B.E. CHEMICAL ENGINEERING SUPPLEMENTARY EXAMINATION 2024

3rd Year, 1st Semester

SEPARATION PROCESSES - I

Time: 3 Hours | (50 Marks for each Part) | Full Marks: 100

Use separate answer script for each Part

Part I *(50 Marks)*

*Answer Q1 OR Q2 **and** Q3*

1. *Humidification: Cooling Towers* **[4+3+5+2+16=30]**

a) Explain the terms: i) Specific enthalpy of saturated air and ii) Enthalpy deviation.
b) Classify the cooling towers based on air flow pattern.
c) What are the design features of a Natural Draft Cooling Tower? Draw a schematic diagram.
d) Mention two factors responsible for creating natural draft in a Natural Draft Cooling Tower.
e) Draw schematic diagrams of each of a) Induced Draft and b) Forced Draft types of Mechanical Draft Cooling Towers. Mention two advantages and two disadvantages of each of these towers.

2. *Stripping* **[30]**

Design a stripping column to remove carbon dioxide (CO_2) from water. The same may be carried out by heating the water + CO_2 mixture and passing it counter-currently through a stripper with a nitrogen stream in. The operation is isothermal and isobaric at 60°C and 1 atm. The carbonated water contains 9.2×10^{-6} mole fraction of CO_2 and flows at 45360 kg/h. The nitrogen stream enters the column as pure N_2 at 1 atm and 60°C with the volumetric flow rate of 70.8 m^3/h. Assume that N_2 is not dissolved in water and that water is not evaporated. Given the Henry's constant for CO_2 in water at 60°C of 3410 atm/(mole fraction). If we desire an outlet water concentration of 2.0×10^{-7} mole fraction of CO_2, find the number of equilibrium stages required.

Hints:

a. The amount of CO_2 in the carbonated water is extremely low, it is reasonable to assume that the flow rate of the carbonated water (i.e. the mixture of water + CO_2) is about the same as the flow rate of pure water.
b. As the concentration of the solute is extremely low, the flow rates of the liquid and the gas phases can be assumed to be constant and the x and y coordinate can be used.

[Turn over

3. *Drying* **[8+12=20]**

a) Derive an expression for total drying time under constant drying conditions considering the constant drying rate period and first falling rate period. Express the first falling rate as a linear function of the moisture content.

b) A wet solid having 48% moisture (dry basis) is to be dried on a tray dryer till a final moisture content of 3.5% is reached. The solid loading is 30 kg dry solid per m^2 tray area. Two critical moisture values are there: X_{c1} =0.19 and X_{c2} =0.08. A laboratory test gives a drying rate of 7 kg/m^2 h in the constant rate period. In the first falling rate period, the drying flux is linear with respect to the moisture content; In the second falling rate period, the drying flux varies as the square of the moisture content. The equilibrium moisture is negligible. Calculate the total drying time in h if the drying conditions are the same as maintained during the laboratory tests. Clearly mention any assumption made.

Ref. No.: Ex/Che/PC/B/T/311/2024(S)

BACHELOR OF CHEMICAL ENGINEERING EXAMINATION, 2024
(3rd Year, 1st Semester)
SEPARATION PROCESSES I

Time : Three hours (50 Marks for each Part) Full Marks : 100

Use separate answer script for each Part

PART II (50 Marks)
Assume any missing data
Answer any **two (2)** questions

Question No	CO No.	Question	Marks
1.A	CO-3	An induced draft counter current cooling tower is to be designed to cool 20kg/s water from 45°C to 29°C. The design wet-bulb temperature of the entering air is to be 24°C having an enthalpy of 72 kJ/kg dry air. It has been decided to use 30% excess air over the minimum air rate. Make-up water is available at 10°C. For the packing to be used, k_ya is expected to be 1.25 kg/(m^3)(s)(ΔH) provided the minimum liquid rate and gas rates are 2.5 and 2.2 kg/(m^2)(s), respectively. Estimate the diameter and packed height of the tower.	**20**
		Equilibrium data:	

T_L(°C)	29	33	35	39	43	45	47.5
H_y*, kJ/kg dry air	100	117	130	159	196	216	244

Question No	CO No.	Question	Marks
1.B	CO-2	Assuming the drying rate curve for the falling rate period to be linear, what is the expression for the total drying time for batch drying of solid?	**5**
2.A	CO-1	i) Show that wet-bulb lines and adiabatic saturation lines are collinear.	**3**
	CO-4	ii) How is the chance of flooding in counter-current absorption column affected by increasing gas pressure drop?	**4**
2.B	CO-3	Data on drying rate as a function of moisture content of a certain solid are given below. The weight of bone dry solid per unit surface exposed to drying is 45.8 kg/m^2. Estimate the time required to dry the material from 20% to 5% moisture on wet basis.	**18**

[Turn over

Data:

X	0.3	0.2	0.18	0.15	0.14	0.11	0.07	0.02
R	1.22	1.22	1.12	0.98	0.78	0.49	0.24	0.0

Where, X: moisture content of solid, kg water/kg dry solid

R: drying rate, kg/(hr)(m^2)

3.A CO-1 What will happen if absorption factor in an absorption operation is less than unity? What is the most economical range of absorption factor? **5**

3.B CO-2 In a certain apparatus used for the absorption of carbon dioxide from air by means of mono methylamine, at one point the gas contained 20 vol% CO_2 and was in contact with the liquid containing 0.06 mol% CO_2. The temperature was 50°C and pressure 1.2 std atm. The overall mass transfer coefficient based on gas phase concentration is K_G = 9x10^{-10} kmol/m^2.s. Of the total diffusional resistance, 40% present in the gas phase and the remaining in the liquid. (a) Calculate the overall coefficient based on liquid concentration in terms of mol/vol; (b) Calculate the individual mass transfer coefficient for the gas phase expressed in k_G, k_y and k_c and for the liquid phase as k_L and k_x; (c) Determine the interfacial concentration in each phase. **20**

The equilibrium partial pressure of carbon dioxide over aqueous solution of monomethylamine (30%) is given below:

mol CO_2/mol solution	0.058	0.060	0.062	0.064	0.066	0.068	0.070
Partial pressure of CO_2, mm Hg	5.6	12.8	29.0	56.0	98.7	155	232