BIRLA INSTITUTE OF TECHNOLOGY, MESRA, RANCHI
(END SEMESTER EXAMINATION)

CLASS: B.TECH. **SEMESTER : IV**
BRANCH: CHEMICAL ENGG **SESSION : SP/2023**

SUBJECT: CL215 MASS TRANSFER OPERATIONS-I

TIME: 3 Hours **FULL MARKS: 50**

INSTRUCTIONS:
1. **The question paper contains 5 questions each of 10 marks and total 50 marks.**
2. **Attempt all questions.**
3. **The missing data, if any, may be assumed suitably.**
4. **Before attempting the question paper, be sure that you have got the correct question paper.**
5. **Tables/Data hand book/Graph paper etc. to be supplied to the candidates in the examination hall.**

CO BL

Q.1(a) A sphere of naphthalene having a diameter of 5 mm is suspended in a large volume of still air at 318 K and 1.01325×10^5 Pa. The surface temperature of the sphere is 318 K and its vapor pressure at 318 K is 0.555 mm Hg. The D_{AB} of naphthalene in air at 318 K is 6.92×10^{-6} m^2/s. Calculate the rate of evaporation of naphthalene from surface. [4] CO1 3

Q.1(b) Two bulbs are connected by a straight tube, 0.001 m in diameter and 0.15 m in length. Initially the bulb at End 1 contains N_2 and the bulb at End 2 contains H_2. Pressure and temperature are constant at 25°C and 1 atm. At a time after diffusion starts, the nitrogen content of the gas at End 1 of the tube is 80 mol% and at End 2 is 25 mol%. If the binary diffusion coefficient is 0.784 cm^2/s, determine: (a) The rates and directions of mass transfer in mol/s (b) The species velocities relative to stationary coordinates, in cm/s [6] CO1 3

Q.2(a) How do you obtain over all mass transfer coefficients from individual mass transfer coefficients?
A spherical ball of benzoic acid (diameter=1.5 cm) is submerged in a pool of still water. The solubility & diffusivity of benzoic acid in water are 0.03 kmol/m 3 & 1.25×10^{-9} m^2/s respectively. Sherwood number is given as $Sh = 2.0 + 0.6Re^{0.5}\ Sc^{0.33}$. Find the initial rate of dissolution (in kmol/s) of benzoic acid. [4] CO2 3

Q.2(b) In an experimental study of the absorption of ammonia by water in a wetted-wall column, the value of overall mass transfer coefficient, K_G was found to be 2.75×10^{-6} $kmol/m^2skPa$. At one point in the column, the composition of the gas and liquid phases were 8.0 and 0.115 mole% NH_3, respectively. The temperature was 300 K and the total pressure was 1 atm. Eighty-five % of the total resistance to mass transfer was found to be in the gas phase. At 300 K, Ammonia–water solutions follow Henry's law up to 5 mole% ammonia in the liquid, with m=1.64 when the total pressure is 1 atm. Calculate the individual film coefficients and the interfacial concentrations. Interfacial concentrations lie on the equilibrium line. [6] CO2 4

Q.3(a) A gas mixture with a solute concentration of 10 mol% is being fed in an absorption column at a flow rate of 50 kmol/hr. It is expected to remove 82% of solute by introducing a fresh solvent in counter current direction. Estimate the minimum solvent rate. Also estimate the no. of ideal stages and liquid exit concentration if the actual solvent rate is 1.5 times the minimum. The equilibrium data has been tabulated below: [6] CO3 5

X	0	0.02	0.03	0.04	0.06	0.08	0.1	0.12	0.14
Y	0	0.017	0.025	0.033	0.046	0.058	0.068	0.076	0.083
X	0.15	0.16	0.18	0.2	0.22	0.24	0.25		
Y	0.085	0.087	0.091	0.092	0.094	0.099	0.112		

Q.3(b) A packed tower is to be designed to absorb sulphur dioxide from air by scrubbing with water. The entering gas is 20% SO_2 by volume and the leaving gas is to contain 0.5% SO_2 by volume. The entering water is free from SO_2. The water flow rate is to be twice the minimum. The air flowrate is 31.8 $kmol/m^2hr$ in solute free basis. The temperature and pressure of the system are 30°C and 2 atm. absolute, respectively. The equilibrium relation is given by $y = 21.8x$, where x and y are in mole fraction. Compute the NTU on the basis of overall gas phase mass transfer. [4] CO3 3

PTO

Q.4(a)	A reboiler is considered as a theoretical plate but a total condenser is not. Justify. Why reflux stream is necessary for a continuous distillation column?	[3]	CO4	4
Q.4(b)	A liquid mixture of benzene toluene is being distilled in a fractionating column at 101.3 k Pa pressure. The feed of 100 kmole/h is liquid, and it contains 45 mole% benzene (A) and 55 mole% toluene (B) and enters at 327.6 K. A distillate containing 95 mole% benzene and 5 mole% toluene and a bottoms containing 10 mole% benzene and 90 mole% toluene are to be obtained. The amount of liquid is fed back to the column at the top is 4 times the distillate product. The average heat capacity of the feed is 159 KJ/kg mole. K and the average latent heat 32099 kJ/kg moles. Calculate i. The kg moles per hour distillate, kg mole per hour bottoms ii. No. of theoretical stages at the operating reflux. iii. The minimum no. of theoretical stages required at total reflux. iv. If the actual no. of stage is 10, what is the overall efficiency increased at operating condition compared to the condition of total reflux? The equilibrium data:	[7]	CO4	5

Temp.(K)	353.3	358.2	363.2	366.7	373.2	378.2	383.8
x_A (mole fraction)	1.000	0.780	0.580	0.450	0.258	0.13	0
y_A (mole fraction)	1.000	0.900	0.777	0.657	0.456	0.261	0

Q.5(a)	Write down the steps to find dew point of a multicomponent distillation process.	[3]	5	1
Q.5(b)	A feed 100 kmoles/h of saturated liquid containing 10 mole % LNK, 55 mole % LK, and 35 mole % HK and is to be separated in a distillation column. The reflux ratio is 1.2 the minimum. It is desired to have 99.5 % recovery of the light key in the distillate. The mole fraction of the light key in the distillate should be 0.75. Equilibrium data: $\alpha_{NK} = 4.0$, $\alpha_{LK} = 1.0$, $\alpha_{HK} = 0.75$. Find (i) Minimum number of stages required by Fenske method (ii) Minimum reflux ratio by Underwood method (iii) Number of ideal stages at R = 1.2 R_{min} by Gilliland method (iv) Also find the number of ideal stages at rectifying section and the stripping section at the operating reflux ratio and location of feed stage.	[7]	5	5

::::::25/04/2023::::::M