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

CLASS: BE **SEMESTER : V**
BRANCH: CHEMICAL/CHEMICAL P&P **SESSION : MO/19**

SUBJECT: CL5001 MASS TRANSFER OPERATIONS

TIME: 3 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) The diffusivity of acetone in water at low concentration at 25°C is 1.16×10^{-9} m^2/s. What would be the diffusivity at 60°C? The viscosity values of the solvent (water) are 0.9 cP at 25°C, and 0.48 cP at 60°C. [2]

Q.1(b) A binary gaseous mixture of components A and B at a pressure of 1 bar and temperature of 300 K undergoes steady-state equimolar counter diffusion along a 1-mm-thick diffusion path. At one end of the path the mole fraction of component A is 70%, while at the other end it is 20%. Under these conditions, D_{AB} = 0.1 cm^2/s. Calculate the molar flux of component A. [4]

Q.1(c) 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 9.5×10^{-10} m^2/s. [6]

Q.2(a) A gas absorber to be designed to handle 900 m^3/h of coal gas containing 2% benzene (by volume). Coal gas enters the absorber at a temperature of 26°C and 1 atm pressure and a 95 % removal is required. The solvent is to enter at 26°C containing 0.005 mole fraction of benzene and has an average molecular weight of 260. Calculate the circulation rate of solvent in kg/s, if the column is to be operated at 1.5 times the minimum value. The equilibrium relationship is given as [6]

$$\frac{Y}{(1+Y)} = 0.125\frac{X}{(1+X)}$$

where, Y and X are the mole ratios of benzene to dry gas and to solvent, respectively.

Q.2(b) A certain air has a dry–bulb temperature of 30°C and a dew point of 20°C. The total pressure is 760 mm Hg. Calculate the following without using humidity chart: (i) molar humidity, (ii) absolute humidity, (iii) percentage relative humidity, (iv) percentage saturation, (v) humid volume, (vi) enthalpy. [6]
Given:
latent heat of vaporization at reference temperature (λ_o) = 2502300 J/kg
specific heat of air = 1005 J (for wet air)/(kg dry air °C)
Specific heat of water = 1884 J (for wet air)/(kg dry air °C)
Antoine equation for water vapor: $\log_{10}(P) = 8.07131 - 1730.63/(233.426+t)$, where P and t are vapor pressure of water in mmHg and temperature in °C, respectively.

Q.3(a) A liquid mixture containing 40 mole% benzene and 60 mole% toluene is subjected to flash distillation at a separator pressure of 101.325 kPa to vaporize 50 mole% of feed. What will be the equilibrium composition of vapor and liquid? Average relative volatility (α_{AB}) for the given system is 2.16. [3]

Q.3(b) An ethanol-water mixture containing 36% by weight of ethanol is differentially distilled at 1 atm pressure and the mixture is reduced to a maximum ethanol concentration of 6 mole %. Determine the composition of the distillate. The VLE data are: [4]

mole fraction ethanol in liquid (x)	0.18	0.16	0.14	0.12	0.10	0.08	0.06
mole fraction ethanol in vapor (y)	0.517	0.502	0.485	0.464	0.438	0.405	0.353

Q.3(c) 1000 kmol/h of an ethanol-propanol mixture containing 65 mole% ethanol is to be separated in a continuous plate column operating at 1 atm total pressure. The desired terminal composition in terms of mole fraction of ethanol are: x_D = 0.92 and x_W = 0.07. The feed is saturated vapor and total condenser is used. Find the reflux ratio which is 1.5 times of minimum reflux ratio. Also calculate the liquid to vapor flow rate ratio in the upper section of the column. Average relative volatility of the ethanol-propanol system may be taken as 2.10. [4]

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

Q.4(b) Draw neat ternary phase diagrams for systems of three liquids: A- carrier, B-Solvent, and C- solute for the cases of: (i) A and B are partially soluble, (ii) Pairs A-B and C-B are partially soluble, (iii) A and B are completely immiscible [3]

Q.4(c) Nicotine (C) in a water (A) solution containing 5% nicotine is to be extracted with kerosene (B) at 20°C. Water and kerosene are essentially insoluble. Determine the percentage extraction of nicotine if 100 kg of feed solution is extracted with three theoretical stages using 50 kg pure solvent in each stage. Equilibrium relation is given as $y'^*=0.923x'$, where y'^* is the equilibrium value of kg nicotine/kg kerosene, and x' is the corresponding value of kg nicotine/kg water. [7]

Q.5(a) Explain Mier's supersaturation theory of crystallization with neat diagram. [4]

Q.5(b) 1400 kg (bone dry) of granular solid is to be dried under constant drying conditions from a moisture content of 0.2 kg/kg of dry solid to a final moisture content of 0.02 kg/kg dry solid. The material has an effective area of 0.0615 m^2/kg. under the same conditions the following rates were previously known. Calculate the time required for drying. [8]

X kg/kg dry solid	0.3	0.2	0.14	0.119	0.098	0.077	0.056	0.046	0.026	0.02
Rate, N kg/(m^2.h)	1.71	1.71	1.71	1.60	1.49	1.38	1.29	0.88	0.54	0.50

Q.6(a) Define mass transfer zone (MTZ) for a fixed bed adsorption system. [2]

Q.6(b) For two stage cross-current adsorption operation with fresh adsorbents, where Freundlich isotherms are applicable, derive the following relation for the requirement of minimum adsorbent amount. [4]

$$\left(\frac{Y_1}{Y_2}\right)^{1/n} - \frac{1}{n}\frac{Y_0}{Y_1} = 1 - \frac{1}{n}$$

Q.6(c) Equilibrium isotherm data for adsorption of glucose from an aqueous solution to activated alumina are as follows: [6]

C (g/cm^3)	0.0040	0.0087	0.019	0.027	0.094	0.195
q (g of solute/g of alumina)	0.0260	0.0530	0.075	0.082	0.123	0.129

Determine the Langmuir isotherm parameters K_L and q_{max} from the given data.

Q.7(a) Define membrane selectivity. How a high membrane selectivity can be obtained? [2]

Q.7(b) A reverse osmosis membrane module is used for water desalinization. The feed water flows at 298 K, 70 bar, and 2 wt.% NaCl. The permeate flows at a pressure of 3 bar and a salt content of 0.05 wt.%. For this membrane, a water permeance of 1.1×10^{-5} g/cm^2-s-bar has been measured. Calculate the transmembrane flux of water, in m^3/m^2-day [4]

Q.7(c) Explain followings with neat sketch: (i) symmetric membrane, (ii) Asymmetric membrane, (iii) composite membrane [6]

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