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

CLASS: BE **SEMESTER : V**
BRANCH: CHEMICAL/CHEMICAL P&P **SESSION : MO/18**

SUBJECT: CL5001 MASS TRANSFER OPERATIONS

TIME: 3.00 HOURS **FULL MARKS: 60**

INSTRUCTIONS:
1. The question paper contains 7 questions each of 12 marks and total 84 marks.
2. Candidates may attempt any 5 questions maximum of 60 marks.
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.

Q.1(a) What is film theory? Write the assumptions of film theory. [4]

Q.1(b) Calculate the rate of diffusion of acetic acid (A) across a film of non-diffusing water (B) 0.001 m thick at 290 K if the concentrations of acetic acid on the opposite sides of the film are 9 wt.% and 3 wt.%, respectively. The densities of 9 wt.% and 3 wt.% solutions are 1012 kg/m^3 and 1003 kg/m^3, respectively. The diffusivity of acetic acid in water is 0.95×10^{-9} m^2/s. [8]

Q.2 An air (B) - water-vapor (A) sample has a dry bulb temperature 55°C and an absolute humidity 0.030 kg water/kg dry air at 1 atm (101325 N/m^2). Calculate the following quantities of the mixture. [12]

(a) Molar humidity
(b) Saturation humidity
(c) Relative humidity
(d) Humid volume
(e) Humid heat
(f) Enthalpy

Given: Vapor pressure of water at 55°C = 15730 N/m^2
Heat capacity of water vapor = 1884 J/(kg.°C)
Heat capacity of dry air = 1005 J/(kg.°C)
Latent heat of vaporization = 2502300 J/kg

Q.3(a) A mixture of A and B containing 50 mole% A is to be separated in a continuous fractionating column to give a product of 95 mole% of A at a top and a bottom product contains 1 mole% of A. Using an average relative volatility (α_{AB}) of 2.4, calculate the minimum number of plates required at total reflux condition. [4]

Q.3(b) An equimolar mixture of n-heptane (A) and n-octane (B) were subjected to differential distillation at atmospheric pressure such that bottoms contains 34 mole% of n-heptane (A). Calculate the composition of distillate. [8]
The equilibrium data are given below:

x	0.50	0.46	0.42	0.38	0.34
y*	0.689	0.648	0.608	0.567	0.523

Q.4(a) Define selectivity of a solvent in an extraction operation. [2]

Q.4(b) It is desired to extract acetone (C) from an equimolar mixture containing acetone (C) and water (A), using chloroform (B) as solvent, in two cross current extraction stages. The amount of solvent in each stage is equal. In first stage 60 mole% acetone is extracted. Assuming that water (A) and chloroform (B) are completely immiscible, Determine the following quantities: [10]

(i) amount of solvent used in each stage per mole of feed
(ii) mole fraction of acetone in final product (raffinate phase)

Equilibrium condition is given by y' = 0.5x'
where, x' = moles of acetone (C)/moles of water (A), and y' = moles of acetone (C)/moles of chloroform (B)

Q.5(a) State Mccabe's ΔL law of crystallization. [2]

Q.5(b) Explain Mier's supersaturation theory of crystallization. [4]

Q.5(c) A wet solid is to be dried from 35% to 10% moisture under constant drying conditions in 5 h. If the equilibrium moisture content is 4% and the critical moisture content is 14%. Assuming falling rate is linear, calculate time required to dry the solids to 6% moisture under the same conditions? Given moisture contents are on the wet basis. [6]

Q.6(a) Adsorption on activated carbon is to be used for reducing phenol concentration in waste water from 0.004 g/g of water to 0.0008 g/g of water. The adsorption isotherm at the operating temperature can be expressed as $X = 5.386\ Y^{1/3}$, where X is the phenol concentration in solid (g of phenol/g of solid) and Y is phenol concentration in water (g of phenol/g of water). Calculate the minimum amount of adsorbent needed per kg of water. [4]

Q.6(b) An aqueous solution contains a valuable solute is to be recovered by adsorption on carbon. It is desired to reduce the solute from its original value 9.6 unit/kg of solution to 10 % of its original value. The equilibrium relation is given by $Y^* = 8.91 \times 10^{-5} X^{1.66}$, where Y is unit solute/kg of solution, and X is unit solute/kg of carbon. Calculate the minimum requirement of the carbon per 1000 kg of solution for a single-stage operation and for a two-stage crosscurrent operation. [8]

Q.7(a) Sketch various separator arrangements for membrane separation process in an industry. [2]

Q.7(b) Write short notes on (i) Knudsen diffusivity and (ii) membrane structure [4]

Q.7(c) Classify membrane separation processes and write a short note on each process. [6]

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