to 4 % (on dry basis). The time taken is 4 hrs. The equilibrium moisture content is 2% (on dry basis). Critical moisture content is 10% (on dry basis). How long will it take to dry to 7% (on dry basis)? Assume falling rate is linear.

   (b) Write short note on:
   (i) Adsorption isotherm (ii) Theory of crystallization.

6 + (3 + 3) = 12

7. (a) An inlet water solution of 100 kg/hr containing 0.01 wt fraction nicotine in water is stripped with a kerosene stream of 200 kg/hr containing 0.0005 wt fraction nicotine in a countercurrent process.

The water and kerosene are essentially immiscible with each other. It is desired to reduce the concentration of exit water to 0.0010 wt fraction nicotine. Determine the wt fraction of nicotine in exit kerosene stream.

(b) Explain the breakthrough curve of adsorption system.

8 + 4 = 12

Group – E

8. (a) In a cross flow ultra filtration system used for filtration of proteins from a fermentation broth, gel resistance increases with protein concentration according to the following equation:
   $R_G = 0.5 + 0.01C$, where C is in mg/L.
   Pressure at the entrance system is P_i = 6atm and at the exit is P_0 = 2atm. The shell side of the filter is open to the atmosphere, resulting in P_f = 1atm. The membrane resistance is R_M = 0.5 atm/(mg/m^2 .h), and the protein concentration in the broth is C = 100mg/L. Determine:
   (i) The pressure drop across the membrane
   (ii) Filtration flux
   (iii) Rejection coefficient of the membrane for effluent protein concentration of C_i = 5mg/L.

   (b) Write a note on any one membrane separation process applied in biotechnology.

6 + 6 = 12

9. Experiments at 25°C were performed to determine the permeabilities of a cellulose-acetate membrane. The laboratory test section shown in figure has membrane area $A = 2.00 \times 10^{-3} m^2$. The inlet feed solution concentration of NaCl is C_1 = 10.0kg NaCl/m^3 solution (10.0g NaCl/L, ρ_1 = 1004 kg solution/m^3). The water recovery is assumed low so that the concentration C_1 in the entering feed solution flowing past the membrane and the concentration of the exit feed solution are essentially equal. The product solution contains C_2 = 0.39 kg NaCl/m^3 solution (ρ_2 = 997 kg solution/m^3) and its measured flow rate is 1.92×10^{-8} m^3 solution/s. A pressure differential of 54.42 atm is used. Calculate the permeability constants of the membrane and the solute rejection R. (Given π = 7.48 atm).

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