UNIVERSITY OF GHANA

B.SC ENGINEERING SECOND SEMESTER EXAMINATIONS, 2014/2015

FPEN 312: MASS TRANSFER (2 Credits)

ANSWER ALL QUESTIONS IN SECTION A, AND 3 OTHERS IN SECTION B (i.e. making a total of 5 questions)

TIME ALLOWED: 2 HOURS.

SECTION A

1

i. Define Fick's first law and coefficient of diffusivity
ii. Explain the phenomenon of molecular diffusion in fluids
iii. Explain the term chemical potential/activity of a solute in two phases in equilibrium
iv. Explain the conditions or the principles that are common to all systems involving the distribution of substances between two insoluble phases.
v. What is a stage in mass transfer operation?

(20 Marks)

2

Methane is diffusing through a stationary hydrogen medium which has an estimated diffusivity of 5.0×10^{-5} m^2/s. Assume the partial pressure of Methane at two planes, 30×10^{-3} m apart are 20 kN/m^2 and 10 kN/m^2 respectively. Calculate the rate of diffusion of methane through the hydrogen medium at 1 atmosphere and 27 °C.

Gas constant R = 8.314×10^3 Nm/kmol K.

Note: 1 atm = 101.325 kN/m^2

(20 Marks)

SECTION B

3

a) Using the equation of continuity and the material balance of component A flowing through three faces with coordinates x,y,z, when velocity =0, and no chemical reaction occurring.

Derive the Fick's second law

$$\frac{\partial C_A}{\partial \theta} = D_{AB}\left(\frac{\partial^2 C_A}{\partial x^2} + \frac{\partial^2 C_A}{\partial y^2} + \frac{\partial^2 C_A}{\partial z^2}\right)$$

(10 Marks)

b) Calculate the rate of diffusion of acetic acid (A) across a film of non-diffusing water (B) solution 1 mm thick at 17 °C when the concentration on opposite sides (1 and 2) of the film are respectively 9 and 3 wt % acid. The diffusivity of acetic acid in the solution is 0.95×10^{-9} m²/s, $M_A = 60.03$ $M_B = 18.02$, Density of the 9% and 3% solutions are 1012 kg/m³ and 1003.2 kg/m³.

(10 Marks)

4

a) Oxygen (A) is diffusing through carbon monoxide (B) under steady state conditions, with the carbon monoxide non-diffusing. The total pressure is 1×10^5 N/m² and the temperature O °C. The partial pressures of oxygen at two plane 2.0 mm apart is, respectively 13000 N/m² and 6500 N/m². The diffusivity for the mixture is 1.87×10^{-5} m²/s. Calculate the rate of diffusion of Oxygen in kmol/s through each square meter of the two planes.

(10 Marks)

b) Recalculate the rate of diffusion of oxygen (A) assuming that the non-diffusing gas is a mixture of methane (B) and hydrogen (C) in the volume ratio 2:1. The diffusivities are estimated to be $D_{AB} = 6.99 \times 10^{-5}$ m²/s and $D_{AC} = 1.86 \times 10\text{-}5$ m²/s

(10 Marks)

5

a) Derive the 'overall resistance' expression in the gas phase and also in the liquid phase in terms of their total mass transfer coefficient and their local mass transfer coefficients in both phases.

(10 Marks)

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} kgmol/m².s.Pa. At one point in the column, the gas phase contained 8 mol ammonia and the liquid phase concentration was 0.064 kgmol ammonia/m³ of solution. The tower operated at 293 K and at 1.013×10^5 Pa. At that temperature the Henry's constant (m) = 1.358×10^3 Pa/(kgmol/m³). If 85% of the total resistance was encountered in the gas phase, determine the individual film mass transfer coefficient and the interfacial composition.

(10 Marks)

6

CO_2 is absorbed into a water film flowing down a vertical wall 1 m long at the rate of 0.05 kg/s per water width at 25 °C . The gas is pure CO_2 at 1 std atm. The water is essentially CO_2 free initially.

The solubility of CO_2 in water at 25 °C 1 std atm is $C_{A,i} = 0.0336$ kmol/m³ ,$D_{AB} = 1.96 \times 10^{-9}$ m²/s, $\rho = 998$ kg/m³, $\mu = 8.94 \times 10^{-4}$

i. What is the thickness of the film
ii. Estimate the Reynolds Number
iii. What is the average coefficient of diffusion $k_{L,av}$
iv. What is the average velocity
v. Estimate the rate of absorption of CO_2

(20 Marks)