

**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<sub>2</sub> (1), O<sub>2</sub> (2) and N<sub>2</sub> (3) in a gas mixture having the composition: CO<sub>2</sub>: 28.5 %, O<sub>2</sub>: 15%, N<sub>2</sub>: 56.5%. The gas mixture is at 273K and 1.2 x10<sup>5</sup> Pa. The binary diffusivity values are given as:(at 273 K)

$$D_{1-2} P = 1.874 \text{ m}^2 \text{ Pa/sec}$$

$$D_{1-3} P = 1.945 \text{ m}^2 \text{ Pa/sec}$$

$$D_{2-3} P = 1.834 \text{ m}^2 \text{ Pa/sec}$$

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

[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:  $D_{N_2-O_2} = 18.1 \times 10^{-6} \text{ m}^2/\text{s}$  at 273 K and 1 atm

$D_{N_2-CO} = 19.2 \times 10^{-6} \text{ m}^2/\text{s}$  at 288K and 1 atm

$D_{N_2-CO_2} = 15.8 \times 10^{-6} \text{ m}^2/\text{s}$  at 298K and 1 atm

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

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 =  $1.89 \times 10^{-5} \text{ m}^2/\text{sec}$ .

## QUESTION 3

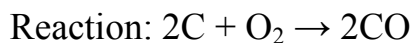
A. Under steady-state conditions,  $O_2$  is diffusing through non-diffusing  $CO$  at 273K and under total pressure of  $101.3 \text{ kN/m}^2$ . The partial pressure of  $O_2$  at two planes 2 mm apart is  $13.5 \text{ kN/m}^2$  and  $6.5 \text{ kN/m}^2$ . If the diffusivity for the mixture is  $1.85 \times 10^{-5} \text{ m}^2/\text{s}$ , determine the rate of diffusion of  $O_2$  through one square meter of the two planes.  $R = 8.314 \text{ kN.m/kmol.K}$  [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  $1.375 \text{ g/cm}^3$  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<sup>3</sup> at 1 atm and 273 K. Give your answer in m<sup>2</sup>/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<sub>2</sub> 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<sup>3</sup> 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<sub>2</sub> and 79% mol N<sub>2</sub>. D<sub>O<sub>2</sub>-gas mixture</sub> at operation temperature = 1.35x10<sup>-4</sup> m<sup>2</sup>/s.



$$W_{\text{O}_2} = 4\pi CrD \ln\left(\frac{1}{1.21}\right)$$

r = radius of coal particle; D = diffusivity of O<sub>2</sub> 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:

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

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<sub>G</sub> [3].

ii) Liquid –film coefficient, k<sub>L</sub> [3].

iii) Molar flux N<sub>A</sub> [4].

$$H = 7.5 \times 10^{-3} \text{ atm}/(\text{mol a/m}^3 \cdot \text{sol})$$