Ex/PG/ChE/T/112B/2024

M.E. CHEMICAL ENGINEERING FIRST YEAR FIRST SEMESTER – 2024

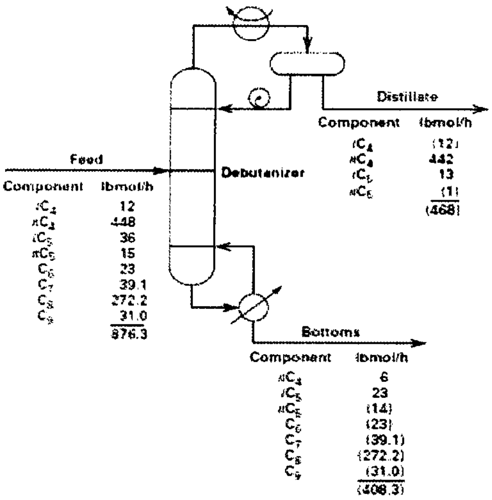
ADVANCED MASS TRANSFER

Time: 3 Hours Full Marks:100

Answer any two questions between 1-3 and 4-6 (total 4questions to be answered)

Assume any missing data

1. **a)** Identify light-key, heavy-key, light non key and heavy non key components from the following schematic and justify. **[5]**



b) A stripper at 50 psia with three stages is used to strip 1,000 kmol/h of liquid at 250°F with molar composition 0.05% C1, 0.20% C2, 1.85% C3, 4.5% nC4, 8.6% nC5, and 84.80% nC10. The stripping agent is 100 kmol/h of superheated steam at 300°F and 50 psia. Use the Kremser method to estimate compositions and flow rates of the stripped liquid and rich gas. **[15]**

Component	*K*-value
C_1	67
C_2	26
C_3	12.2
nC_4	6.0
nC_5	2.85
nC_{10}	

c) Write MESH equation for multicomponent distillation. Clearly mention the assumptions. **[5]**

2. One thousand kmol/h of a saturated-liquid mixture of 50 mol% methanol, 25 mol% ethanol, and 25 mol% n-propanol is fed to the middle stage of a distillation column having three equilibrium stages, a total condenser, a partial reboiler, and an operating pressure of 1 atm. The distillate rate is 500 kmol/h, and the external reflux rate is 2,000 kmol/h of saturated liquid. Assuming ideal solutions with K-values from vapor pressures and constant-molar overflow such that the vapor rate leaving the reboiler and each stage is 2,500 kmol/h, calculate one iteration of the BP method up to and including a new set of Tj values. To initiate the iteration, assume a linear-temperature profile based on a distillate temperature equal to the normal boiling point of methanol and a bottoms temperature equal to the arithmetic average of the normal boiling points of the other two alcohols. **[25]**

Given: The boiling points of these three components are, respectively, 64.7°C, 78.4°C, and 97.8°C.

[Turn Over

$P' = \exp\left(C1 + \frac{C2}{T} + C3 \ln T + C4 T^{C5}\right)$, P' is in Pa and T is in K, where the constants are:

Component	C1	C2	C3	C4	C5
M	81.768	-6876	-8.7078	7.1926E-6	2
E	74.475	-7164.3	-7.327	3.1340E-6	2
P	88.134	-8498.6	-9.0766	8.3303E-18	6

3. a) A mixture of ortho, meta, and para-mononitrotoluenes containing 50% ortho, 5 mol% meta and 45% mol para mononitrotoluene is to be continuously distilled to give a top product of 98mol% ortho and the bottom is to contain 12% ortho.
The mixture is to be distilled at a bottom temperature of T_B= 410K requiring a pressure in the boiler of about 6KN/m^2. If a reflux ratio of 8 is used, how many ideal plates will be required and what will be the approximate compositions of the product streams? Use Lewis Matheson method to calculate. The volatility of ortho relative to para is 1.7 and of the meta is 1.16 over the temperature range of 380-415kN. **[20]**
b) What are the basic differences between BP, SR, NR and Inside-out method? **[5]**

4. a) Water vapor in an air stream is to be adsorbed in a 10-cm-i.d. column packed with 3.1-mm-diameter Alcoa F-200 activated alumina beads of external porosity of 0.5. At a location in the bed where the pressure is 653.3 kPa, temperature is 21°C, gas flow rate is 1.327 kg/minute, and dew-point temperature is 11.2 °C, estimate the external, gas-to-particle mass-transfer and heat-transfer coefficients. At dew point temp vap pr of water is 1.32kPa. Cp= 1.09KJ/Kg. K; k= 0.0256 J/m.s.K; μ=183 micropoise **[20]**
b) Derive am expression for length of unused bed. What is mass transfer zone in fixed bed adsorber? **[5]**

5. a) Derive Langmuir equation and clearly state all the assumptions. **[5]**

b) A 60 mol% propane and 40 mol% propylene gas mixture is to be separated into products containing 15 and 85 mol% propane by adsorption in a continuous, countercurrent system operating at 25°C and 1 atm. The adsorbent is silica gel, for which equilibrium data are given below. Determine by the McCabe–Thiele method the: (a) adsorbent flow rate per 1,000 m^3 of feed gas at 25°C and 1 atm for 1.2 times the minimum, and (b) number of stages required. **[20]**

Total Pressure, torr	Millimoles of Mixture Adsorbed/g	y_{C_3}, Mole Fraction in Gas Phase	x_{C_3}, Mole Fraction in Adsorbate
769.2	2.197	0.2445	0.1078
760.9	2.013	0.299	0.2576
767.8	2.052	0.4040	0.2956
761.0	2.041	0.530	0.2816
753.6	1.963	0.5333	0.3655
766.3	1.967	0.5356	0.3120
754.0	1.974	0.6140	0.3591
753.6	1.851	0.6220	0.5550
754.0	1.701	0.6252	0.7007
760.0	1.686	0.7480	0.723
—	2.180	0.671	0.096
760.0	1.993	0.8964	0.253
760.0	1.426	0.921	0.401

6. a) Water containing 3.3 mg/L of trichloroethylene (TCE) is to be treated with activated carbon to obtain an effluent with only 0.01 mg TCE/L. At 25°C, adsorption-equilibrium data for TCE on activated carbon are correlated with the Freundlich equation: **[20]**

$$q = 67\, c^{0.564}$$

where, q = mg TCE/g carbon and c = mg TCE/L solution. TCE is to be removed by slurry adsorption using powdered activated carbon with an average d_p of 1.5 mm. Assume the small-particle absorption rate is controlled by external mass transfer with a Sherwood number of 30. Particle surface area is
5 m^2/kg. The molecular diffusivity of TCE in low concentrations in water at 25°C may be obtained from the Wilke–Chang equation.

a) Determine the minimum amount of adsorbent needed.
b) For operation in the batch mode with twice the minimum amount of adsorbent, determine the time to reduce TCE content to the desired value.
c) For operation in the continuous mode using twice the minimum amount of adsorbent, obtain the required residence time.

Wilke Chang Equation: $D_{TCE,B} = \frac{7.4\times10^{-8}(\varphi_B \times M_B)^{\frac{1}{2}}}{\mu_B \times \vartheta_{TCE}{}^{0.6}}$, where $\vartheta_{TCE} = 98.1\ cm^3/mol$,
$\mu_B = 0.94$, $M_B = 18$, $\varphi_B = 2.6$

b) Explain with the aid of diagrams Brauner's five types of gas adsorption isotherms. **[5]**