**Registration No :** | | | | | | | | | | |

**Total number of pages : 03** **B.Tech**

**PCE3I104**

**3rd Semester Regular/Back Examination 2018–19**

**MASS TRANSFER - I**

**BRANCH : CHEM, PT**

**Time : 3 Hours**

**Max Marks : 100**

**Q.CODE : E929**

**Answer Question No.1 (Part-I) which is compulsory, any eight from Part-II, and any two from Part-III.**

***The figures in the right-hand margin indicate marks.***

***Assume suitable notations and any missing data wherever necessary.***

***Answer all parts of a question at a place.***

## Part – I

**Q1** **Answer the following questions :** **(2 × 10)**

**a)** How does the binary gas phase diffusivity depend upon the total pressure and temperature?

**b)** Give the physical significances of the dimensionless groups in mass transfer.

**c)** What is equimolar counter-diffusion?

**d)** Write the Gilliland's equation and explain each terms used in it. Mention its importance.

**e)** What is the physical significance of NTU?

**f)** What are the factors that influence $H_{tOG}$ and $N_{tOG}$ of a packed tower?

**g)** What happens if a column heated by open steam is operated at total reflux for a long time?

**h)** What are the common packings and materials for a cooling tower?

**i)** What is wet bulb depression?

**j)** What are the important factors that influence the design and operation of a cooling tower?

## Part – II

**Focused-Short Answer Type Questions(Answer Any EIGHT out of TWELVE)**

**Q2** **Answer the following questions :** **(6 × 8)**

**a)** Two vessels are connected by a tube 6 cm in diameter and 20 cm in length. Vessel 1 contains 70 % $N_2$and 30 % $O_2$while vessel 2 contains 30 % $N_2$ and 70 % $O_2$. The temperature is $20^0$C and the total pressure is 2 atm. Calculate (i) the steady-state flux and the rate of transport of $N_2$ from vessel 1 to 2 and (ii) the same quantities for $O_2$. Given:Diffusivity of $N_2$-$O_2$ pair is 0.23 $cm^2$/s at 316 K and 1 atm.

**b)** In a reactor the gas (A) is sparged in an agitated suspension of catalyst particles, 0.5 mm in diameter, in a liquid (B). The gas dissolves in the liquid and is transported to the surface of the catalyst particles where it undergoes an instantaneous reaction. In a particular case the concentration of A in the liquid is 0.8kmol/$m^3$, the rate of reaction is $3.0 \times 10^{-6}$kmol/$m^2$.s based on the external surface area of the catalyst particles, and the diffusivity of A in the liquid is $6.8 \times 10^{-10}$ $m^2$/s. If the diffusion of dissolved A to the catalyst surface occurs through a stagnant film surrounding a particle, calculate the thickness of the liquid film.

**c)** Discuss in detail the types of mass transfer coefficients.

**d)** Determine the relation between the gas-phase mass transfer coefficients $k_G$ and $k_Y$.

**e)** Describe the penetration theory with a neat model.

**f)** Discuss the important criteria for the selection of solvent and stripping medium for absorption.

**g)** In the $n^{th}$ tray of an absorption column: $G_s$ = 100 kmol/h; $L_s$ = 120 kmol/h; $y_{n+1}$ = 0.15; $x_n$ = 0.08; and $x_{n-1}$ = 0.06. The equilibrium relation is linear in the form y = 1.02 x. If the liquid on the tray is well mixed, calculate the Murphree tray efficiency.

**h)** Discuss about deviation from ideality and formation of azeotropes.

**i)** Derive the Fenske's equation.

**j)** A charge of 52kmol of a mixture of benzene and chlorobenzene having 58mol % of the less volatile is to be batch distilled. If 30 moles of the solution is vaporized and condensed as the distillate, calculate the concentration of the accumulated distillate. The relative volatility of benzene in the mixture is 4.0.

**k)** Discuss the construction and working of a counter flow induced draft cooling tower with a neat diagram.

**l)** Discuss the hygrometer method of humidity measurement.

## Part – III

### Long Answer Type Questions (Answer Any Two out of Four)

**Q3** The gas phase mass transfer coefficient for the evaporation of a drop of ethyl alcohol in a stream of air at 300 K and 1.2 bar pressure is $k_G = 2.5 \times 10^{-6}$kmol/s.$m^2$.mmHg. Calculate the values of the mass transfer coefficient if the driving force is expressed in terms of difference in (i) mole fraction of alcohol in the gas phase, (ii) mole ratio of alcohol, (iii) concentration of alcohol in kmol/$m^3$. Also calculate the coefficient $F_G$. If the diffusivity of alcohol in air is 0.1 $cm^2$/s at $0^0$C, estimate the thickness of the stagnant gas-film. Vapour pressure of alcohol = 0.09 bar at 300 K. **(16)**

**Q4** $SO_2$is scrubbed from an air stream in a small packed tower by contacting it with an organic solvent. The feed gas contains 2 % $SO_2$ by volume and 90 % of it is to be absorbed. The total gas rate is 140 $m^3$/h at $20^0$C and 1 bar absolute pressure. The liquid enters the column at 1.2kmol/h. **(16)**

Given: the overall mass transfer coefficient $K_G = 3 \times 10^{-4}$kmol/$m^2$.s.$\Delta$p ($\Delta$p in bar); the effective gas-liquid contact area = 100 $m^2/m^3$ of packed volume; and slope of the equilibrium line m = 0.15.

Determine the number of overall gas phase mass transfer units and the packed height if the column is 0.5 m in diameter.

**Q5** An aqueous solution of ethanol (29 mass % ethanol) is to be enriched into a top product having 90 mass % alcohol. The bottom product must not contain more than 3 mass % alcohol. The feed enters the column at $40^0$C at a rate of 5100 kg/h. The reflux is at its bubble point and the reflux ratio is 1.2. Enthalpy of the feed = 4790 kJ/kmol. Determine: **(16)**

The number of ideal trays required using the Ponchon-Savarit method;
The heat duty of the condenser and of the reboiler.
The enthalpy concentration (kJ/kmol; reference states: pure liquids at $0^0$C) and the VLE data at the operating pressure of 1 atm are given below.

| **x, y** | 0.0 | 0.0417 | 0.0891 | 0.1436 | 0.207 | 0.281 |
|---|---|---|---|---|---|---|
| **$H_L$** | 7540 | 7125 | 6880 | 6915 | 7097 | 7397 |
| **$H_V$** | 48150 | 48250 | 48300 | 48328 | 48436 | 48450 |
| **x, y** | 0.37 | 0.477 | 0.61 | 0.779 | 1.0 | - |
| **$H_L$** | 7750 | 8105 | 8471 | 8945 | 9523 | - |
| **$H_V$** | 48450 | 48631 | 48694 | 48950 | - | - |

| **x** | 0.0 | 0.00792 | 0.016 | 0.0202 | 0.0417 | 0.0891 | 0.1436 | 0.281 | 0.37 |
|---|---|---|---|---|---|---|---|---|---|
| **y** | 0.0 | 0.0850 | 0.1585 | 0.191 | 0.304 | 0.427 | 0.493 | 0.568 | 0.603 |
| **x** | 0.477 | 0.61 | 0.641 | 0.706 | 0.779 | 0.86 | 0.904 | 0.95 | 1.0 |
| **y** | 0.644 | 0.703 | 0.72 | 0.756 | 0.802 | 0.864 | 0.902 | 0.9456 | 1.0 |

**Q6** A sample of air has a dry bulb temperature of $35^0$C and wet bulb temperature of $25^0$C at a total pressure of 1 atm. **(16)**

Determine humidity, enthalpy, dew point, humid volume, and humid heat;
If the sample of air is heated to $48^0$C, what will be its wet bulb temperature?
How much heat is rejected if 1 kg of air (dry basis) is cooled down from 35 to $18^0$C?
If the air sample is heated to $48^0$C and its pressure doubled, what would be its relative humidity and dew point?