NOVEL SEPARATION PROCESSES
(CHEN 3232)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) An example of a concentration-driven membrane process is
(a) Reverse Osmosis (b) Ultrafiltration
(c) Haemodialysis (d) Nanofiltration

(ii) The minimum pore size of an ultrafiltration membrane is approximately
(a) 1 μ (b) 10 nm
(c) 100 nm (d) 1 nm

(iii) The cake resistance in microfiltration varies with the particle diameter d as:
(a) Proportional to d^{-2} (b) Inversely proportional to d^{-2}
(c) Proportional to d^{-1} (d) Proportional to d^{-3}

(iv) A membrane separation process that can be used for dehydration of solvents is
(a) Pervaporation (b) Reverse Osmosis
(c) Electrodialysis (d) Microfiltration

(v) A pressure differential of more than 100 bar may be required in
(a) Nanofiltration (b) Pervaporation
(c) Reverse Osmosis (d) Dialysis

(vi) Relative centrifugal force is measured _____
(a) in multiples of standard acceleration due to gravity at the earth's surface
(b) as 0.001118 fold to rotor rpm times of particle distance from the centre
(c) as 0.001118 fold to the square of rotor rpm times of particle distance from the centre
(d) both (a) and (c)

(vii) For diagnostic application the frequency of ultrasound is in the range of _____.
(a) 2-18 MHz (b) 20-30 MHz
(c) 2-18 kHz (d) 20-30 kHz

(viii) Rotation of a molecule can only be happened at _____ energy during electromagnetic frequency corresponds to a wavelength of 12 cm.

(a) 0.094 J/mol (b) 0.94 J/mol
(c) 1.94 J/mol (d) 1.094 J/mol

(ix) The magnetron tube generates microwaves at a fixed frequency of _____

(a) 2405 MHz (b) 2045 MHz
(c) 2450 MHz (d) 2550 MHz

(x) The mixed surfactant system's HLB value is _____ after mixing 5% (v/v) of surfactant A (HLB=16) with the surfactant B (HLB=7)

(a) 7.0 (b) 7.8
(c) 7.6 (d) 7.2

Group – B

2. (a) What are the different configurations of a hollow-fiber membrane? Mention some parameters which can be used to characterize a porous membrane

(b) In the feed to a RO unit, there is 4% NaCl mixed with water. The permeate side is continuously flushed with distilled water to keep the salt concentration zero at the permeate side. The membrane used is a cellulose acetate membrane 13 μ thick. At a transmembrane pressure difference of 80 atm, the water flux J_w is 6.5 μg/cm^{2}s, and the salt flux J_s is 0.015 μg/cm^{2}s at 25°C. The equilibrium water sorption C_w is 0.156 g/cm^3 of the polymer. The equilibrium sorption of NaCl followed Henry's law: $C_s = H_s C_f$, where C_s is expressed as grams of NaCl/cm^3 of membrane, C_f = grams of NaCl/cm^3 of feed solution, H_s = 0.037. The osmotic pressure of 4% NaCl solution is 39 atm. Calculate the diffusivities of water and salt in the given cellulose acetate membrane.

(3 + 3) + 6 = 12

3. (a) Differentiate between a **sharp** and **diffuse** molecular weight cutoff for UF membranes.

(b) A 0.02 molar feed solution is to be concentrated to a 0.1 molar solution by a batch UF process. The solute rejection is 95% and the effect of concentration polarization can be neglected. If the upstream gauge pressure is 3.5 atm and the downstream side is at atmospheric pressure, calculate the ratio of the pressure driving forces at the beginning and end of the process. Also estimate the fractional reduction in solvent flux at the end of the process.

4 + 8 = 12

Group – C

4. (a) In a patient with acute kidney failure, a haemodialyser is used to purify blood. Blood from the patient's body is pumped through a concurrent haemodialysis unit at 300 ml/min and the blood urea concentration is reduced from 220 mg% to 20 mg%. The available membrane area is 1.25 m^2 and the overall mass

transfer coefficient is estimated to be 1.2×10^{-6} m/s. The volume of blood in the patient's body can be taken as approximately 5 liter. If the dialysate flowrate is maintained at a very high value, estimate the time required for dialysis. Assume the dialysate fluid to be solute- free.

(b) What are some membrane materials that can be used for pervaporation process? Mention some industrial applications of pervaporation.

8 + (2 + 2) = 12

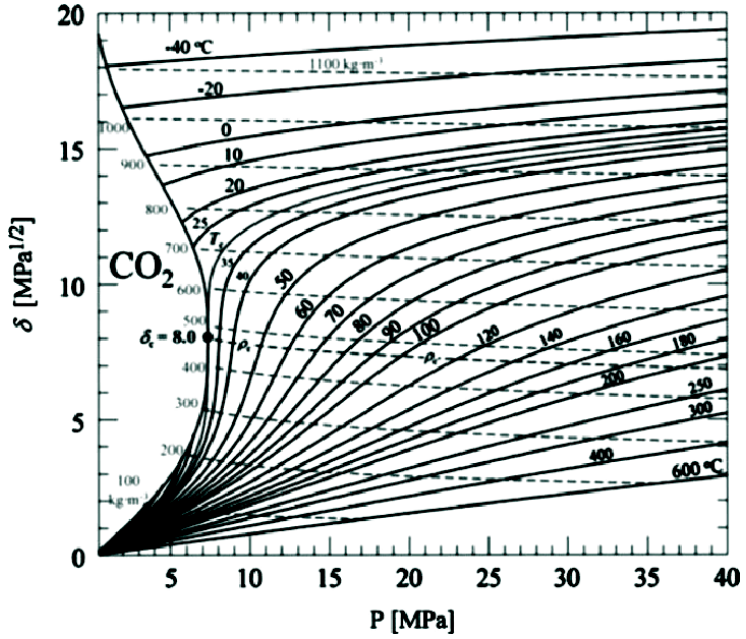
5. (a) Selective permeation of CO_2 from a mixture of 10% CO_2 (A) and 90% CH_4 (B) occurs at 35°C and 10 atm pressure in a small apparatus with a well-mixed feed compartment. An asymmetric polysulphone membrane of 1 μm thickness is used. The permeate side is continuously swept with Nitrogen gas. The following data are given:
α_{AB} = 22, Henry's law constant for CO_2 solubility in polysulphone at 35°C = 2.1, permeability of CO_2 = 5.6 barrer. Calculate the CO_2 flux, its average diffusivity in polysulphone and the permeance of methane in polysulphone.

(b) Explain the principles and application of gel-permeation chromatography.

8 + 4 = 12

Group – D

6. (a) During an extraction process using supercritical CO_2 the temperature was maintained at 45°C, while the pressure was elevated to 20 MPa from 8 MPa. The critical pressure for supercritical CO_2 is 7.6 MPa. Find how much fold increase in Hildebrand solubility parameter and density has been made once the pressure was enhanced to 20 MPa from 8 MPa (Use the following figure).



(b) A viscous solution containing particles with a density 1461 kg/m^3 is to be clarified by centrifugation. Based on the below information (i) comment on the feasibility of the separation of the particles and (ii) find out the residence time required for the separation.

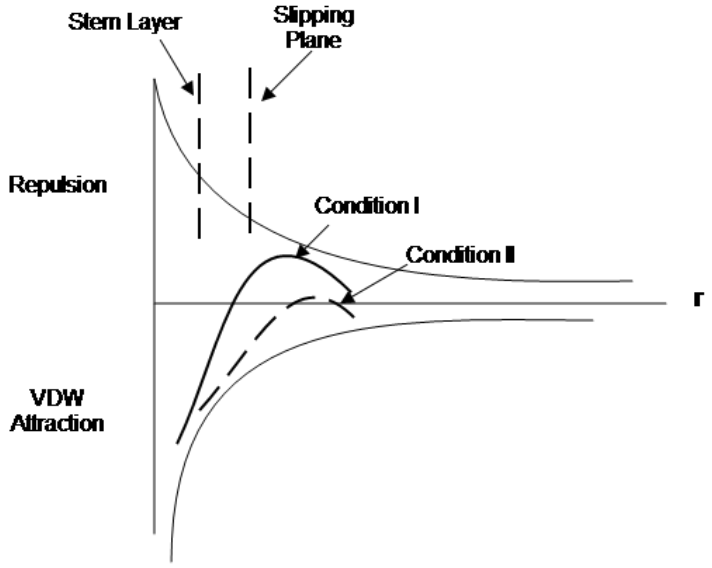
Given: Solution density = 801 kg/m^3; Viscosity = 0.1 Pas; Average particle diameter = 0.6 μm; Rotor rpm = 10000 rpm; RCF = 1118g; Height of the liquid column = 0.2 m; Radius of the centrifuge bowl = 0.02 m; Volume of the liquid column = 0.00021 m^3.

(3 + 3) + (2 + 4) = 12

7. (a) "In case with the supported liquid membrane (SLM) the diffusivity of the solutes within the membrane is somehow being retarded compared to the diffusivity within bulk liquid membrane." – Justify the appropriateness of the statement.

(b) In case with the supported liquid membrane, show that at steady state condition the solute concentration difference between the membrane and the feed can be given by $\Delta C = \alpha_S \left[E_{e(max)} C_f - C_S \left(\frac{K_S}{K_M} \right) \right]$, where α_S is the fraction of the solute transported that is extractable from strip phase, C_f is the feed side concentration of solute, C_S is is the strip side concentration of solute, K_S is the partition coefficient between strip and membrane phase, K_M is the partition coefficient between feed and membrane phase and $E_{e(max)}$ is the maximum concentration enrichment factor.

(c) Below figure is showing the potential scenario for an emulsion system. Condition I is the primary system that was formed at temperature T and at a certain pH. In condition II more salt with the counter ions are added to the system maintaining the same temperature and pH. Based on the following figure, comment on the stability of the emulsified system at condition II.



3 + 5 + 4 = 12

Group – E

8. (a) Within an emulsion system of type O/W find out the distance at which the potential barrier for the stability of the system will be maximum. Given: H = 5 × 10^{-21} J; Particle radius = 250 nm; Surface charge density=2 mC/m^2; Monovalent salt concentration = 8 mM; Dielectric constant for water = 80 at 25^{o}C; Permittivity of vacuum = 8.854 × 10^{-12} F/m.

(b) Whether the Debye-Hückel Approximation is equally valid for the capillary electrophoresis, where the pH of the buffer is close to 1? Justify your answer.

9 + 3 = 12

9. (a) What is the basic difference based on which one can identify an electroosmosis process an electrochromaography one? How it differs from electrophoresis?

(b) Show that for an open cylindrical channel (radius r) flow of ions in case of electroosmosis, under steady state condition and with no external pressure gradient, the velocity profile appears as the potential flow provided $r\kappa >> 1$. κ is the inverse of the Debye length.

(2 + 2) + 8 = 12

Department & Section	Submission Link
CHE	https://classroom.google.com/c/Mjk2ODgwNzIzMzAx/a/MzU3NDU3NTU1NjQ1/details