Ref. No. Ex/CHE/ T/415C/2017

BACHELOR OF CHEMICAL ENGINEERING EXAMINATION, 2017
(4th Year, 1st Semester)
MODERN SEPARATION PROCESSES

Use Separate answer script for each part

Time: 3 Hr. **Full Marks: 100**

Answer any **four**
Assume any **missing** data

1.

a) Explain the mechanism of 'Reverse Osmosis' process in light of "Solution-Diffusion" model for membrane transport.

b) How the ultra filtration membranes are characterized based on their MWCO?

c) A membrane is to be used to separate a gaseous mixture of A and B whose feed flow rate is $1x10^4$ cm^3 (at STP)/s and feed composition of A is 0.5 mole fractions. The desired composition of the reject is 0.25 mole fraction. The membrane thickness is $2.54x10^{-3}$ cm, the pressure on feed side is 80 cm Hg and pressure on permeate side is 20 cm Hg. The permeabilities are:

$(P_M)_A = 50x10^{-10} cm^3(STP).cm/s\text{-}cm^2\text{-}cm\ Hg$

$(P_M)_B = 5x10^{-10} cm^3(STP).cm/s\text{-}cm^2\text{-}cm\ Hg$

Assume complete mixing model, derive the expression for permeate composition & reject concentration and calculate the values of permeate composition, fraction permeated and membrane area.

7+3+15

2.

a) How the 'maximum capacity' and 'molar selectivity coefficient' is determined for an ion-exchange resin?

b) Design an RO module for production of pure water by rejection of salt in terms of fractional rejection of salts and fractional recovery of water.

Design a RO module for 1500 m^3/day potable water containing not more than 250 ppm salt from sea water containing 34 g salt per litre. A proprietary asymmetric cellulose acetate membrane with an inherent salt rejection ability of 98% is to be used. The water permeation coefficient is 0.043 m^3/m^2.day.atm. The recovery of feed water should be 35% and an operating pressure of 70 atm gauge is suggested. The permeate side is at essentially atmospheric condition. If spiral wound modules of 5 m^2 effective membrane area each is used, how many modules in parallel are required? What fraction of the input power can be recovered from the retentate if a turbine of 70% efficiency is used for energy recovery? The osmotic pressure of 5% brine (linear in salt concentration) is 39.5 atm.

c) At complete rejection condition, show that concentration polarization modulus, $(C_m/C_b) = \exp(J_w/k_l)$, where;

C_m = solute conc. at membrane
C_b= solute conc. in bulk solution
J_w = volumetric solvent flux
k_l= liquid phase mass transfer coefficient

6+(8+7)+4

3.

a) Reverse osmosis plants operate at relatively high pressure. Why?

b) Describe the Resistance Model to interpret flux behavior in ultra filtration process with variation of applied pressure and also limiting flux attained by the module.

c) An amberlite IR-120 ion-exchange resin with maximum ion-exchange capacity of 2.3 eq/L of bed, is used to remove cupric ion from a waste stream containing 19.5 meq Cu^{2+}/L solution. The equilibrium ion-exchange reaction is of the divalent-monovalent type. The equilibrium data for the cupric ion with a 19.5 meq/liter solution:

c, meq Cu^{2+}/L solution	0.022	0.786	4.49	10.3
q, meq Cu^{2+}/g resin	0.66	3.26	4.55	4.65

For each data compute the molar selectivity coefficient and compare it with that obtained from individual relative molar selectivity of cation and anion.

Relative molar selectivity for Cu^{2+} with 8% cross-linked strong acid resin: 3.8

Relative molar selectivity for H^+ with 8% cross-linked strong acid resin: 1.3

d) Dialysance and clearance are the indicators of the performance of a dialyser. Discuss these two terms.

4+8+7+6

4.

a) What is Gibbs-Donnan effect in hemodialysis process?

b) Discuss how uranium isotopes are separated based on gaseous diffusion principle.

c) A gas mixtute having 20% A and 80% B is to be separated in a cross flow separator using asymmetric membrane of 0.2 micron active layer. The permeability of A is 7.2 barrer and its ideal separation factor with respect to B is 5. The gas on the feed side is in cross flow, permeate flows normal to the membrane surface and get mixed up at the exit only. A stage cut of 30% is suggested. The feed rate is 200 m^3/h(STP) and the constant upstream and downstream pressures are 22 atm, 1.1 atm. Calculate the average permeate composition and membrane area required.

5+5+15

5.

a) The ideal separation factor of B over A for diffusion through a polymer film is $\alpha_{BA}^{*} = 4.5$. The permeability of A is 3 barrer. What is the permeability of B?
b) Compare Knudsen diffusion and molecular diffusion in case of gaseous transport.\
c) A commercial, ion-exchange resin is made 88 wt% and 12% divinyl benzene. Estimate the maximum ion exchange capacity in eq/kg resin.
d) What are the special features of pervaporation process with respect to other membrane separation processes?

e) A dialyser unit has to be designed, the area of which is 1.2 m^2. There are a total of 5000 fibres having diameter 300m. the overall mass transfer coefficient is 1.3×10^6 m/s. the wall thickness of the fibres is rather small and the flow rate of dialysate is much larger than that of blood. If the extraction ratio of 0.85 is achieved in the dialyser, calculates its HTU.

Extraction ratio, $E = \frac{C_{bi} - C_{bo}}{C_{bi}} = 1 - e^{-N_T} = 0.85$

4+4+6+3+8