M.E. CHEMICAL ENGINEERING 1ST YEAR 2ND SEM. EXAMINATION, 2017

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) What are the factors on which the selectivity of membrane depends?

   b) What do you mean by molecular weight cut-off (MWCO) of a membrane? Can all the membranes be classified based on the concept of MWCO?

   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?

   d) How can you distinguish between a homogeneous membrane and asymmetric membrane?

   e) Derive the basic equation for concentration polarization model. What are the main assumptions those you have used in deriving the final equation?

   5×5 = 25

2. a) How does the hydrophobicity/ hydrophillicity of a membrane affect its selection for its use in a particular task? Explain with an example.

   b) What are the main applications of the nanofiltration (NF) process? Cite few applications where NF could be highly beneficial over the other pressure-driven membrane separation process.

   c) What are the differences between the electrodialysis and dialysis from operational point of view?

   d) How can you measure the membrane hydraulic resistance (or, solvent permeability) in a pressure-driven membrane separation process, such as ultrafiltration?

   5 + 7 + 5 + 8 = 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) Explain the operational principles of liquid membranes.

d) Consider separation of 10kg/m^3 concentration of a protein solution using ultrafiltration. Filtration is gel layer controlled, with gel concentration 300 kg/m^3. Filtration takes place in a thin channel with equivalent diameter 2 mm and width 4 cm. The cross flow velocity is 0.5 m/s and protein diffusivity is 2 x 10^{-11} m^2/s. If the filtrate rate is 100 L/day, find the length required of the membrane module.

Use the following correlations to estimate mass transfer coefficient, which is valid for laminar flow:

$$Sh = 1.86\left(\mathrm{Re}\,Sc\,\frac{d_e}{L}\right)^{\frac{1}{3}}$$

5 + 5 + 5 + 10 = 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 1.5 kg/m^3 and trans-membrane pressure at 178 kPa. Use **Velocity-variation technique** to find the mass-transfer coefficient and membrane surface concentration for each of the above runs.

Run No.	**Permeate concentration, c_p, kg/m^3**	**Stirrer speed, rpm**	**Permeate flux, m^3/m^2.s × 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

b) What are the main postulates of surface force-pore flow model? (You need not write/derive any equation, only cite the basic presumptions)

c) What are the main advantages of the hollow-fiber membrane over the spiral-wound membrane module?

15+5+5=25

5. a) How can you determine membrane parameters σ and P_m by **modified Nakao & Kimura method**, which is generally implemented in "Pore plugging model"? Write down all the relevant equations and describe the algorithm (preferably in the form of flow chart).

b) How can you determine the ultrafiltration performance (flux and rejection) for a system obeying osmotic pressure model? Assume that the osmotic pressure of the solute can be correlated by a virial equation of the form $\pi = B_1C + B_2C^2 + B_3C^3$, where B_1, B_2 and B_3 are virial coefficients and c the solute concentration. Describe all the equations, and write down the algorithm (preferably in the form of flow-chart) to determine flux and rejection.

c) 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?

10 + 10 + 5 = 25