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

CLASS: B.TECH. **SEMESTER : V**

BRANCH: CHEMICAL ENGG. **SESSION : MO/2023**

SUBJECT: CL301 MASS TRANSFER OPERATION-II

TIME: 03 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.

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Q.1(a)	A feed of 500 kg aqueous solution of acetone containing 50 mass% acetone(C) has been extracted with 400 kg of chlorobenzene(B) containing 0.5 mass% acetone in a mixer-settler unit, followed by separation into extract and raffinate. The solute concentration in the raffinate is found as 0.236 mass fraction. The weight of extract and raffinate phases are 600 kg and 300 kg, respectively. Calculate the percent of acetone extracted.	[3]	1	3
Q.1(b)	A 2000 kg/h of meal containing 26 mass% oil(C) has been extracted with 2100 kg/h of benzene(B). The final underflow leaving the countercurrent cascade contains 0.015 mass fraction of oil and 0.3175 mass fraction of solvent. The solvent benzene has 0.005 mass fraction oil in it. The overflow is solid free. Compute the mass fraction of overflow leaving the cascade and the number of ideal stages required by using Ponchon-Savarit diagram. The equilibrium data are given as follows:	[7]	1	3

Y_C	$Z_{V'}$	X_C	$Z_{L'}$
0	0	0	2.030303
0.1	0	0.100119	1.978546
0.2	0	0.20047	1.940035
0.3	0	0.300376	1.891009
0.4	0	0.399831	1.817695
0.5	0	0.5	1.751789
0.6	0	0.600214	1.679528
0.7	0	0.700104	1.61233

Q.2(a)	A wet solid of 28% moisture is to be dried to 0.5 % moisture in a tray dryer. A laboratory test shows that it requires 8 hrs to reduce the moisture content of the same solid to 2 %. The critical moisture content is 6 % and the equilibrium moisture is 0.2 %. The falling rate of drying is linear in the free moisture content. Calculate the drying time of the solid if the drying conditions similar to those in the laboratory test are maintained. All moistures are expressed as percent of bone-dry mass of the solid.	[4]	2	3
Q.2(b)	A granular wet solid is taken on a tray (1 m × 0.6 m) and dried in a stream of hot air (120 °C; humidity = 0.02 kg/kg dry air; velocity, u = 4.5 m/s). The initial moisture content of 28% (dry basis) is to be reduced to 0.5 %. From laboratory tests it is known that the critical moisture content is 12% and the equilibrium moisture is negligible. The falling rate of drying is linear in the moisture content. If the solid loading (dry basis) is 35 kg/m2, calculate the drying time. Assume that the air flow is large, and its temperature drop across the tray is small. (Assume that the heat transfer and drying occur at the top open surface only) Given: $h_c = 0.0204(G')^{0.8}$, T_W = 41.5 °C, saturation humidity at 41.5 °C = 0.0545 kg/kg dry air.	[6]	2	4

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Q.3(a)	Why natural draft cooling towers are in hyperbolic shape? Mention the advantages and disadvantages of forced draft cooling tower.	[1.5+2.5]	2	2
Q.3(b)	A cooling tower is to be designed to cool water from 45 °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 5000 kg/m^2.h and the air rate is 1.3 times the minimum. Determine the tower height and wet bulb depression if the individual gas-phase mass transfer coefficient ($k_Y^{/}\bar{a}$) is 5700 kg/m^{3}h ($\Delta Y^{/}$). The volumetric water side heat transfer coefficient is given by $h_L\bar{a} = 0.059L^{0.51}G_S$, in Kcal/m^{3}h K, where L and G_s are mass flow rates of water and air (dry basis). Absolute humidity and Enthalpy at DBT= 30 °C & WBT= 25 °C is 0.019 and 78.7 kJ/kg. Antoine Equation: $\ln P_A^v(bar) = 11.96481 - 3984.923/(T - 39.724)$	[6]	2	5

T (°C)	*lnPv* (Antoine Equation)	p^v (bar)	*Y'* (kg moist/kg dry air)	*H'* kJ/kg dry air
21	-3.694517	0.024859	0.0156487	60.84463
23	-3.572406	0.028088	0.0177391	68.22991
25	-3.452184	0.031676	0.0200784	76.26473
27	-3.333809	0.035657	0.0226937	85.02109
29	-3.217237	0.040066	0.025615	94.57904
31	-3.102429	0.04494	0.028876	105.0278
33	-2.989343	0.05032	0.0325139	116.4669
35	-2.877943	0.05625	0.0365707	129.0081
37	-2.76819	0.062776	0.0410932	142.7765
39	-2.660049	0.069945	0.0461344	157.9135
41	-2.553483	0.07781	0.0517539	174.5789
43	-2.448459	0.086427	0.0580195	192.9541
45	-2.344944	0.095853	0.0650086	213.2463
47	-2.242905	0.10615	0.0728098	235.6928

Q.4(a)	i) Compare physical and chemical adsorption. ii) Describe the steps involved to determine the number of stages needed for a cross-current adsorption.	[2+3]	3	2
Q.4(b)	i) Mention the assumptions and equation of Langmuir isotherm. ii) In a desulphurization unit of natural gas H_2S is adsorbed on ZnO bed. H_2S adsorbed on ZnO bed as 0.25 kg/kg of ZnO at partial pressure 20 kg/cm^2 and 0.85 kg H_2S/kg ZnO at partial pressure 200 kg/cm^2. Assuming Langmuir isotherm is applicable, find the amount of H_2S (in kg) adsorbed on 100 kg ZnO bed at partial pressure 50 kg/cm^2.	[2.5+2.5]	3	2, 4
Q.5(a)	A salt solution weighing 10000 kg with 30 wt% Na_2CO_3 is cooled to 293 K. The salt crystallizes as decahydrate. i)What will be the yield of Na_2CO_3.10H2O crystals if the solubility is 21.5 kg of anhydrous Na_2CO_3/100 kg of total water if no water is evaporated? ii) What will be the yield if 3% of total weight of the solution is lost by evaporation in cooling?	[5]	4	3
Q.5(b)	Illustrate the mechanism of electrodialysis and reverse osmosis. Cite their industrial applications.	[5]	5	2

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