NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF INDUSTRIAL TECHNOLOGY

DEPARTMENT OF CHEMICAL ENGINEERING

BACHELOR OF ENGINEERING (HONS) DEGREE

Part II Examination

2013

TCE 2101 Transport Phenomena (Supplementary)

Duration of Examination: 3 Hours

Instructions to candidates:

Answer **ALL** questions and each question carries 25marks
Answer each question on a **FRESH PAGE**
Write CLEARLY

QUESTION 1

A. Explain four (4) methods of evaluating convective mass transfer coefficient.

[8].

B. Determine the diffusivity of CO_2 (1), O_2 (2) and N_2 (3) in a gas mixture having the composition: CO_2: 28.5 %, O_2: 15%, N_2: 56.5%. The gas mixture is at 273K and 1.2 x10^5 Pa. The binary diffusivity values are given as:(at 273 K)

D_{1-2} P = 1.874 m^2 Pa/sec
D_{1-3} P = 1.945 m^2 Pa/sec
D_{2-3} P = 1.834 m^2 Pa/sec

$$D_{1-mixture} = \frac{1}{\frac{y_2'}{D_{1-2}} + \frac{y_3'}{D_{1-3}} + \cdots + \frac{y_n'}{D_{1-n}}}; \quad y_2' = \frac{y_2}{y_2 + y_3 + \cdots + y_n}$$

[17].

QUESTION 2

A. Determine the diffusivity of N_2 through the gas mixture having the following composition by volume:

N_2 = 67%; CO_2 = 16%; CO = 11%; O_2 = 6% at 273 K and 1.5 atm. **[10].**

Given: $D_{N2\text{-}O2} = 18.1\text{x}10^{-6}$ m^2/s at 273 K and 1 atm

$D_{N2\text{-}CO} = 19.2\ \text{x}10^{-6}$ m^2/s at 288K and 1 atm

$D_{N2\text{-}CO2} = 15.8\text{x}10^{-6}$ m^2/s at 298K and 1 atm

$$\frac{D_{AB,T1}}{D_{AB,T2}} = \left(\frac{T_1}{T_2}\right)^{3/2}\left(\frac{P_2}{P_1}\right)$$

B. Oxygen is diffusing in a mixture of oxygen-nitrogen at 1 std. atm and 25°C. Concentration of oxygen at planes 2 mm apart are 10 and 20 volume % respectively. Nitrogen is non-diffusing.

i) Derive the appropriate expression to calculate the flux of oxygen. Define units of each term clearly. **[12].**

ii) Calculate the flux of oxygen. **[3].**

Diffusivity of oxygen in nitrogen = 1.89 $\text{x}10^{-5}$ m^2/sec.

QUESTION 3

A. Under steady-state conditions, O_2 is diffusing through non-diffusing CO at 273K and under total pressure of 101.3kN/m^2. The partial pressure of O_2 at two planes 2 mm apart is 13.5kN/m^2 and 6.5kN/m^2. If the diffusivity for the mixture is $1.85\text{x}10^{-5}$ m^2/s, determine the rate of diffusion of O_2 through one square meter of the two planes. R = 8.314 kN.m/kmol.K **[8].**

B. E.M. Larson using an Arnold cell measured the diffusivity of chloroform in air at 25°C and 1 atm pressure. The liquid density of chloroform at 25°C is 1.375 g/cm^3 and its vapour pressure at 25°C is 250 mmHg. At time t = 0, the liquid chloroform surface was 6.55 cm from the top of the tube and after 8.5 hrs the liquid surface had dropped to 0.33 cm. If the concentration of chloroform is zero at the top of the tube, what would be the gas diffusion coefficient of chloroform in air? Molecular weight of chloroform is 119.39, 1 gmole of gas occupies 22 400 cm^3 at 1 atm and 273 K. Give your answer in m^2/s. Use a sketch diagram to answer the question. **[17].**

QUESTION 4

A. A fluidized coal fired boiler operates at 1150K. The combustion is preceded by a diffusion process whereby O_2 diffuses to the coal particle surface and CO formed diffuses back in a counter-flow mechanism. Assume that coal is pure carbon of density 1280 kg/m^3 and that the particle is spherical with an initial diameter of 0.15 mm. determine the time required to reduce the diameter of carbon to 0.05mm. Combustion air contains 21 mol % O_2 and 79% mol N_2. $D_{O2\text{-gas mixture}}$ at operation temperature = 1.35×10^{-4} m^2/s.

Reaction: $2C + O_2 \rightarrow 2CO$

$$W_{O2} = 4\pi C r D \ln\left(\frac{1}{1.21}\right)$$

r = radius of coal particle; D = diffusivity of O_2 in the gas film enveloping the coal particles. **[15].**

B. Desorption of a component A from an aqueous solution into an air stream is taking place in a mass transfer tower at a certain operating temperature and pressure. At a particular point in the tower, analysis report reveals:

$P_{A,G}$ = 12 mmHg; $C_{A,L}$ = 4 $kmol/m^3$; K_G = 0.269 kmol A/(h.m^2.atm)

If Henry's law is satisfied by the system and is 56 % of the total mass transfer resistance is encountered in the gas film, calculate:

i) Gas – film coefficient, k_G **[3].**

ii) Liquid –film coefficient, k_L **[3].**

iii) Molar flux N_A **[4].**

H = 7.5×10^{-3} atm/(mol a/m^3. sol)