

**TRANSFER OPERATION 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) _____ is concerned with the adsorption equilibria.
(a) Fick's law (b) Gibb's equation
(c) Freundlich equation (d) none of these.
- (ii) For a fixed number of ideal stages in a distillation column, as the reflux ratio is increased, the difference in composition between the top and bottom product streams
(a) decreases (b) increases
(c) remains unaffected (d) passes through a maximum.
- (iii) During constant rate drying period, vaporisation rate per unit drying surface area
(a) increases with time
(b) decreases with time
(c) does not change with time
(d) does not affect the moisture content of the wet solid.
- (iv) 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.
- (v) Plate efficiency
(a) is a function of the mass transfer between liquid and vapour.
(b) increases due to foaming.
(c) increases due to liquid entrainment.
(d) increases due to weeping and dumping of liquid.

- (vi) Which of the following is not a membrane separation process?
(a) Ultra-filtration (b) Chromatography
(c) Flash distillation (d) Pervaporation.
- (vii) Molecular diffusion induced by temperature is
(a) eddy diffusion (b) thermal diffusion
(c) forced diffusion (d) none of the above.
- (viii) In absorption minimum operating line
(a) touches the equilibrium line
(b) has a slope of $(L/V)_{\min}$
(c) shows the maximum possible liquid concentration
(d) all the above.
- (ix) Diffusivity of a liquid is 5 to 6 orders less than that of a gas because
(a) diffusion of liquids occur by random motion of molecules.
(b) average distance travelled by liquid molecules is less than their molecular diameter.
(c) mean free path travelled by a gas is less than that of a liquid molecule.
(d) none of the above.
- (x) Separation of inorganic salts of low molecular weight is done by
(a) Reverse osmosis (b) Ultra-filtration
(c) Dialysis (d) Electrophoresis.

Group - B

2. A tray tower is to be designed to absorb SO₂ from an air stream by using pure water at 293K. The entering gas contains 20mol% SO₂ and that leaving gas contains 2mol% SO₂ at a total pressure of 101.3kPa. The inert air flow rate is 150kgair/h.m², and the entering water flow rate is 6000kg water/h.m². Assuming an overall tray efficiency of 25%, how many theoretical trays are needed? What should be the number of trays actually to be employed? Assume the tower to operate at 293K and equilibrium relationship is given by $y^* = 20x$.

12

3. (a) CO₂ and O₂ experience equimolar 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 CO₂ 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 CO₂ at a distance 0.75m from the end where the partial pressure is 190mm of Hg. $D_{AB} = 2.1 \times 10^{-5} \text{m}^2/\text{s}$.
- (b) Diffusivity of CCl₄ through O₂ is determined in a steady state evaporating cell. The cell having cross sectional area 0.82cm². It was operated at 273K and 755mm Hg. The average length of diffusion path was 17.1cm. If 0.0208cm³ of CCl₄ was evaporated in 10h of steady state operation, what should be the value of diffusivity of CCl₄ through O₂. Vapour pressure of CCl₄ at 273K = 33mm Hg.

7 + 5 = 12

Group - C

4. A batch of solid for which the following table of data applies, is to be dried from 25% to 6% moisture under conditions identical to those for which the data were tabulated. The initial weight of the wet solid is 300 kg and the drying surface is 1 m²/8 kg dry weight. Determine the time for drying.

X (kg moisture/ kg dry solid)	0.35	0.25	0.20	0.18	0.16	0.14	0.12	0.10	0.09	0.08	0.064
R (kg moisture evaporated / hr.m ²)	0.3	0.3	0.3	0.266	0.239	0.208	0.18	0.15	0.097	0.07	0.025

12

5. A bubble cap fractionating column consisting of 12 plates working at an average efficiency of 75% is being used to distill 1000 kg/hr of aqueous methanol at its bubble point entering the tower. The feed, overhead product and bottom product are 50 mol%, 90 mol% and 10 mol% methanol, respectively. A total condenser is provided. The operating reflux ratio is 1.7 times of the minimum reflux ratio. Check, whether the column available is satisfactory or not. VLE data are:

x	0.08	0.1	0.2	0.3	0.4	0.5	0.7	0.8	0.95
y	0.365	0.418	0.579	0.665	0.729	0.779	0.87	0.958	0.975

12

Group - D

6. It is desired to separate by distillation a mixture of 42 mol% heptane and 58 mol% ethyl benzene to produce a distillate containing 97 mol % heptane and a residue containing 99 mol % ethyl benzene.
- (i) Using a reflux ratio of 2.5 determine the number of equilibrium stages needed for a saturated liquid feed by McCabe Thiele method.
 - (ii) Determine the minimum reflux ratio.

The vapour liquid equilibrium data for heptanes-ethyl benzene system is

x	0	0.08	0.185	0.251	0.335	0.489	0.651	0.788	0.914	1.0
y	0	0.233	0.428	0.514	0.608	0.729	0.814	0.904	0.963	1.0

9 + 3 = 12

- 7. (a) Derive Raleigh equation for Batch distillation.
- (b) Describe the function of packed type extraction tower.

6 + 6 = 12

Group - E

8. Experiments at 25°C were performed to determine the permeabilities of a cellulose-acetate membrane. The laboratory test section has membrane area $A = 2.0 \times 10^{-3} \text{m}^2$. The inlet feed solution concentration of NaCl is $C_1 = 10 \text{kg NaCl/m}^3$ solution (density = 1004kg solution/m³). 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 $C_2 = 0.39 \text{kg NaCl/m}^3$ solution (density = 997kg solution/m³) and its measured flowrate is $1.92 \times 10^{-8} \text{m}^3 \text{ solution/s}$. A pressure differential of 54.42 atm is used. Calculate the permeability constants of the membrane and the solute rejection $R(\pi = 7.48 \text{ atm})$.

12

- 9. (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 $P_1 = 6$ atm and at the exit is $P_0 = 2$ atm. The shell side of the filter is open to the atmosphere, resulting in $P_f = 1$ atm. The membrane resistance is $R_M = 0.5$ atm / (mg/m².h), and the protein concentration in the broth is $C = 100$ mg/L. Determine:

- (i) The pressure drop across the membrane
 - (ii) Filtration flux
 - (iii) Rejection coefficient of the membrane for effluent protein concentration of $C_i = 5$ mg/L.
- (b) Write short notes on any two membrane separation process applied in biotechnology.

6 + 6 = 12