Name : ....

Roll No. : ....

Invigilator's Signature : ....

CS/B.TECH (CHE)/SEM-7/CHE-704E/2012-13

2012

ADVANCED SEPARATION PROCESS

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.*

GROUP – A

(Multiple Choice Type Questions)

1. Choose the correct alternatives for any *ten* of the following :

$10 \times 1 = 10$

    i)   If the refection coefficient is zero, an osmotic membrane is

        a)   fully permeable

        b)   impermeable

        c)   partially permeable

        d)   no concentration polarization.

ii) The pressure range of operation of ultrafiltration is

   a)   0·1 - 1 bar   b)   1 - 10 bar

   c)   2 - 10 bar   d)   10 - 20 bar.

iii) In membrane filtration solute molecules are carried to the membrane surface by

   a)   Knudsen diffusion   b)   Fickian diffusion

   c)   Convective diffusion   d)   both (b) and (c).

iv) Which of the following problems are typical for a cellulose acetate membrane used for reverse osmosis ?

   a)   Concentration polarization

   b)   Biological attack

   c)   Hydrolysis under acidic or alkaline condition

   d)   Attack by free chlorine that may be present in water.

v) A hollow-fibre membrane with isotropic dense wall is suitable for

   a)   microfiltration   b)   ultrafiltration

   c)   reverse osmosis   d)   pervaporation.

vi) Polysulfone membrane at room temperature is a.............. type.

    a) rubbery   b) glassy

    c) crystalline   d) none of these.

vii) Pervaporation is an advanced separation process involving

    a) liquid-liquid system

    b) phase change in separation

    c) liquid-solid system

    d) gaseous system.

viii) The driving force for dialysis is

    a) pressure gradient

    b) concentration gradient

    c) both (a) and (b)

    d) none of these.

ix) Polyvinyl alcohol membrane is

    a) hydrophilic   b) hydrophobic

    c) both (a) and (b)   d) none of these.

x) Crystallinity in polymer generally tends to

    a) reduce permeability   b) increase permeability

    c) remains unaffected   d) cannot be determined.

xi) In case of cross flow model during gas permeation through membrane the feed side is assumed to be in

a) mixed flow b) plug flow

c) cannot be predicted d) none of these.

xii) During .... , there is a temperature drop at membrane surface.

a) dialysis b) gas permeation

c) microfiltration d) pervaporation.

GROUP – B
(Short Answer Type Questions)

Answer any *three* of the following 3 × 5 = 15

2. Develop a mathematical model for competitive facilitated transport through liquid membrane with two permeant and one carriers.

3. Discuss different types of conventional membrane module mentioning their major advantages.

4. What is pervaporation ? Write down the factors affecting the membrane performance during pervaporation. 2 + 3

5. A membrane process is being designed to recover solute *A* from a dilute solution of concentration $2 \cdot 1 \times 10^{-2}$ kg mol A/m^3 by dialysis through a membrane to a solution having concentration $0 \cdot 3 \times 10^{-2}$ kg mol A/m^3. The membrane thickness is $1 \cdot 59 \times 10^{-5}$ m, the distribution coefficient K' is 0·77 and diffusivity of the solute is $3 \cdot 512 \times 10^{-11}$ m^2/s in the
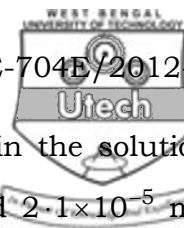
membrane. If the mass transfer coefficient in the solutions across the membrane are $3 \cdot 6 \times 10^{-5}$ m/s and $2 \cdot 1 \times 10^{-5}$ m/s respectively, calculate the total resistance and steady state flux.

6. Write down the basic mechanism of gas sorption and permeation in a polymer. What is permeability ? 3 + 2

GROUP – C

(Long Answer Type Questions)

Answer any *three* of the following. 3 × 15 = 45

7. a) Discuss different types of models of transport during reverse osmosis. Discuss the application of reverse osmosis process.

   b) Experiments at 25°C were performed to determine the water permeability and salt (NaCl) rejection of a cellulose acetate membrane. The membrane area is 2×10^{-3} m². The inlet salt concentration is 10 kg NaCl/m³ of solution. The water recovery is low so that the salt concentration in the entering and exit feed solutions are assumed to be equal. The product solution contains 0·4 kg NaCl/m³ of solution and the flow rate is 2×10^{-9} m³ solution/s. A pressure differential of 55 atm is used. Calculate : (i) Solute rejection and (ii) Permeability coefficient of the membrane.

   (5 + 3) + (4 + 3)

8. a) What is concentration polarization ? Determine an expression of solvent flux according to concentration polarization model during ultrafiltration.

   b) An Ovalbumin solution having molecular weight of 500 Da and concentration 1 mass% is passed through a tubular UF membrane module of 1 cm internal diameter and 100 cm long at a temperature of 25°C. Membrane water permeability is $85 \cdot 85 \times 10^{-3}\,m^3/m^2$ day psi. Rejection coefficient is 0·995, applied pressure difference 2·0 bar; solute diffusivity, $8 \times 10^{-11}\,m^2/s$. Calculate the flow velocity to be maintained in the tube in order to prevent gel layer formation on the membrane surface.   (2 + 6) + 7

9. a) A mixture of 10% CO_2 (A) 90% CH_4 (B) is to be separated at a rate of 90 m^3/h (STP) in a membrane permeator with well-mixed compartments to reduce the CO_2 content to 3·5%. An asymmetric cellulose acetate membrane with 0·15 µm skin layer is to be used. Given the following data, calculate the product rate, the mean product composition.

   [Data : Upstream pressure = 24 atm; downstream pressure = 1·4 atm; ideal separation factor = 32; permeability of CO_2 in the membrane = 4·75 barrer; temperature = 35°C.]

   b) Derive the equation used.
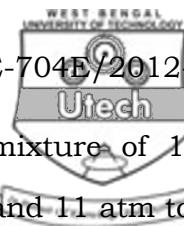
c) Selective permeation of CO_2 from a mixture of 12% CO_2(A) and 88% CH_4(B) occurs at 38°C and 11 atm total pressure in a small apparatus with a well-mixed feed compartment. An asymmetric polysulphone membrane of 1 micron skin layer thickness is used. The permeate side is continuously swept with nitrogen gas. Calculate the flux of CO_2.

[Given : Permeability of CO_2 = 5·6 barrer.]   12 + 3

10. a) Pervaporation experiment was conducted at a feed temperature of 60°C for a permeate pressure of 76 mm Hg to separate the component of ethanol(1)-water(2) binary solution. At 60°C, vapour pressures are 352 and 149 mm Hg for ethanol and water respectively. At a particular time the 1·73 kg/m^2.h permeate flux was obtained while ethanol concentration were reported to be 36 wt% and 23 wt% in feed side liquid and in permeate vapour respectively. Liquid phase activity coefficient at 60°C for the system are given by :

$$ln\, \gamma_1 = 1 \cdot 627 \left[\frac{0 \cdot 923 x_2}{1 \cdot 627 x_1 + 0 \cdot 923 x_2} \right]^2$$

$$ln\, \lambda_2 = 0 \cdot 923 \left[\frac{1 \cdot 627 x_1}{1 \cdot 627 x_1 + 0 \cdot 923 x_2} \right]^2$$

Calculate the permeance of water and ethanol.

b) Write down the application of pervaporation.   10 + 5

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