Ex/PG/ChE/T/129B/2018

M.E. CHEMICAL ENGINEERING FIRST YEAR SECOND SEMESTER - 2018

MEMBRANE SCIENCE & ENGINEERING

Time: Three hours | Full Marks: 100

Answer __any four__ questions. All questions carry equal marks.
All the symbols have their usual meaning
Assume any missing data

1. a) How can you distinguish between a homogeneous membrane and asymmetric membrane? Write the merits and demerits of both these types of membranes.
   b) Derive the basic equation for concentration polarization model. What are the main assumptions that you have used in deriving the final equation?
   c) What are the parameters used for characterization of a membrane supposed to be used for pressure-driven applications, such as reverse osmosis, ultrafiltration, etc? What do you mean by solution diffusion model?
   d) Write in details the methodologies used for determination of those membrane parameters based on experimental studies. Write all the steps clearly. Is it necessary to determine the membrane surface concentration in the process? Explain.
   e) What do you mean by MWCO of a membrane? What is sharp cut-off membrane? How can you quantify the membrane based on pore-size distribution?

5×5 = 25

2. a) How does the hydrophobicity/ hydrophillicity of a membrane affects its selection for use for a particular task. Explain with an example.
   b) What are the differences between the electrodialysis and dialysis from operational point of view?
   c) Derive the Leveque solution for flow through a thin channel from theoretical point of view under the condition of no wall suction, starting from the basic convective-diffusion equation of the form: $u\frac{\partial c}{\partial x}+v\frac{\partial c}{\partial y}=D\frac{\partial^2 c}{\partial y^2}$
   d) Cite examples of some applications where pervaporation is more effective than other membrane separation processes.

5+5+10+5 = 25

3. a) What are the typical characteristics of a membrane intended to be used for gas separation (say, helium recovery from natural gas)?
b) What is Darcy's law? Is it valid for solution? Explain.
c) Derive the basic transport model for cross-flow gas permeation.
d) How can you evaluate membrane performance using solution diffusion model for the case of RO/NF.

5+5+10+5 = 25

4. a) Consider the following data, which was obtained during ultrafiltration (UF) of a solute in a stirred dead-end module. The solute concentration was fixed in all the runs at 0.5 kg/m^3 and trans-membrane pressure at 138 kPa.

Run No.	Permeate concentration, c_p, kg/m^3	Stirrer speed, rpm	Permeate flux, $m^3/m^2.s \times 10^6$
1.	0.04	80	4.4
2.	0.02	100	6.8
3.	0.01	120	8.0
4.	0.006	150	8.8

Use Velocity-variation technique to find the mass-transfer coefficient and membrane surface concentration for each of the above runs.
b) What are the main postulates of pore-plugging theory? (You need not derive any equation, only cite the basic presumptions)

17+8=25

5. a) It is known that in any pressure-driven membrane separation process, concentration polarization is inhabitable and a highly undesirable phenomenon. How can you minimize the effects of concentration polarization by modifying the module design and/or flow configuration?

b) The performance of an *osmotic pressure controlled ultrafiltration* is investigated. The pure distilled water flux is found to be 5.2×10^{-5} $m^3/m^2.s$ at 276 kPa and 1.1×10^{-4} $m^3/m^2.s$ at 552 kPa pressure. Under high stirring speed and at 138 kPa pressure and for 5.0 kg/m^3 solute concentration, the permeate concentration is obtained as 0.4 kg/m^3. The osmotic pressure of the solute is given as, $\pi = 37.5\times10^2 c + 10c^2$, where, π is in Pa and c is in kg/m^3. The solution viscosity and density may be assumed to be those of water. Find permeate flux and membrane surface concentration. If necessary, you can assume mass transfer coefficient to be 6.82×10^{-7} m/s.

8+17 = 25

6. a) Consider the ultrafiltration of milk at 50°C. The important physical properties are: density (ρ) = 1.03gm/cm^3, viscosity = 0.8cp, diffusivity = 7×10^{-7} cm^2/s, protein content of milk (bulk concentration, C_B) = 3.1% w/v and gel concentration (solubility limit, C_g) is 22% w/v. Calculate the flux expected from a hollow fiber and the tubular unit with the specification given below (assume total rejecting membrane, i.e. $C_p = 0$):

	Hollow fiber	Tubular
Diameter (d_h), cm	0.11	1.25
Length (L), cm	63.5	240
No of fibers or tubes	660	18
Fluid velocity in each tube, m/s	1.0	2.0
Pressure drop across membrane, kg/cm^2	0.9	2.0

<u>Hint</u>: use following correlation for mass transfer coefficient:
For turbulent region (Re > 4000)
$Sh = 0.023(\text{Re})^{0.8}(Sc)^{0.33}$

For laminar region (Re< 1800)
$Sh = 1.86(\text{Re})^{0.33}(Sc)^{0.33}(d_h / L)^{0.33}$ (This is Leveque equation)

b) Write down the systematic procedure fr evaluation of membrane performance when the osmotic pressure model is valid. Derive all the necessary equations. Derive the expression of the permeate flux under the condition of low polarization and $C_p=0$ i.e. perfectly rejecting membrane, assuming osmotic pressure can be calculated by an equation of the form $\pi = bC$.

15+10 = 25