BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI
Second Semester 2022-2023
CHE F244: Separation Processes-I
Mid-Semester Examination

Date: 18.03.2023 **Time: 9:00-10:30 AM** **Maximum Marks: 90**

***Note*:** The question paper consists of two parts. Answer **Part A** and **Part B** in separate answer books. Collect answer book for **Part B** after submitting **Part A** answer book.

PART – A (Closed Book)

Time: 9:00 - 9.40 A.M. **Marks: 40**

1. (10 Marks) Define the following terms with respect to mass transfer (give suitable examples wherever required):

   Phase, Property, System, Phase equilibrium, Molecular diffusion, Molar flux (N), Molar diffusion flux (J), Stage, Stage efficiency, Murphree stage efficiency (E_M).

2. (5 Marks) Write the physical significance (in terms of ratios) of the dimensionless numbers (Sc, Sh, St_M, Pe_M) which are generally used in mass transfer. Obtain a relationship between mass transfer coefficient (k_L) and heat transfer coefficient (h) using Colburn j-factors (j_H and j_D) for heat and mass transfer (Colburn Analogy).

3. (10 Marks) Assuming the equilibrium distribution curve to be a straight line of slope $m = (Y_2^* - Y_2) / (X_2 - X_2^*)$, derive the relation between Murphree stage efficiencies, E_{MG} and E_{ML} as

   $E_{MG} = E_{ML}/[S(1- E_{ML}) + E_{ML}]$, where $S = mG'/L'$, Stripping factor.

   The symbols have their usual meanings. Start from LHS to reach RHS.

4. (15 Marks)

   (a) Outline the properties of the interface.

   (b) State the assumptions made in the two-film theory.

   (c) Outline the theories of mass transfer showing the relationship between mass transfer coefficient and the diffusivity.

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PART – B (Open Book)

Time: 9:40 – 10:30 A.M. **Marks: 50**

***Note*:** Only Text book (Seader), Ref. book (Treybal) and hand-written class notes are allowed. Photocopy of the class notes are not allowed.

1. (**20 *Marks***)

   Oxygen (A) is diffusing through non-diffusing nitrogen (B) at 1std atm and 27^{o}C. The partial pressures of oxygen at two planes 2 mm apart are 0.25 and 0.10 atm, respectively. Calculate

   (a) the mutual diffusivity of oxygen and nitrogen at 27^{o}C and 1 atm using FSG equation.

   (b) the molar flux of diffusion of oxygen, N_A in kmol/m^{2}s.

   (c) the mass transfer coefficients F, k_p, k_y and k_c for this system.

2. **(30 *Marks*)**

   Propane is to be stripped from a non-volatile oil by steam in a cross-current cascade. The propane-oil is fed at 100 mole/h and the steam rate is 4 mole/h in each stage. The oil originally contains 2.55 mole% propane, and this concentration must be reduced to 0.25 mole%. The cascade is maintained at 135^{o}C and 4 atm absolute pressure. The molecular weight of the heavy oil is 300 and that of propane is 44. The equilibrium relationship is as given below:

X = Mole propane/ Mole pure oil	0	0.005	0.010	0.015	0.020	0.025
Y = Mole propane/Mole pure steam	0	0.136	0.312	0.550	0.890	1.412

   (a) How many equilibrium stages will be required?

   (b) If each stage operates at 90% efficiency, how many real stages will be required?

   (c) If the separation is carried out in a counter-current cascade with 100 mole/h of oil-propane feed and 4 moles/h of pure steam, how many equilibrium stages will be needed?

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