Name : ....

Roll No. : ....

Invigilator's Signature : ....

CS/M.TECH(CHE-OLD)/SEM-2/CH-07/2012

2012

ADV. 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 Q. No. *1* and any *four* from the rest.

1. An adiabatic tray absorber absorbs an entering gas mixture at 25°C containing 72 mole % CH_4, 13% C_2H_6, 10% n-C_3H_8 and 5% n-C_4H_{10} using an entering liquid containing 1·0 mole % n-C_4H_{10}, 99% non-volatile hydrocarbon oil at 25°C. The entering liquid to gas ratio is 3·5 mole liquid / mole entering gas. The pressure is 2 std. atmospheres. At least 70% of the propane and 29·4% of

ethane of the entering gas are to be absorbed. The solubility of methane in liquid is negligible.

a) Estimate the number of ideal trays required and the compositions of the effluent gas streams. The total absorption of gas is 0·15 kmol based on 1·0 kmol of feed gas.

b) Compute the bottom tray temperature, given the top tray temperature 26°C. The following data are available :

Component	Sp. Heat kJ/kmol. K		Latent heat of vaporization kJ/kmol.	Equilibrium Constant M = y^*/x
	Gas	Liquid	—	—
CH_4	35·59	insoluble	—	—
C_2H_6	53·22	105	10032	13·25
n-C_3H_8	76·04	116	16580	4·1
n-C_4H_{10}	102·4	138·6	22530	1·19
oil	—	377	—	

Use Edmister equation as given below

$$\frac{Y'_{N_p+1} - Y'_1}{Y'_{N_p+1}} = \left(1 - \frac{L_0 X_0}{A\, G_{N_p+1} Y'_{N_p+1}}\right)\frac{A^{N_p+1} - A}{A^{N_p+1} - 1}$$

The symbols have their usual meanings. 14

2. A mixture of benzene, toluene and *o*-xylene is to be separated in a distillation column equipped with a total condenser and a partial reboiler. The feed is a saturated liquid containing 30% benzene, 45% toluene and 25% *o*-xylene. The bottoms are to contain 95% of the *o*-xylene charged with a concentration of 0·99 mole fraction *o*-xylene. Determine the plate liquid composition for the first three plates from the top at a reflux ratio of 3·0 and a pressure of 1 atm. Assume top three plate temperatures are 103°C, 108°C and 113°C respectively.

Constants of the Antoine equations $P_0 = e^{(A-B/T)}$ are given below :

Name	A	B
Benzene	17·397	3802·1
Toluene	17·599	4208·8
o-xylene	17·962	4728·6

Where P_0 = Vapour pressure mm Hg, and T = Temp. in K.

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3. a) Carbon dioxide is absorbed in NaOH solution in a counter-current packed absorption tower. The reaction between dissolved carbon dioxide and NaOH is second order and irreversible for short contact time. Under steady state condition, the flow is assumed to be one-dimensional in Z direction. The effect of dispersion is negligible. Use the equation of continuity for mass transfer to calculate the final concentration of carbon dioxide in the exit liquid stream. The overall resistance is due to physical mass transfer as well as chemical reaction resistances.

The equation of continuity for mass transfer with chemical reaction is given below.

$$\frac{\partial C_A}{\partial t} + \left(V_x \frac{\partial C_A}{\partial x} + V_y \frac{\partial C_A}{\partial y} + V_z \frac{\partial C_A}{\partial z} \right) = D_{AB} \left(\frac{\partial^2 C_A}{\partial x^2} + \frac{\partial^2 C_A}{\partial y^2} + \frac{\partial^2 C_A}{\partial z^2} \right) + R_A$$

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b) Ethyl acetate drops (pressurized with water) are dispersed in an aqueous solution of NaOH in a liquid-liquid extraction spray tower. The flow is counter-current. The reaction is given by

$CH_3\ CO_2\ C_2\ H_5\ + NaOH = CH_3\ CO_2\ Na + C_2\ H_5\ OH$

The reaction is irreversible. The following conditions are maintained :

i) Steady state one dimensional flow in z-direction

ii) Effect of velocity is negligible.

iii) The change in the concentration of NaOH is negligible. The reaction is pseudo first order with respect to acetate concentration in aqueous film.

iv) The resistance is due to chemical reaction only.

Use equation of continuity for mass transfer to obtain the governing differential equation and solve this equation using the boundary conditions :

$Z = 0$, $C_A = C_{Ai}$, $Z = Z_L$, $C_A = C_{AL}$, where Z_L = thickness of aqueous film, C_{Ai} = Conc. of acetate in the aqueous phase at interface. 7

c) Explain surface renewal theory by Danckwerts. 2

4. Estimate the vapour composition at 1 atm that is in equilibrium with a liquid mixture that contains 2·5 mole % ethanol, 39·5 mole % *n*-propanol and 58 mole % *n*-butanol. Also calculate the Bubble Point.

Constants of the Antoine equation $\ln P_0 = A - B / (C + T)$ are given below :

Name	**A**	**B**	**C**
ethanol	18·9119	3803·98	– 41·68
n-propanol	17·544	3166·38	– 80·15
n-butanol	17·216	3137·02	– 94·43

Where P_0 = Vapour pressure mm Hg, and T = Temp in K.

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5. The following feed at 82°C 1635 kN/m ^{2} is to be fractionated at that pressure so that the vapour distillate contains 98% of the C_3H_8 but only 1% of C_5H_{12} .

Component	CH_4	C_2H_6	n-C_3H_8	n-C_4H_{10}	n-C_5H_{12}	n-C_6H_{14}
Mole fraction In feed	0·03	0·07	0·15	0·33	0·3	0·12

Estimate the minimum reflux ratio and the corresponding product. Values of *m* for each component at different temperatures are given below : 14

Component	30°C	60°C	90°C	120°C
CH_4	16·1	19·3	21·8	24
$C_2 H_6$	3·45	4·9	6·25	8·15
n-$C_3 H_8$	1·1	2	2·9	4
n-$C_4 H_{10}$	0·35	0·7	1·16	1·78
n-$C_5 H_{12}$	0·085	0·26	0·5	0·84
n-$C_6 H_{14}$	0·03	0·13	0·239	0·448

6. a) Derive an equation to calculate the number of theoretical plates for multicomponent distillation. 8

   b) Differentiate beween multicomponent Azeotropic and Extractive distillation with a suitable example. 6

7. a) Write short notes on any *one* : 7

   i) Pervaporation

   ii) Nanofiltration.

   b) Derive a model equation showing CP modulus of a ultrafiltration module the depends on the fractional rejection of the solute. 7