B.E. CHEMICAL ENGINEERING FOURTH YEAR FIRST SEMESTER – 2024

SEPARATION PROCESSES-III

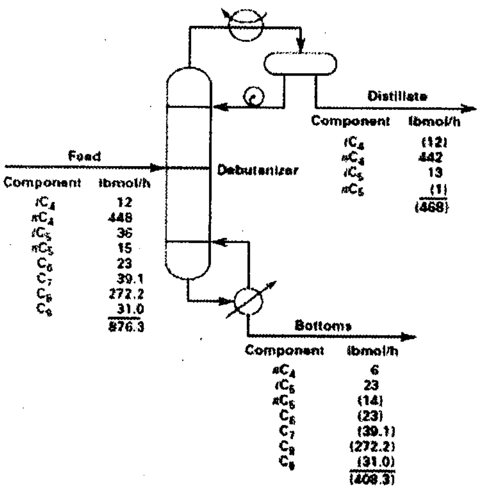
Time: 3 Hours Full Marks:100

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

Assume any missing data

CO	CO1	CO2	CO3	CO4	Total
Total Marks	30	20	30	20	100

1. a) Identify light-key, heavy-key, light non key and heavy non key components from the following schematic and justify. **(CO1)** **[5]**



b) Derive Underwood equation for minimum reflux for multicomponent distillation. **(CO2)** **[10]**

c) A feed consisting of 62 mol% pare-dichlorobenzene in ortho-dichlorobenzene is to be separated by distillation at near atmospheric pressure into a distillate containing 97 mol% para isomer and bottoms containing 95 mol% ortho isomer.

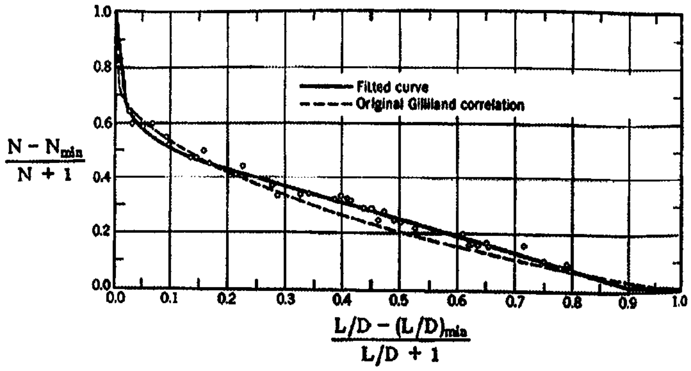
If a total condenser and partial reboiler are used, q = 0.8, average relative volatility = 1.154, and reflux/minimum reflux = 1.17, use the Fenske-Underwood-Gilliland procedure to estimate the number of theoretical stages required. **(CO1)** **[10]**

2. **a)** Write MESH equation for multicomponent distillation. Explain briefly the strategy to solve using modified mass equation using TDMA algorithm. **(CO1)** **[15]**

b) Write steps and necessary equations to calculate optimal feed location using approximate methods. **(CO2)** **[10]**

3. An atmospheric distillation column with a total condenser and a partial re-boiler is used to separate a mixture of 40 mol% benzene, 30% toluene, and 30% cumene, in which the feed is input as a saturated vapour. It is required that 98% of toluene be in the distillate and that 98% of cumene be in the bottom. If the CMO is assumed and the reflux is a saturated liquid determine a) the number of equilibrium stage for total reflux distillation and b) the fractional recovery of benzene in the distillate, c) determine the minimum reflux ratio, based on the feed rate of 100 kmol/h, d) estimate total number of equilibrium stages and optimal feed stage (N_F) if actual reflux ratio (L/D) is set at 2.5. **(CO1, CO2)**

Given the constant volatilities with respect to toluene as $\alpha_{benz\text{-}tol} = 2.25$ and $\alpha_{cume\text{-}tol} = 0.21$ **[25]**



Gilliland's correlation chart (modified by Liddle in 1968)

4. a) Considering mass transfer in dialysis, develop an expression for solute flux through a dialysis membrane in terms of the bulk concentrations in the first (c_1) and the second (c_2) liquid phases, mass transfer coefficients in the first (k_{c1}) and the second (k_{c2}) liquid phases, thickness of the membrane, δ, the equilibrium distribution coefficient, K_s, and the diffusivity of the solute through the membrane, D_{sm}. **(CO3)** **[5]**

b) Derive an expression relating outlet concentration of the concerned species in the blood leaving the dialyser with number of transfer unit (NTU) in a countercurrent hemodialyser. **(CO3)** **[10]**

c) A countercurrent hemodialyser has a membrane area of $1.5m^2$, and the overall mass transfer coefficient is estimated to be $K_L=1.05x10^{-6}$ m/s. (a) Calculate the extraction ratio if the blood flow rate is 300ml/min, and the dialysate flow rate is ten times as high, (b) Also, calculate the time of reduction of urea from 210mg% to 10mg%, if the blood volume in patient's body is 5litre. **(CO4)** **[10]**

5. a) Derive the implicit form of Kedem-Katchalsky model for permeate flux through an ultrafiltration (UF) membrane. **(CO3)** **[10]**

b) Define molecular weight cut-off and membrane permeability. **(CO3)** **[5]**

c) Reverse osmosis is to be used to separate sodium chloride solution from water to produce 50 m^3/h of water with a concentration of less than 300 ppm NaCl (MW=58.45). The initial quantity of feed is 4000 ppm. A membrane is available for which the following test results have been reported (Feed concentration: 1500 ppm NaCl; Pressure difference: 16 bar; Temperature: 25°C; Solute rejection: 99%; Flux: $10.7x10^{-6}$ $m^3/m^2.s^1$).

Assume that solute rejection is constant for different feeds and there is no pressure drop along the membrane surfaces. Test conditions are such that the cut fraction of water recovered is low enough for retentate concentration to be equal to the feed concentration. If the density of all solutions is 997 kg/m3, estimate the permeate and retentate concentrations and membrane area for cut fractions of 0.1 to 0.5 and pressure difference of 40 bar across the membrane. **(CO4)** **[10]**

6. a) Explain concentration-polarization with help of a diagram. Derive an expression for concentration-polarization in a rectangular channel. **(CO3)** **[7+8]**

b) A cellulose triacetate membrane is being used for reverse osmosis of a saline water solution containing predominantly NaCl (MW=58.45) at 27°C. The concentration of NaCl in the feed solution is 3000 ppm and its density is 999 kg/m^3. Water permeability constant is 4.79 x 10^{-4} $kg/s.m^2$ atm and solute (NaCl) permeability constant is $4.38x10^{-7}$ m/s. Calculate the solute and water flux through the membrane using an applied pressure difference of 30 atm and solute rejection R. Also calculate concentration of product solution. Use Table 1 to compute the osmotic pressure. **(CO4)** **[10]**

Table 1 Osmotic pressure of various dilute aqueous solutions of

gmol NaCl/kg H2O	*Density (kg/m3)*	*Osmotic Pressure (atm)*
0	997.0	0
0.01	997.4	0.47
0.1	1001.1	4.56
0.5	1017.2	22.55
1.0	1036.3	45.8
2.0	1072.3	96.2