NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF INDUSTRIAL TECHNOLOGY
DEPARTMENT OF CHEMICAL ENGINEERING
BACHELOR OF ENGINEERING (HONS) DEGREE
Part Two Examination January 2011

Transport Phenomena-TCE 2101

Duration of Examination: 3 Hours

Instructions to Candidates

1. Answer question **ONE** and any other **THREE** questions
2. Each question carries 25 marks
3. Show all steps clearly in any calculation
4. Start the answers for each question on a fresh page

Question One

(a) State the equation for momentum diffusivity and thermal diffusivity. Give the names and units of the parameters. **(4 marks)**

(b) State the equation for the Sc and Pr numbers. Give the names and units of the parameters. **(4 marks)**

(c) Estimate the liquid mass diffusivity of propanol in a dilute solution of water at 15^oC. **(4 marks)**

Data: $V_c = 14.8\ cm^3/mol$ $V_H = 3.7\ cm^3/mol$ $V_o = 7.4\ cm^3/mol$

(d) State the two equations used to evaluate gas mass diffusivity and one that is used evaluate liquid mass diffusivity clearly defining each term and giving the appropriate units. **(13 marks)**

Question Two

(a) State the Wilke and Chang equation and contrast its application with the Fuller and Hirschfelder equations. **(3 marks)**

(b) Give a schematic representation of diffusion with a crystal and explain each process in detail. **(7 marks)**

(c) The mass transfer co-efficient for a turbulent boundary layer formed over a flat plate has been correlated in terms of the local Nusselt number by

$$Nu_x=0.029Re_x^{4/5}Sc^{1/3}$$

Where x is the distance from the leading edge of the flat plate, the transition from laminar to turbulent flow occurs at $Re_x=3*10^5$. Develop an expression for the mean mass transfer coefficient for a flat plate of length L. **(15 marks)**

Data

$k_{c,lam} = 0.332(D_{AB}/x)(Re_x)^{1/2}(Sc)^{1/3}$
$k_{c,turb} = 0.0292(D_{AB}/x)(Re_x)^{4/5}(Sc)^{1/3}$

k_c average = integral of the sum of $k_{c,lam}$ and $k_{c,turb}$ all dived by L with limits of 0 to L_t and L_t to L respectively.

Question three

(a) Show clearly the derivation of the following analogies: - Chilton-Colburn, Prandtl and Reynold. Each correct stage carries marks. **(15 marks)**

(b) A beaker of ethyl alcohol was accidentally upset covering the top smooth surface of a laboratory bench. The exhaust fan in the laboratory hood produced a 6m/s air flow parallel to the surface, flowing across a 1m wide bench. The air was maintained at 289K and 1 atm ($1.013*1\ 0^5$kPa). The vapour pressure of ethyl alcohol at 289K is 4000Pa. Determine the amount of alcohol evaporating from 1 square meter surface area each 60sec. **(10marks)**

Data

$\nu = 1.48*\ 10^{-5} m^2/s$ $\quad$ $D_{AB} = 1.26*10^{-5}\ m^2/s$ @ 289K
$R = 8.314\ Pa.m^3/mol.K$ $\quad$ $W_A = k_c\ A\ (C_{A,S} - C_{A,\infty})$

Question Four

(a) Define molecular diffusion and briefly explain its significance in mass transfer. **(2 marks)**

(b) Determine the diffusivity of carbon monoxide through a gas mixture in which the mole fractions are: **(5 marks)**

$y_{O2} = 0.25$
$y_{N2} = 0.71$
$y_{CO} = 0.04$

Data: $D_{CO-O2} = 0.185\times10^{-4} m^2/s$ at 273K, 1 atm
$D_{CO-N2} = 0.192\times10^{-4} m^2/s$ at 288K, 1 atm

(c) State the mass transfer equivalent dimensionless number of the Nu number. Give the equation, names and units of the parameters. **(3 marks)**

(d) Show clearly, from first principle, that $1/K_L = 1/mk_G + 1/k_L$ and $1/K_G = 1/k_G + m/k_L$ and explain in detail the physical significance of each term. **(13 marks)**

(e) Clearly explain the physical significance of $1/K_L$ and $1/K_G$. **(2 marks)**

Question Five

In an experimental study of absorption of NH_3 by water in a wetted wall column, the value of K_G was found to be 0.205 lb mole NH_3/hr ft^2 atm. At one point in the column, the gas contained 8 mole percent NH_3 and the liquid phase concentration was 0.004 mole of NH_3 per ft^3 of solution. The temperature was 68^o F, and total pressure was 1 atm. 85% of the total resistance to mass transfer was found to be in the gas phase. If Henry's constant at 68^o F is 0.215atm/ (lb mole NH_3/ ft^3 of solution, calculate the individual film coefficients and interfacial compositions. **(25 marks)**

All The Best!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!