Name : ....

Roll No. : ....

Invigilator's Signature : ....

CS/M.TECH(CHE)/SEM-2/CHE-10/2012

2012

ADVANCED MASS TRANSFER

Time Allotted : 3 Hours *Full Marks* : 70

The figures in the margin indicate full marks.

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

Answer *five* questions in all taking at least *one* from each Group.

GROUP – A

1. a) Derive Underwood Equation for multicomponent distillation.

   b) A saturated liquid feed containing 36 mole % benzene(1), 20 mol% toluene(2) and 44 mol% cumene(3) is to be separated to recover 99% benzene in distillate and 99·2% cumene in the bottoms. Calculate the minimum reflux ratio and the distribution of the intermediate key toluene using Underwood method. The average relative volatilities with respect to toluene are given : $\alpha_{12} = 2 \cdot 28$, $\alpha_{32} = 0 \cdot 22$.

   c) Write down Gilliland correlation and state its significance. 5 + 7 + 2

2. a) Write a short note on Lewis-Matheson method for determining the number of ideal trays of a distillation column in case of multi-component distillation.

   b) A feed containing 30 mol% benzene (A), 25 mol% toluene (B) and 45 mol% ethyl benzene (C) is to be separated by distillation so that 98·5% of benzene and not more than 2% of the toluene should go to the distillate. Calculate the minimum number of ideal stages required. Also estimate the approximate distribution of ethyl benzene, the heavy non-key between the distillate and the bottoms using the Fenske equation. The average relative volatilities are $\alpha_{AB} = 2 \cdot 43$ and $\alpha_{AC} = 5 \cdot 0$.

   c) Derive the expression for flash equation in case of multicomponent distillation. 4 + 6 + 4

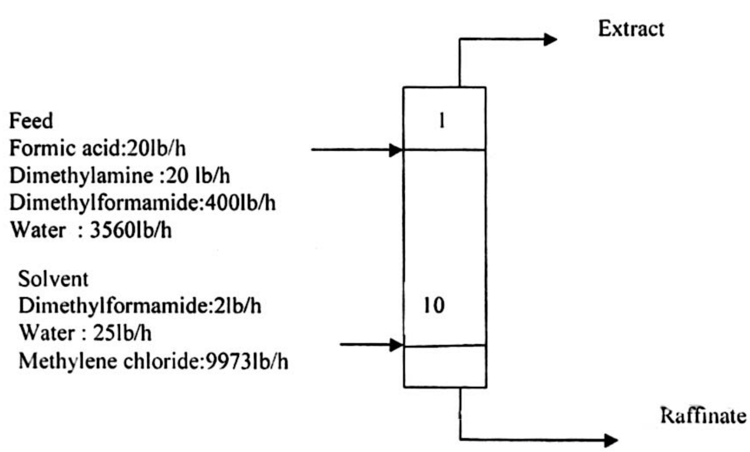
GROUP – B

3. a) A gas analyzing 70 mol% CH_4, 15% C_2H_6, 10% n-C_3H_8 and 5% n-C_4H_{10}, at 25°C. 2 atm is to be scrubbed in an adiabatic tray absorber with a liquid containing 1 mol% n-C_4H_{10}, 99% nonvolatile hydrocarbon oil, at 25°C, using 3·0 mol liquid/mol entering gas. The pressure is to be 2 std atm, and at least 75% of the C_3H_8 of the entering gas is to be absorbed. The solubility of CH_4 in the liquid will be considered negligible, and the other components form ideal solutions. Estimate the number of ideal trays and composition of effluent streams.

Component	Average specific heat at 0-40°C kJ/K-mol-K: Gas	Liquid	Latent heat of vaporization at 0°C, kJ/Kmol	$K = y^*/x$ 25 (°C)	27·5 (°C)	30 (°C)
C1	35·59					
C2	53·22	105·1	10032	13·25	13·6	14·1
C3	76·04	116·4	16580	4·1	4·33	4·52
C4	102·4	138·6	22530	1·19	1·28	1·37
Oil		37·7				

b) Derive the Horton Franklin method for calculating compositions in a multicomponent absorption column and explain how this method can be modified to obtain Edmister's method for calculating compositions of exit gas. 9 + 5

4. a) Countercurrent liquid-liquid extraction with methylene chloride is to be used to recover DMF from the aqueous stream in an extraction column comprising 10 stages. Estimate the interstage flow rates and compositions of the extract and raffinate streams by Group method. Temperature and pressure of the streams are assumed to remain constant throughout the column at 20°C and 20 psia respectively.



b) Explain the different steps for the design strategy of an absorption column in which chemical reaction takes place along with absorption. 9 + 5

GROUP – C

5. a) Write down the difference between ultrafiltration and reverse osmosis.

b) What do you understand by concentration polarization and concentration polarization modulus ? Obtain an expression of concentration polarization modulus.

c) It is required to design an RO module for producing 1400 m^3/day potable water containing not more than 250 ppm salt from sea water containing 34·5 g salt per litre. An asymmetric cellulose acetate membrane with water permeation coefficient of 0·041 m^3/m^2.day.atm and salt rejection ability of 97% is to be used. The recovery of the feed water should be 36% and an operating pressure of 68 atm gauge is suggested. If spiral wound modules of 5 m^2 effective membrane area each is used, how many modules in parallel are required ?

[Given, the osmotic pressure of 5% brine (linear in salt concentration) is 39·5 atm.] 3 + 3 + 8

6. a) Blood from a patient's body is pumped through a haemodialyser in a co-current mode at the rate of 300 ml/min to reduce the creatinine concentration from 150 mg% to 15 mg%. The other undesirable substances are also expected to be removed in the process. The available membrane area is 2·1 m^2 and the overall mass transfer coefficient is $1 \cdot 2 \times 10^{-6}$ m/s. The volume of blood in normal human body is about 5 litre. If the flow rate of dialysate fluid is maintained high, estimate the time of dialysis. Assume dialysate fluid is solute free.

b) In a membrane separation process employing microfiltration pilot plant on a batch basis, a volume reduction factor of 20 is approached. The microfiltration membrane has a maximum permeate flux of 300 L/m^2 h (corresponding to pure water) at a pressure drop of 1·2 bar at 25°C which typically drops to 80 L/m^2h at end of day.

i) Calculate the resistance to flow offered by the membrane if viscosity of water is 0·9 cp at 25°C.

ii) Also determine the tortuosity of the membrane if the membrane thickness is 80 μm and average porosity is 1 μm.

iii) A full scale plant was designed to operate with a permeate flux of 40 L/m^2 h. Calculate the permeate and retentate flow rates and the membrane area.

c) Explain the different types of fouling in a microfiltration membrane and state the different models used to predict the flux during membrane fouling. 5 + 6 + 3

GROUP – D

7. a) Explain the basic principle of electrodialysis.

b) Explain Stern's model for electric double layer mentioning the significance of zeta potential.

c) State the advantages and disadvantages of enzyme immobilization and explain in brief the different types of membrane reactors. 5 + 4 + 5

8. a) What do you understand by 'separation factor' in case of a binary gas mixture permeating through a polymeric membrane ?

b) A membrane module uses silicone-polycarbonate copolymer membrane to separate 220 m^3 (STP) of air per hour to produce a permeate stream containing 26% oxygen. The stage cut is 42% and 52% of the permeate which is to be recycled into the feed stream. Permeability of N_2 in the 0·1 μm thick dense layer of the membrane is 32 barrer. The separation factor is 5·5. The feed side pressure is 48 bar and that on permeate side is 4 bar. Calculate the membrane area if both the feed and permeate side are well mixed.

c) Mention the factors that can affect the membrane performance during pervaporation.

d) It is required to remove water from 85% *n*-butanol using pervaporation. The feed and permeate side are at 60°C and 32°C respectively. Find the stage cut θ. Data given, Latent heat of vaporization of *n*-butanol = 141·6 cal/g, Latent heat of vaporization of water = 9·72 kcal/g mol, Specific heat of *n*-butanol = 0·625 cal/g °C.

2 + 7 + 2 + 3

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