

**BIRLA INSTITUTE OF TECHNOLOGY, MESRA, RANCHI**  
(END SEMESTER EXAMINATION MO/2025)

CLASS: B.TECH.  
BRANCH: CHEMICAL ENGINEERING

SEMESTER: V/ADD  
SESSION: MO/2025

SUBJECT: CL301 MASS TRANSFER OPERATION-II

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. Tables/Data handbook/Graph paper etc., if applicable, will be supplied to the candidates
5. Mention the roll no. in the graph paper and submit along with answer sheet.

- Q.1(a) 100 kg of a solution of acetic acid and water containing 30% acid is to be extracted in a single stage operation with pure iso-propyl ether as the extracting solvent. The operation is carried out using 40kg of solvent at 20 °C. Find the quantities of raffinate and extract phases produced in this operation. Equilibrium data is given in the following table. [7] CO 1 BL 3

Water layer			Isopropyl ether layer		
%A	%B	%C	%A	%B	%C
98.1	1.2	0.69	0.5	99.3	0.18
97.1	1.5	1.41	0.7	98.9	0.37
95.5	1.6	2.89	0.8	98.4	0.79
91.7	1.9	6.42	1	97.1	1.93
84.4	2.3	13.5	1.9	93.3	4.82
71.1	3.4	25.5	3.9	84.7	11.4
58.9	4.4	36.7	6.9	71.5	21.6
45.1	10.6	44.3	10.8	58.1	31.1
31.7	16.5	46.4	15.1	48.7	36.2

- Q.1(b) Two ideal stages operate to extract P from a feed containing P & Q. The mass flow rates of P & Q for stage 1 are 1000 kg/hr and 10000 kg/hr respectively. Pure solvent S is injected at mass flow rate of 5000 kg/hr and 15000 kg/hr to stage 1 and stage 2 respectively. Q and S are immiscible.  $Y = 1.5 X$ , where X is mass of P per unit mass of Q in raffinate and Y is mass of P per unit mass of S in extract. Extract and raffinate phase are in equilibrium. Find the mass flow rate of P in kg/hr in raffinate from stage 2. [3] CO 1 BL 3
- Q.2 (a) A cooling tower is to be designed to cool the water from 43 °C to 30 °C by countercurrent contact with air of dry bulb temperature 30 °C and wet-bulb temperature of 25 °C. The water rate is 5500 kg/h.m<sup>2</sup> and the air rate is 1.25 times the minimum. Determine the tower height if the individual gas phase mass transfer coefficient,  $(k'_y \bar{a})$  is 5743.5 kg/m<sup>3</sup>h  $(\Delta Y')$ . Given: Tie lines are vertical and at  $T_{G1} = 30$  °C &  $T_{W1} = 25$  °C, absolute humidity is 0.019 kg/ kg dry air. [7] CO 2 BL 4

T (°C)	p <sup>v</sup> (bar)	Y' (kg moisture/kg dry air)	H' (kJ/kg dry air)
21	0.025	0.016	60.84
23	0.028	0.018	68.23
25	0.032	0.020	76.26
27	0.036	0.023	85.02
29	0.040	0.026	94.57
31	0.044	0.029	105.03
33	0.050	0.033	116.47
35	0.056	0.037	129.00
37	0.063	0.041	142.78
39	0.069	0.046	157.91
41	0.078	0.052	174.57
43	0.086	0.058	192.95
45	0.096	0.065	213.25
47	0.11	0.073	235.69

- Q.2(b) Explain the differences in the working principles of natural, forced and induced draft cooling towers. [3] 2 2
- Q.3(a) Sheet material, measuring 1 m<sup>2</sup> and 5 cm thick, is to be dried from 45% to 5% moisture under constant drying conditions. The dry density of the material is 450 kg/m<sup>3</sup> and its equilibrium moisture content is 2%. The available drying surface is 1 m<sup>2</sup>. Experiments showed that the rate of drying was constant at 4.8 kg/(hr)(m<sup>2</sup>) between moisture contents of 45% and 20% and thereafter the rate decreased linearly. Calculate the total time required to dry the material from 45% to 5%. All moisture contents are on wet basis. [5] 3 3
- Q.3(b) Differentiate between heat of adsorption and heat of liquefaction. Write down the characteristics and properties of adsorbent. [2+3] 4 2
- Q.4(a) Explain the adsorption process by mass transfer zone and breakthrough. [3] 4 3
- Q.4(b) A colored impurity is to be removed from an aqueous solution by adsorbing it on decolorizing carbon. Experiments yielded an equilibrium data that is given in the following table. [7] 4 4
- |                                |     |       |       |       |      |      |
|--------------------------------|-----|-------|-------|-------|------|------|
| kg carbon / kg solution        | 0   | 0.001 | 0.004 | 0.008 | 0.02 | 0.04 |
| Equilibrium color/ kg solution | 9.6 | 8.6   | 6.3   | 4.3   | 1.7  | 0.7  |
- The color intensity was measured on an arbitrary scale, proportional to the concentration of the colored substance. It is desired to reduce the color to 10 % of its original value (9.6). Determine the quantity of fresh carbon required per 1000 kg of solution for the a) single stage and b) two stages cross current operation when the intermediate color value is 3.5.
- Q.5(a) Explain the mechanism of homogenous and heterogeneous nucleation in crystallization process. [3] 4 2
- Q.5(b) Sodium acetate solution is available at a temperature of 70 °C with a solute content of 58%. Find out i) percentage saturation, ii) yield of crystal if 2000 kg of this solution is cooled to 10 °C, iii) percentage yield. [3] 5 3  
Data: Solubility at 70 °C = 146 gm of sodium acetate/ 100 gm of water.  
Solubility at 10 °C = 121 gm of sodium acetate/ 100 gm of water
- Q.5(c) What are the types of motion of molecules through membrane? [2+2] 5 2  
Cite examples of application of RO & MF membrane in the chemical industry?

:::::19/11/2025:::::M