NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF ENGINEERING

DEPARTMENT OF CHEMICAL ENGINEERING

TRANSPORT PHENOMENA

ECE 2102

Final Examination Paper

December 2024

This examination paper consists of 4 pages

Time Allowed: 3 hours

Total Marks: 100

INSTRUCTIONS

1. Answer any four (4) questions
2. Each question carries 25 marks
3. Use of calculators is permissible

MARKS ALLOCATION

QUESTION	MARKS
1.	**25**
2.	**25**
3.	**25**
4.	**25**
5.	**25**
TOTAL ATTENABLE MARKS	**100**

QUESTION 1

A. With the aid of a sketch diagram explain molecular diffusion and also briefly explain any two industrial applications of molecular diffusion in mass transfer operations. **[15]**

B. Estimate the liquid **diffusion coefficient of ethanol** (C_2H_5OH) in a dilute solution of water at 10°C. At 10°C, the viscosity of a solution containing 0.05 mol of alcohol/liter of water is 1.45 centipoises, ϕ for water = 2.26 and M_w of water is 18. **See Table 24.5 attached for data.** **[10]**

$$\frac{D_{AB}\mu_B}{T} = \frac{7.4\,x\,10^{-8}}{(V_A)^{0.6}}(\phi_B M_B)^{1/2}$$

QUESTION 2

A. With the aid of a fully labeled diagram, explain Pseudo Steady State Molecular Diffusion through stagnant gas film **[8]**

B. A small diameter tube closed at one end was filled with acetone to within 18 mm of the top and maintained at 290 K and 99.75 kPa with a gentle stream of air blowing across the top. After 15 ks, the liquid level had fallen to 27.5 mm. The vapor pressure of acetone at that temperature is 21.95 kN/m^2. With the aid of a labeled diagram, calculate the diffusivity of acetone in air. Molecular weight of acetone is 58 and density of acetone is 790 kg/m^3. R = 8.314 kPa.m^3/(kmol.K) **[17]**

$$t = \frac{P_{A,L}}{M_A}\left(\frac{RTP_{B,LM}}{PD_{AB}(P_{A1}-P_{A2})}\right)\left(\frac{z_t^2 - z_{t0}^2}{2}\right)$$

QUESTION 3

An ethanol (A)-water (B) solution in the form of a stagnant film 2.0 mm thick at 293 K is in contact at one surface with an organic solvent in which ethanol is soluble and water is insoluble. At point 1 the concentration of ethanol is 16.8 wt % and the solution density, $\rho = 972.8$ kg/m^3. At point 2 the concentration of ethanol is 6.8 wt % and $\rho = 988.1$ kg/m^3. The diffusivity of ethanol is 0.740×10^{-9} m^2/s. Calculate the steady-state flux N_A. The molecular weight of ethanol is 46 and for water 18. **[25]**

$$N_A = \frac{D_{AB}}{\Delta Z \, x_{B,LM}} \left(\frac{\rho}{M}\right)_{av} (x_{A1} - x_{A2})$$

QUESTION 4

A. CO_2 is diffusing through non diffusing air under steady state conditions at a total pressure of 1 atm and temperature 300 K. The partial pressure of CO_2 is 20 kPa at one point and 5 kPa at the other point. The distance between the points is 5 cm. Calculate the flux of CO_2, given that at 300 K and 1 atm, $D_{AB} = 2 \times 10^{-5}$ m^2/s; R = 8 314 m^3 Pa/(kmol.K) **[12]**

$$N_A = \frac{D_{AB}}{RT\Delta Z} \frac{P}{P_{B,LM}} (P_{A,1} - P_{A,2})$$

B. In an experimental study of the absorption of ammonia by water in a wetted-wall column, the overall mass-transfer coefficient, K_G was found to be 2.74×10^{-9} kg mol/(m^2 s Pa). At one point in the column, the gas phase contained 8 mol ammonia and the liquid-phase concentration was 0.064 kg mol ammonia/m^3 of solution. The tower operated at 293 K and 1.013×10^5 Pa. At that temperature, the Henry's law constant is 1.358×10^3 Pa/(kg mol/m^3). If 85% of the total resistance to mass transfer is encountered in the gas phase, determine the individual film mass-transfer coefficients and the interfacial compositions.

[13]

QUESTION 5

A. Name five (5) conditions that exist for the application of similarity analogies in transport phenomena when analyzing convective mass transfer mechanism. **[5]**

B. A large volume of pure water at 26.1°C is flowing parallel to a flat plate of solid benzoic acid, where L= 0.244 m in the direction of flow. The water velocity is 0.061 m/s. The solubility of benzoic acid in water is 0.02948 kg mol/m^3. The diffusivity of benzoic acid is 1.245×10^{-9} m^2/s. Calculate the mass-transfer coefficient (k_c) and the molar flux (N_A).

Data: $\mu = 8.71 \times 10^{-4}$ Pa.s, $\rho = 996$ kg/m^3, $D_{AB} = 1.245 \times 10^{-9}$ m^2/s **[20]**

$$J_D = 0.99 Re^{-0.5} = \frac{k_c}{v} Sc^{2/3}$$

Table 24.5 Atomic volumes for complex molecular volumes for simple substances†

Element	Atomic volume, in cm^3/g mol	Element	Atomic volume, in cm^3/g mol
Bromine	27.0	Oxygen, except as noted below	7.4
Carbon	14.8	Oxygen, in methyl esters	9.1
Chlorine	21.6	Oxygen, in methyl ethers	9.9
Hydrogen	3.7	Oxygen, in higher ethers	
Iodine	37.0	and other esters	11.0
Nitrogen, double bond	15.6	Oxygen, in acids	12.0
Nitrogen, in primary amines	10.5	Sulfur	25.6
Nitrogen, in secondary amines	12.0		

†G. Le Bas, *The Molecular Volumes of Liquid Chemical Compounds*, Longmans, Green & Company, Ltd., London, 1915.

END OF EXAMINATION QUESTION PAPER