UNIVERSITI TEKNOLOGI PETRONAS

FINAL EXAMINATION
MAY 2023 SEMESTER

COURSE	**:**	**YBB2083 - SEPARATION PROCESS**
DATE	**:**	**2 AUGUST 2023 (WEDNESDAY)**
TIME	**:**	**9:00 AM - 12:00 NOON (3 HOURS)**

INSTRUCTIONS TO CANDIDATES

1. Answer **ALL** questions in the Answer Booklet.
2. Begin **EACH** answer on a new page in the Answer Booklet.
3. Indicate clearly answers that are cancelled, if any.
4. Where applicable, show clearly steps taken in arriving at the solutions and indicate **ALL** assumptions, if any.
5. **DO NOT** open this Question Booklet until instructed.

Note :

i. There are **ELEVEN (11)** pages in this Question Booklet including the cover page .

ii. **DOUBLE-SIDED** Question Booklet.

iii. Graph paper(s) will be provided

1. a. Oxygen diffuses in a mixture of oxygen-nitrogen at 1 std. atm, 25 °C. The concentration of oxygen at planes 2 mm apart are 10 and 20 vol.%, respectively. Nitrogen is non-diffusing.

   i. Construct the appropriate expression to calculate the flux of oxygen. Define the units for each term clearly.

   [6 marks]

   ii. Calculate the flux of oxygen. Given the diffusivity of oxygen in nitrogen is 1.89×10^{-5} m^2/s.

   [2 marks]

   b. Helium (A) and nitrogen (B) gases are contained in a conduit 6 mm in diameter and 0.1 m long at 298 K and a uniform constant pressure of 1.0 atm. The partial pressure of He at one end of the tube is 0.60 atm and at the other end is 0.20 atm. The diffusivity D_{AB} of helium into nitrogen is 6.87×10^{-5} m^2/s. Calculate the flux *of He* in mole/m^2.s.

   [4 marks]

   c. In the absorption process, two types of towers used are tray towers and packed towers, for separating organic pollutants from wastewater. Illustrate the principle of separating organic pollutants from wastewater using various types of tray towers.

   [4 marks]

   d. A gas mixture at 1.0 atm abs containing air and CO_2 is contacted in a single-stage mixer continuously with water at 293 K. The two exit gas and liquid streams reach equilibrium. The inlet gas flow is 100 kmol/h, with a mole fraction of CO_2 of $y_{A,b}$ = 0.20. The liquid flow rate is 300 kmol/h of water. Calculate the amounts and compositions of the two outlet phases. Assume that water does not vaporise to gas.

   [4 marks]

2. a. The gas adsorption process can be divided into two categories: physical adsorption and chemical adsorption.

i. Define the physical adsorption and chemical adsorption processess.

[3 marks]

ii. Outline the difference between physical adsorption and chemical adsorption processes.

[4 marks]

b. A wastewater solution having a volume of 1.0 m^3 contains 0.21 kg phenol/m^3 of solution. A total of 1.40 kg of fresh granular activated carbon is added to the solution, which is then mixed thoroughly to reach equilibrium. Given the isotherm, $q = 0.199c^{0.229}$.

i. Determine the final equilibrium value.

[5 marks]

ii. Calculate the percent of phenol extracted.

[2 marks]

c. Adsorption chromatography involves the analytical separation of a chemical mixture based on the interaction of the adsorbate with the adsorbent. Outline the forces of attraction involves in adsorption chromatographic separation process.

[6 marks]

3. a. Vapor-liquid equilibrium or VLE is a state at which a pure component or mixture exists in both the liquid and vapor phases

i. Name the factors that are affecting the VLE.

[3 marks]

ii. Outline the cause of azeotrope formation during the separation of two different liquids.

[4 marks]

b. A saturated liquid feed of 200 mol/h at the boiling point containing 42 mol% heptane and 58 mol% ethyl benzene is to be fractioned at 101.32 kPa abs to give a distillate containing 97 mol% heptane and a bottoms containing 1.1 mol% heptane. The reflux ratio used is 2.5:1. The equilibrium data for the mole fraction of n-heptane is shown **Table Q3b**.

TABLE Q3b: Equilibrium data at 101.32 kPa abs pressure for the mole fraction of *n*-heptane, x_H and y_H

Temperature (°C)	x_H	y_H
136.1	0	0
129.4	0.08	0.230
119.4	0.250	0.514
110.6	0.485	0.730
102.8	0.790	0.904
98.3	1.000	1.000

Using the McCabe Theile method:

i. Calculate the molar flow rate of distillate in mol/h.

[6 marks]

ii. Calculate the molar flow rate of the bottoms product in mol/h.

[3 marks]

iii. Calculate the theoretical number of trays.

[2 marks]

iv. Estimate the feed tray number.

[2 marks]

4. a. Illustrate the principle (s) of liquid-liquid extraction.

[3 marks]

b. In single-equilibrium stage extraction at 25°C and 101 kPa, 55 wt% water (A) solution - 45 wt% glycol (B) is contacted with twice its weight of pure furfural solvent (C). **FIGURE Q4b** shows the ternary diagram of A, B and C.

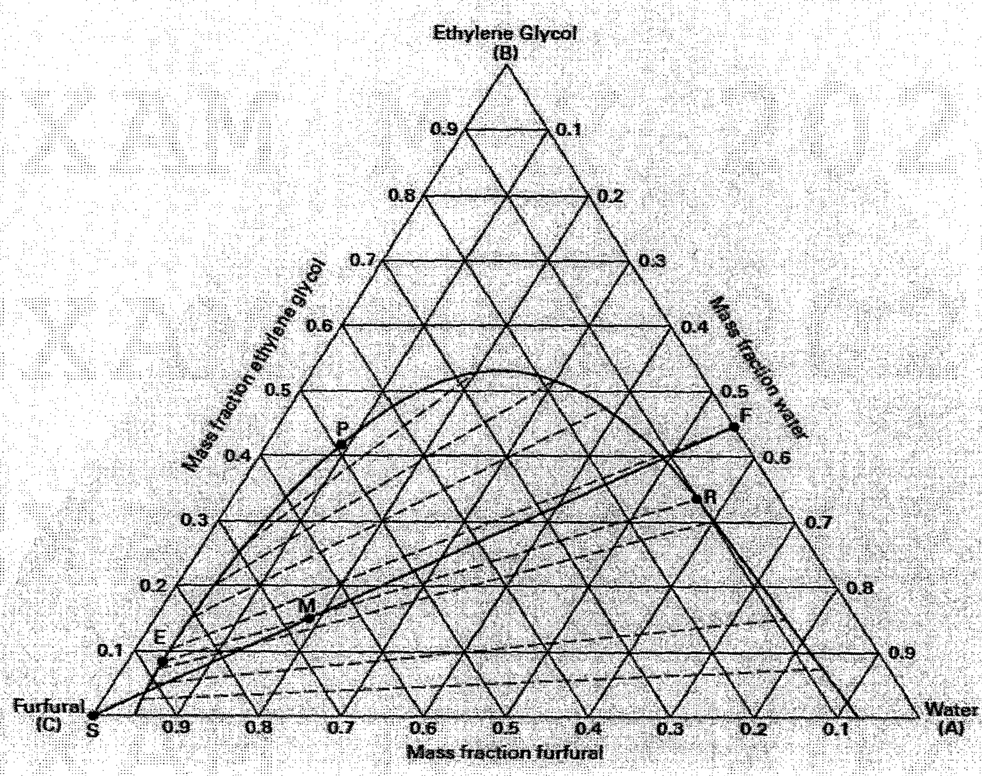

FIGURE Q4b: Ternary diagram of A, B and C.

i. Determine the feed composition of the water rich, F and organic rich phase, S.

[3 marks]

ii. Determine the composition of extract, E and raffinate, R.

[4 marks]

iii. Calculate the product flow rates, L1 and V1.

[5 marks]

c. Rationalize the preference of utilizing the liquid-liquid extraction over distillation in separation of formic acid and water mixture. Given, B_p of formic acid is 100.6 °C, and B_p of water is 100 °C.

[5 marks]

5. a. A membrane separation process is a process where a membrane is used to separate the components in a solution by rejecting unwanted substances and allowing the others to pass through the membrane. However, the separation performance is evaluated by analysing various parameters. Describe the **TWO (2)** parameters that are critically important to assess membrane separation performance.

[4 marks]

b. A liquid containing dilute solute A at a concentration C_1= 3 x 10^{-2} kg mol/m^3 is flowing rapidly through a membrane of thickness L = 3.0 x 10^{-5} m. The distribution coefficient K' = 1.5 and D_{AB} = 7.0 x 10^{11} m^2/s in the membrane. The solute diffuses through the membrane and its concentration on the other side is C_2 = 0.50 x 10^{-2} kg mol/m^3. The mass-transfer coefficient k_{C_1} is large and can be considered as infinite and k_{C_2}= 2.02 x 10^5 m/s.

i. Calculate the steady-state flux, N_A and construct the concentration profile of the two liquid films and membrane.

[6 marks]

ii. Calculate the flux and the concentrations at the membrane interfaces.

[4 marks]

c. Separation of hydrogen from methane is performed by the gas permeation membrane process. Using **TABLE Q5c**, suggest and justify the best membrane material for the separation based on selectivity.

TABLE Q5c: Permeability data of various membrane materials

Material	Permeability, P_m (barrer)	
	Hydrogen	Methane
Ethyl Cellulose	49.2	7.47
Polystyrene	56.0	2.72
Polyester	1.65	0.0035

[6 marks]

-END OF PAPER-

APPENDIX I

PHYSICAL CONSTANTS

Atomic mass unit	1 amu	=	1.661×10^{-24} g
	1 g	=	6.022×10^{23} amu
Avogadro's number	N	=	6.022×10^{23} / mol
Boltzmann's constant	k	=	1.381×10^{-23} J/K
Electron charge	e	=	1.602×10^{-19} C
Faraday's constant	$F = Ne$	=	9.649×10^{4} C/mol
Gas constant	R	=	8.314 J/mol-K
		=	0.08206 L-atm/mol-K
Mass of electron	m_e	=	9.110×10^{-31} kg
Mass of neutron	m_n	=	1.675×10^{-27} kg
Mass of proton	m_p	=	1.673×10^{-27} kg
Atomic mass constant	m_u	=	1.660×10^{-27} kg
Pi	π	=	3.142
Planck's constant	h	=	6.626×10^{-34} J-s
Speed of light	c	=	2.998×10^{8} m/s
Rydberg constant	R_H	=	1.097×10^{7} m^{-1}
	hcR_H	=	2.179×10^{-18} J

APPENDIX II

LIST OF FORMULA

$$J_A^* = -D_{AB}\frac{dc_A}{dz} = \frac{D_{AB}(P_{A1}-P_{A2})}{RT(z_1-z_2)}$$

$$N_A = -D_{AB}\frac{dc_A}{dz} + \frac{c_A}{c}(N_A+N_B)$$

$$N_A = \frac{D_{AB}P}{RT(z_2-z_1)}\ln\frac{P-p_{A2}}{P-p_{A1}}$$

$$N_A = \frac{D_{AB}C_v}{(z_2-z_1)x_{BM}}(x_{A1}-x_{A2})$$

$$N_A = \frac{c_1-c_2}{\frac{1}{k_{c1}}+\frac{1}{p_m}+\frac{1}{k_{c2}}}$$

$$C_{AV} = \frac{\frac{\rho_1}{M_1}+\frac{\rho_2}{M_2}}{2}$$

$$q_F M + c_F S = qM + cS$$

$$\overline{L}\overline{X}_{A,b} + \overline{V}\overline{Y}_{A,t} = \overline{L}\overline{X}_{A,t} + \overline{V}\overline{Y}_{A,b}$$

$$L_b x_{A,b} + V_t y_{A,t} = L_t x_{A,t} + V_b y_{A,b}$$

$$\overline{X}_A = \frac{x_A}{1-x_A} = \frac{\text{mole fraction of A in the liquid}}{\text{mole fraction of non-A components in the liquid}}$$

$$\overline{Y}_A = \frac{y_A}{1-y_A} = \frac{\text{mole fraction of A in the vapour}}{\text{mole fraction of non-A components in the vapour}}$$

$$\overline{Y}_{A,t} = \frac{\overline{L}}{\overline{V}}\overline{X}_{A,t} + \left(\overline{Y}_{A,b} - \frac{\overline{L}\overline{X}_{A,b}}{\overline{V}}\right)$$

$$y_{n+1} = \frac{L_n x_n}{V_{n+1}} + \frac{V_1 y_1 - L_0 x_0}{V_{n+1}}$$

$$L_1 x_{A,1} + V_1 y_{A,1} = M x_{A,M}$$