UNIVERSITI KUALA LUMPUR

MALAYSIAN INSTITUTE OF CHEMICAL AND BIO-ENGINEERING TECHNOLOGY

FINAL EXAMINATION

OCTOBER 2025 SEMESTER

COURSE CODE	:	CPD22203
COURSE TITLE	:	MASS TRANSFER
PROGRAMME NAME	:	DIPLOMA IN CHEMICAL ENGINEERING TECHNOLOGY
DATE	:	26 JANUARY 2026
TIME	:	9:00AM - 12:00PM
DURATION	:	3 HOURS

INSTRUCTIONS TO CANDIDATES

1. Please read the instructions given in the question paper CAREFULLY.
2. This question paper is printed on both sides of the paper.
3. This question paper consist of TWO sections.
4. Section A consist total of 60 marks. Answer ALL questions.
5. Section B consist of three questions. Answer TWO (2) questions only.
6. Please write your answer on the answer booklet provided.
7. Please answer all questions in English only.
8. Refer to the attached Formula/ Appendies. ☐ *Tick if applicable*

THERE ARE 11 PAGES OF QUESTIONS INCLUDING THIS PAGE

SECTION A (Total: 60 marks)

Answer ALL questions.

Please use the answer booklet provided.

Question 1

Answer the following Questions.
All separation processes are based on the principle of mass transfer and diffusion.

(a) Explain the significance of the negative sign in Fick's First Law equation.

(2 marks)

(b) List FOUR(4) key factors affecting diffusion process.

(4 marks)

(c) Describe how a decrease in temperature affects the rate of diffusion in a system.

(2 marks)

(d) Identify one characteristic of equimolar counter diffusion in a binary gas system.

(2 marks)

(e) A binary gas mixture consisting of gases A and B undergoes equimolar counter diffusion in a stationary tube of length 1.0 m. Both ends of the tube are connected to large chambers, so the gas compositions at the ends remain constant. The mole fraction of gas A at point 1 is 0.8, while at point 2 it is 0.2. The total molar concentration of the gas mixture is 4 mol/m^3.The diffusivity of gas A in gas B is 2.5 $\times 10^{-5}$ m^2/s.Estimate the diffusion flux of component A, J_A, in mol/m^2·s.

(5 marks)

Question 2

Answer the following questions

(a) Define the reflux in a distillation column.

(2 marks)

(b) Differentiate between total reflux and minimum reflux ratio in a distillation column.

(4 marks)

(c) Explain the effect of the number of trays or stages on distillation column efficiency.

(2 marks)

(d) State TWO differences between bubble cap tray and sieve tray used in a distillation column.

(2 marks)

(e) Estimate the compositions of vapour (y_A) and liquid (x_A) for Benzene (A) in equilibrium with toluene (B) at temperature 95°C and total pressure of 101.32 kPa. Given the vapor pressure of Benzene and Toluene are 1168 mmHg and 475 mmHg, respectively.

(5 marks)

Question 3

Answer the following question.

(a) List TWO(2) important properties of a good solvent used in gas absorption processes.

(2 marks)

(b) Explain the types of liquid solvent that can affect the efficiency of gas absorption process in industry.

(2 marks)

(c) Describe the application of Henry's Law to estimate the amount of gas absorbed in a solvent for gas absorption process.

(2 marks)

(d) Describe a packed absorption tower process based on vapor-liquid contact type and pressure drop.

(4 marks)

(e) At 303 K, hydrogen sulfide (H_2S) is dissolved in water in a gas absorption system.The amount of H_2S in water is 2.65×10^{-6} kmol, and the amount of water is 0.0555 kmol. The Henry's Law constant(H) for H_2S–water at 303 K is 0.0609×10^4 atm/mole fraction. Estimate the partial pressure of H_2S in the gas phase that must be maintained to prevent H_2S from escaping the aqueous solution.

(5 marks)

Question 4

Answer the following question.

(a) Define the distribution coefficient(K) in liquid-liquid extraction.

(2 marks)

(b) Differentiate between the extract and raffinate phases in terms of solute concentration.

(2 marks)

(c) Describe the effect of temperature on the efficiency of solid-liquid extraction.

(2 marks)

(d) Discuss the effect of agitation on solid-liquid extraction.

(2 marks)

(e) Identify the correct composition of a mixture on a triangular diagram based on given Figure.

Refer Below - Figure1 : Right Triangular Diagram of LLE .

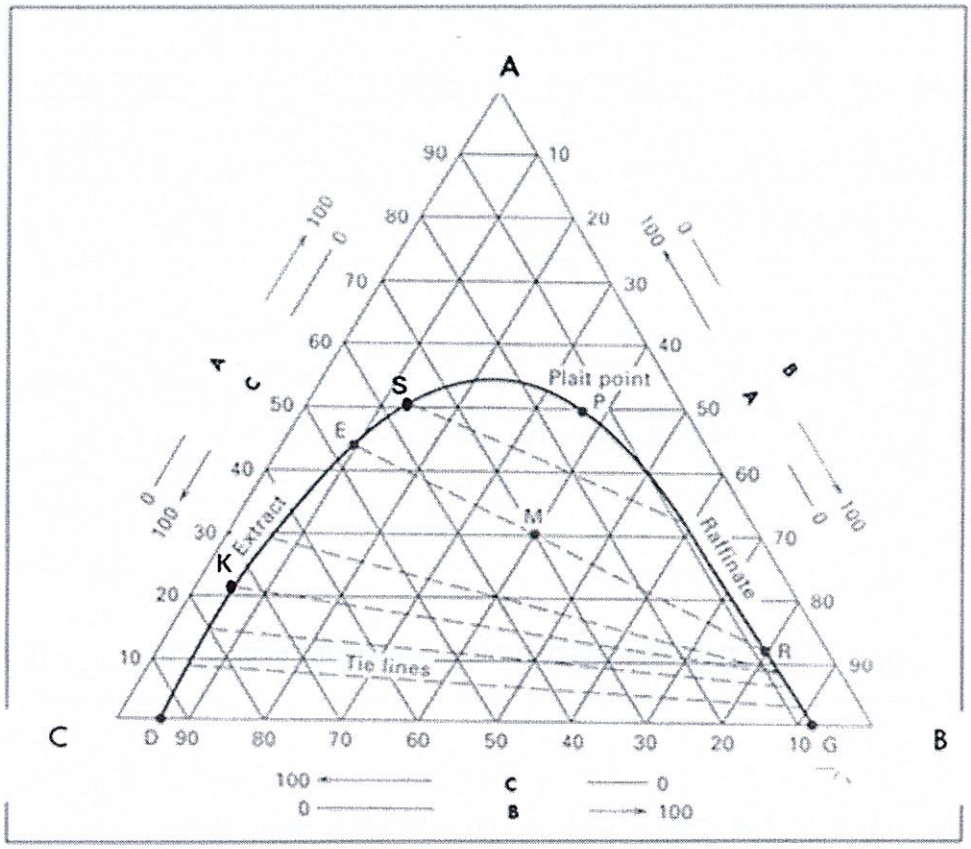

Figure 1: Right Triangular Diagram of LLE

i. Point K

(1 marks)

ii. Point S

(1 marks)

(f) 200 kg of aqueous solution containing 50 wt% acetone is contacted with 600 kg of pure chlorobenzene, followed by separation of the extract and the raffinate phase. The solvent composition at mixing point (M) is x_{CM}= 0.725. It has been found from graphical method that the composition obtained for extract layer, V_1 is y_{A1}= 0.08 and y_{C1}=0.9, Raffinate layer, L_N is x_{AN} =0.04 and x_{CN}=0.017. Estimate the amount of extract (V_1) and raffinate phases L_N.

(5 marks)

SECTION B (Total: 40 marks)

Answer TWO (2) questions only.

Please use the answer booklet provided.

Question 1

Answer the following question.

A continuous fractionating column is to be designed to separate a benzene-toluene mixture, with a feed rate of 14,000 kg/hr. The mixture consists of 56 mol% toluene and 44 mol% benzene. The goal is to produce a distillate product containing 97 mol% benzene and a bottom product containing 98 mol% toluene, under a pressure of 1 atm (101.3 kPa). The feed is preheated and enters the column as a partially vaporized mixture, with 60% in the vapor phase and the remaining 40% in the liquid phase. The equilibrium data for benzene are provided in the table below.

Refer Below - Table1 : Vapor - liquid Equilibrium data for Component Benzene .

Table 1: Vapor - liquid Equilibrium data for Component Benzene

x	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
y	0	0.22	0.39	0.52	0.63	0.71	0.79	0.85	0.91	0.96	1.0

(a) Estimate the minimum reflux ratio (R_{min}) for this separation.

(8 marks)

(b) Determine number of theoretical stages required using Mccabe-Thiele method, if reflux ratio of three times the reflux minimum is used as obtained in answer (a).

(8 marks)

(c) Explain how increasing the reflux ratio affects the number of theoretical stages required and the operating lines in the McCabe–Thiele diagram for a distillation column.

(4 marks)

Question 2

Answer the following question.

100 kg of granulated halibut livers are extracted to produce 26 wt% of oil in a countercurrent multi-batch arrangement by using 50 kg of ether as solvent. It is desired to obtain 80% of oil recovery in the overflow product. The total solution containing solute and solvent in the overflow product is 47.27 kg. It has been found experimentally that the amount of the solution removed in the underflow in association with every kilogram of insoluble matter is given by table below.

Refer Below - Table2 : The entrainment data of oil solute in overflow .

Table 2: The entrainment data of oil solute in overflow

Mass fraction of solute(oil) (overflow), y_A	**Entrainment (kg solution/kg Inert)** **k**
0	0.28
0.1	0.30
0.2	0.40
0.3	0.47
0.4	0.55
0.5	0.66
0.6	0.8
0.67	0.96

(a) Produce the underflow data in term of mass fraction for oil solute (x_A) and solvent(x_S).

(5 marks)

(b) Calculate the composition for underflow outlet product for solute (x_{AN+1}) and solvent(x_{SN+1}).

(7 marks)

(c) Calculate the number of stages required for this extraction using right angle triangular diagram.

(8 marks)

Question 3

Answer the following question.

Pure solvent at the rate of 580 kg/h is being used to extract an aqueous solution of 220 kg/h containing 35 wt% solute by counter-current multistage extraction. The desired exit solute in the aqueous phase is 5wt%. It has been found the composition of mixing point(M) is x_{CM}= 0.725 and x_{AM}= 0.096. The table below presents the liquid-liquid equilibrium data for this system.

Refer Below - Table3 : Liquid-Liquid Solubility Equilibrium Data .

Table 3: Liquid-Liquid Solubility Equilibrium Data

Raffinate Layer			Extract Layer		
Solute	Solution	Solvent	Solute	Solution	Solvent
0	0.988	0.012	0	0.006	0.994
0.029	0.955	0.016	0.008	0.008	0.984
0.133	0.844	0.023	0.048	0.019	0.933
0.369	0.589	0.044	0.216	0.069	0.715
0.464	0.371	0.165	0.362	0.151	0.487

(a) Construct the Right-Angle Triangular diagram Graph (Mass fraction Solvent, (x_C,y_C) against mole fraction Solute (x_A,y_A)) in extract and raffinate phase for this extraction process.

(7 marks)

(b) Estimate the outlet composition of the extract V_1 and the aqueous raffinate L_1 from the answer(a).

(8 marks)

(c) Find the number of stages for this separation.

(5 marks)

END OF EXAMINATION PAPER

Appendix A

$$R = 8.314 \frac{m^3.kPa}{kgmol.K}$$

$$J_A = -D_{AB} \frac{dc_A}{dz}$$

$$J_A = -\frac{cD_{AB}}{(z_2 - z_1)}(y_{A2} - y_{A1})$$

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

$$p_A + p_B = P$$

$$p_i = P_i\, x_i$$

$$P_A x_A + P_B(1 - x_A) = P$$

$$y_i = \frac{P_i\, x_i}{P}$$

$$y_A = \frac{\alpha_{AB} x_A}{1 + (\alpha_{AB} - 1)x_A}$$

$$y_{n+1} = \frac{R}{R+1} x_n + \frac{1}{R+1} x_D$$

$$y_q = \frac{q}{q-1} x_q - \frac{x_F}{q-1}$$

$$y^* = \frac{R_{\min}}{R_{\min} + 1} x^* + \frac{1}{R_{\min} + 1} x_D$$

$$R_{\min} = \frac{x_D - y^*}{y^* - x^*}$$

$$L'\left(\frac{x_2}{1 - x_2}\right) + V'\left(\frac{y_1}{1 - y_1}\right) = L'\left(\frac{x_1}{1 - x_1}\right) + V'\left(\frac{y_2}{1 - y_2}\right)$$

$$L'\left(\frac{x_0}{1 - x_0}\right) + V'\left(\frac{y_{N+1}}{1 - y_{N+1}}\right) = L'\left(\frac{x_N}{1 - x_N}\right) + V'\left(\frac{y_1}{1 - y_1}\right)$$

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

$$x_A = \frac{y_A k}{1+k}$$

$$x_S = \frac{k(1-y_A)}{1+k}$$

$$x_B = \frac{1}{K+1}$$

$$x_{CM} = \frac{Fx_{FC} + Sy_{SC}}{F+S}$$

$$x_{AM} = \frac{Fx_{FA} + Sy_{SA}}{F+S}$$

$$L_O + V_{N+1} = L_N + V_1 = M$$

$$L_O x_{CO} + V_{N+1} y_{N+1} = L_N x_{CN} + V_1 y_{C1} = M x_{CM}$$

$$x_{CM} = \frac{L_0 x_{C0} + V_{N+1} y_{CN+1}}{L_0 + V_{N+1}} = \frac{L_N x_{CN} + V_1 y_{C1}}{L_N + V_1}$$

$$x_{AM} = \frac{L_0 x_{A0} + V_{N+1} y_{AN+1}}{L_0 + V_{N+1}} = \frac{L_N x_{AN} + V_1 y_{A1}}{L_N + V_1}$$

$$\text{mole} = \frac{\text{mass}}{\text{molecular weight}}$$

average MW (in term of mass fraction) $\frac{1}{\bar{M}} = \sum \frac{x_i}{M_i}$

average MW (in term of mole fraction), $\bar{M} = \sum y_i M_i$

$$\text{Molar flowrate} = \frac{\text{mass flowrate}}{\text{molecular weight}}$$

$$\text{Mole fraction, } y_A = \frac{\text{mole of A}}{\text{total mole}}$$

$$\text{Mass fraction, } x_A = \frac{\text{Mass of A}}{\text{total mass}}$$

FACTORS FOR UNIT CONVERSIONS

Quantity	Equivalent Values
Mass	1 kg = 1000 g = 0.001 metric ton = 2.20462 lb_m = 35.27392 oz
	1 lb_m = 16 oz = 5 x 10^{-4} ton = 453.593 g = 0.453593 kg
Length	1 m = 100 cm = 1000 mm = 10^6 microns (μm) = 10^{10} angstroms (Å)
	= 39.37 in = 3.2808 ft = 1.0936 yd = 0.0006214 mile
	1 ft = 12 in = 1/3 yd = 0.3048 m = 30.48 cm
Volume	1 m^3 = 1000 liters = 10^6 cm^3 = 10^6 ml
	= 35.3145 ft^3 = 220.83 imperial gallons = 264.17 gal
	= 1056.68 qt
	1ft^3 = 1728 in^3 = 7.4805 gal = 0.028317 m^3 = 28.317 liters
	= 28 317 cm^3
Force	1 N = 1 kg.m/s^2 = 10^5 dynes = 10^5 g.cm/s^2 = 0.22481 lb_f
	1 lb_f = 32.174 lb_m.ft/s^2 = 4.4482 N = 4.4482 x 10^5 dynes
Pressure	1 atm = 1.01325 x 10^5 N/m^2 (Pa) = 101.325 kPa = 1.01325 bars
	= 1.01325 x 10^6 dynes/cm^2
	= 760 mm Hg at 0°C (torr) = 10.333 m H_2O at 4°C
	= 14.696 lb_f/in^2 (psi) = 33.9 ft H_2O at 4°C
	= 29.921 in Hg at 0°C
Energy	1 J = 1 N.m = 10^7 ergs = 10^7 dyne.cm
	= 2.778 x 10^{-7} kW.h = 0.23901 cal
	= 0.7376 ft-lb_f = 9.486 x 10^{-4} Btu
Power	1 W = 1 J/s = 0.23901 cal/s = 0.7376 ft.lb_f/s = 9.486 x 10^{-4} Btu/s
	= 1.341 x 10^{-3} hp
Temperature	T(K) = T(°C) + 273.15
	T(°F) = 1.8 T(°C) + 32
	T(°R) = T(°F) + 459.67
	T(°R) = 1.8 T(K)