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NATIONAL INSTITUTE OF TECHNOLOGY HAMIRPUR
(An Institute of National Importance under Ministry of HRD)
Department of Chemical Engineering

CH-311 MASS TRANSFER I
END-SEMESTER EXAMINATION

Maximum Marks: 50 | Time: 3 hours

Instructions:

- Make suitable assumptions, if necessary, by clearly stating them.
- Marks will be deducted for omitting steps.
- Draw the figure wherever needed.
- Exchange of calculator, pen, pencil etc. are strictly not allowed.

Q1. (10 Marks)

Benzene-air mixture is to be scrubbed in a counter-current absorption column using non-volatile hydrocarbon oil as solvent. The inlet gas contains 5% benzene and entering gas flow rate is 600 kmol h^{-1}. The solubility of benzene in oil follows Rauolt's law. The column operates isothermally at 299 K and 1 atm. The average molecular weight of oil is 200. Determine:

a) the minimum oil rate in kg h^{-1} needed to recover 90% of the entering benzene
b) number of theoretical stages needed if the oil rate is 1.5 times the minimum

Additional data: The vapor pressure of benzene is 103 mm Hg at 299 K.

Q2. (15 Marks)

a) Discuss the classification of water-cooling tower. *Brief description is needed against each type.*
b) Hot water at 45 °C is to be cooled in a cooling tower by contact with air to a temperature of 29 °C. Calculate the minimum dry air required in kg s^{-1} and the height of the packed tower if the actual dry air rate is 11 kg s^{-1}.

Additional data:
Air: $T = 30$ °C; $Y = 0.016$ kg of moisture (kg of dry air)$^{-1}$, $C_p = 1.00$ kJ (kg °C)$^{-1}$.
Water: $T = 45$ °C, feed rate = 15 kg s^{-1}, $C_p = 4.19$ kJ (kg °C)$^{-1}$; $C_{p,v} = 1.88$ kJ (kg °C)$^{-1}$ and λ_v = 2500 kJ kg^{-1} at prevailing temperature.
$k_Y a = 0.9$ kg m^{-3} s^{-1} $(\Delta Y)^{-1}$
Equilibrium data:

***T* of air (°C)**	29	32.5	35	37.5	40	42.5	45
***H*' of moist air [kJ (kg of dry air)$^{-1}$]**	100	114	129.8	147	166.8	191	216

Q3. (10 Marks)

Component A is being transferred from the liquid phase to the gas phase in a mass transfer apparatus. The equilibrium relation is given by $y = 0.75x$. At one point in the apparatus, the liquid contains 90 mol% A and the gas in contact with the liquid contains 40 mol% A. The gas film coefficient at the above point is 2 kmol m^{-2} h^{-1} $(\Delta y_A)^{-1}$ and 72% of the total resistance to mass transfer lies in the gas phase. Determine the:

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a) molar flux of A
b) interphase concentration of A in both phases
c) overall mass transfer coefficient based on the gas phase.

Q4. (15 Marks)

By what percentage would the rate of absorption be increased or decreased by increasing the total pressure from 100 to 200 kN m^{-2} in the following:

a) the absorption of NH_3 from a mixture of NH_3 and air containing 10% NH_3 by volume using pure water as solvent. Assume al the resistance lies in the gas phase.
b) The same continues as in (a) but the absorbing liquid exerts partial pressure of NH_3 equal to 5 kN m^{-2}.

The diffusivity be assumed to be inversely related to absorption pressure.

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