Ref. No. : Ex/ChE/T/411/2018

B.E. CHEMICAL ENGINEERING FOURTH YEAR FIRST SEMESTER - 2018

SEPARATION PROCESSES-III

Time: Three hours Full Marks: 100

*Answer **any five** questions.*

1. Answer in brief the following questions (any ten)

   a) On what factors, does the selectivity of a membrane depend?
   b) How can you distinguish between a homogeneous membrane and asymmetric membrane? Write the merits and demerits of both these types of membranes.
   c) How does the hydrophobicity/ hydrophillicity of a membrane affects its selection for use for a particular task. Explain with an example.
   d) What do you mean by molecular weight cut-off (MWCO) of a membrane? What is sharp cut-off or wide cut-off membrane?
   e) What are the basic transport mechanisms for solvent or solute flow through solid/liquid membranes?
   f) What are the main limitations of the membrane separation process?
   g) What is Darcy's law? Is it valid for solution? Explain.
   h) What do you mean by retention coefficient and reflection coefficient? Is there any relation between these two parameters?
   i) Why the sea water desalination process by membrane technology is known as "reverse osmosis"? Explain.
   j) What do you mean by concentration polarization in membrane process? Do you observe this phenomenon during electrodialysis?

10×2 = 20

2. (a) What are the parameters used for characterization of a membrane supposed to be used for pressure-driven applications, such as reverse osmosis, ultrafiltration, etc?

   (b) 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.

10+10= 20

3. (a) Derive the basic transport equation for a pressure-driven membrane separation process? What are the initial and boundary conditions for the above equation?

   (b) What are the problems associated with the analytical solution of the above equation, in contrast with the corresponding heat conduction equation? How can you tackle such problems while solving the resultant convective-diffusion equation in case of solute transport through membranes?

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

8+5+7 = 20

4. (a) What do you mean by "Volume concentration factor (VCF)"? How can you correlate the VCF to the final solute concentration in the retentate? Derive the relevant equation(s).

   (b) Under what practical circumstances, will you prefer diafiltration operation? What do you mean by discontinuous diafiltration (DD) and continuous diafiltration (CD)? Draw the typical flux-time profile for both the DD and CD. Explain the nature of the resultant curves.

10+10 = 20

5. A benzene-toluene cut at its bubble point, containing 65mole % benzene and 35mole % toluene is to be fractionated at 8 bar pressure to recover toluene of 99.9% purity with a yield of 95% of toluene in the feed. The feed temperature is 436.2K. Assume ideal behavior and use Antoine's equation for VLE calculation.
   i. Determine minimum reflux by Underwood method.
   ii. Determine minimum number of plates at total reflux by Fenske's method.
   iii. Use Gilliland correlation to find actual number of plates at operating reflux ratio $R_{opt} = 1.5R_m$
   iv. Find feed plate location using Kirkbride correlation.

20

6. (a) Without determining bubble point and dew point temperatures, how can you be sure that flash temperature lies within bubble point and dew point temperature of the feed?

   (b) While solving flash equation for ψ (fraction of feed in liquid phase) by NR method, the initial hues is always taken as $\psi_o = 1$. Why?

   (c) Consider a ternary mixture of propane (C_3), n-butane (n-C_4) and n-pentane (n-C_5) with respective molar compositions being 20%, 30% and 50%. This feed stream enters into a flash tower at 80^{o}C. Find the pressure which must be maintained within the flash tower for 70% vaporization. Determine the compositions of the respective streams under this condition. Assume ideal behavior. The equilibrium data are given in table: 1.

5+5+10 = 20

7. (a) For a multicomponent system containing *c* number of components, the flash equation corresponds to a *c*-th degree polynomial, which should possess *c* number of roots. Explain the physical significance of different roots and nature of flash function under different thermal conditions within flash column (i.e. when $T_F > T_{DP}$, etc.).

   (b) A multicomponent feed stream is flashed adiabatically in a flash tower maintained at pressure P_F. The feed temperature is T, molar flow rate F and composition z_{Fi}, (i=1,…,c), where c is the total number of component. All these parameters are supposed to be known. Suggest a suitable method to estimate the required flash temperature (T_F) that has to be maintained within the flash column for the operation to occur adiabatically. Write a complete step-by-step algorithm to solve the above problem.

10+10 = 20

Table: 1

Antoine's constants, vapor pressure in mm Hg and temperature in Kelvin

Component	**A_i**	**B_i**	**C_i**
Ethane (C_2)	15.6637	1511.42	-17.16
Propane (C_3)	15.7260	1872.49	-25.16
n-Butane (n-C_4)	15.6782	2154.90	-34.42
n-Pentane (n-C_5)	15.8333	2477.07	-39.94
n-Hexane (c-C_6)	15.8366	2697.55	-48.78
Benzene	15.9008	2788.51	-52.36
Toluene	16.0137	3096.52	-53.67
Ethyl benzene	16.0195	3276.47	-59.95
Styrene	16.0193	3328.57	-63.72