UNIVERSITI KUALA LUMPUR
MALAYSIAN INSTITUTE OF CHEMICAL AND BIOENGINEERING TECHNOLOGY

FINAL EXAMINATION
OCTOBER 2025 SEMESTER

COURSE CODE	:	CCB30502
COURSE NAME	:	SEPARATION PROCESSES 1
PROGRAMME NAME	:	BACHELOR OF CHEMICAL ENGINEERING WITH HONOURS
DATE	:	26 JANUARY 2026
TIME	:	2.00 PM – 5.00 PM
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 consists of FOUR (4) questions. Answer ALL questions.
4. Please write your answers on the answer booklet provided.
5. Answer all questions in English language ONLY.

THERE ARE 8 PAGES OF QUESTIONS AND APPENDICES EXCLUDING THIS PAGE.

(Total: 100 marks)

INSTRUCTION: Answer ALL questions.

Please use the answer booklet provided.

Question 1

The feed of 150 kg mol/h is a saturated liquid at the boiling point containing 30 mol % Benzene (A) and 70 mol % Toluene (B) to be fractionated at 101.325 kPa to give a distillate containing 95 mol % benzene and a bottom containing 10 mol % benzene. The reflux ratio is 3:1 and the equilibrium data for benzene – toluene system is given in **Table 1**.

Table 1: The vapor pressure and equilibrium mole fraction data for benzene-toluene system

Temperature (K)	Vapour Pressure (kPa)		Mole Fraction Benzene at 101.32 kPa	
	Benzene	Toluene	x_A	y_A
353.3	101.32	-	1.00	1.00
358.2	116.9	46.0	0.78	0.90
363.2	135.5	54.0	0.58	0.78
368.2	155.7	63.3	0.41	0.63
373.2	179.2	74.3	0.26	0.46
378.2	204.2	86.0	0.13	0.26
383.8	240.0	101.32	0	0

(a) Calculate the relative volatility for the benzene – toluene system at 373.2 K.

(3 marks)

(b) Calculate the molar flowrate of distillate and bottom product.

(6 marks)

(c) Determine the number of theoretical trays needed and allocate the feed tray.

(12 marks)

(d) Determine the pinch point and calculate the minimum reflux ratio (R_m) for the above process.

(4 marks)

Question 2

A continuous rectifying column treats a mixture consisting of 30 wt% of Benzene and 70 wt% of Toluene at the rate of 6 kg/s and separates it into 97 wt% of Benzene in the top product and 98 wt% of Toluene in the bottom product. The feed is liquid at its boiling point. Molecular weight of Benzene and Toluene are 78 g/mol and 92 g/mol,respectively.

(a) Calculate the mass flowrates of Benzene at top and bottom products.

(10 marks)

(b) If the reflux ratio of 3.5 is employed, estimate the number of stages required in the column and also the feed tray using McCabe-Thiele Method. The equilibrium data is given in **Table 2**.

(15 marks)

Table 2: Equilibrium data

Mole fraction of Benzene in liquid	Mole fraction of Benzene in vapor
0	0
0.1	0.22
0.2	0.38
0.3	0.51
0.4	0.62
0.5	0.70
0.6	0.78
0.7	0.85
0.8	0.91
0.9	0.96
1	1

Question 3

(a) A gas mixture at 1.0 atm pressure abs containing air and CO_2 is contacted in a single-stage mixer continuously with pure water at 293 K. The two exit gas and liquid streams reach equilibrium. The inlet gas flow rate is 100 kg mol/h, with a mole fraction of CO_2, y_{A2} = 0.20. The liquid flow rate entering is 300 kg mol water/h. Calculate the amounts and compositions of the two outlet phases.

(10 marks)

(b) It is desired to absorb 90% of the acetone in a gas containing 1.0 mol % acetone in air in a countercurrent stage tower. The total inlet gas flow to the tower is 30.0 kg mol/h and the total inlet pure water flow to be used to absorb the acetone is 90 kg mol H_2O/h. The process is to operate isothermally at 300 K and a total pressure of 101.3 kPa. The equilibrium relation for the acetone (A) in the gas-liquid is $y_A = 2.53x_A$. Determine the number of theoretical stages required for this separation.

(15 marks)

Question 4

Pure solvent isopropyl ether at a flowrate of 600 kg/h is being used to extract an aqueous solution of 200 kg/h containing 30 wt % acetic acid and 70 wt % water by a countercurrent multistage extraction. The desired exit acetic acid concentration in the aqueous phase is 4%. The equilibrium data at 20°C, 1 atm is given in **Table 3.**

(a) Using the equilibrium data presented in **Table 3**, plot a graph to calculate the compositions and amounts of the ether extract and the aqueous raffinate.

(17 marks)

(b) Using the plotted graph in (a), calculate the number of stages required.

(8 marks)

Table 3 Equilibrum data for Water-Acetic Acid – Isopropyl Ether at 20°C and 1 atm

Water Layer, wt %			Isopropyl Ether Layer, wt %		
Acetic Acid	Water	Isopropyl Ether	Acetic Acid	Water	Isopropyl Ether
x_B	x_A	x_C	x_B	x_A	x_C
0.69	98.1	1.2	0.18	0.5	99.3
1.41	97.1	1.5	0.37	0.7	98.9
2.89	95.5	1.6	0.79	0.8	98.4
6.42	91.7	1.9	1.93	1.0	97.1
13.3	84.4	2.3	4.82	1.9	93.3
25.5	71.1	3.4	11.4	3.9	84.7
36.7	58.9	4.4	21.6	6.9	71.5
44.3	45.1	10.6	31.1	10.8	58.1
46.4	37.1	16.5	36.2	15.1	48.7

END OF EXAMINATION PAPER

APPENDIX A

Factors for Unit Conversions

Quantity	Equivalent Values
Mass	1 kg = 1000 g = 0.001 metric ton = 2.20462 lb_m = 35.27392 oz
	1 lbm = 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 ($\mathring{A}$) = 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 lbf
	1 lbf = 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 lbf/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-lbf = 9.486 x 10^{-4} Btu
Power	1 W = 1 J/s = 0.23901 cal/s = 0.7376 ft.lbf/s = 9.486 x 10^{-4} Btu/s
	= 1.341 x 10^{-3} hp

APPENDIX B

Temperature conversion

T(K) = T(°C) + 273.15

T(°R) = T(°F) + 459.67

T(°R) = 1.8 T(K)

T(°F) = 1.8 T(°C) + 32

The gas constant (R)

8.314 m^3.Pa/(mol.K)

0.08314 L.bar/(mol.K)

0.08206 L.atm/(mol.K)

0.7302 ft^3.atm/(lb-mole.°R)

8.314 J/mol.K

Distillation

$$F = D + W$$

$$Fx_F = Dx_D + Wx_W$$

$$R = \frac{L_n}{D}$$

Equation for enriching section

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

Equation for stripping section

$$y_{m+1} = \frac{L_m}{V_{m+1}}x_m - \frac{Wx_W}{V_{m+1}}$$

q line

$$y = \frac{q}{q-1}x - \frac{x_F}{q-1}$$

Minimum reflux ratio

$$\frac{R_m}{R_m+1} = \frac{x_D - y'}{x_D - x'}$$

Roults Law, $P = P_A + P_B = P_AX_A + P_BX_B$

Multistage countercurrent extraction

$$L_0 + V_{N-1} = L_N + V_1 = M$$

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

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

For component A

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

Single-stage equilibrium:

$$V' = V(1 - y_{A1})$$

$$L' = L(1 - x_{A1})$$

$$L'\left(\frac{x_{A0}}{1 - x_{A0}}\right) + V'\left(\frac{y_{A2}}{1 - y_{A2}}\right) = L'\left(\frac{x_{A1}}{1 - x_{A1}}\right) + V'\left(\frac{y_{A1}}{1 - y_{A1}}\right)$$

Design of plate absorption tower

Overall material balance

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

A balance around dashed-line

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

Design of packed towers for absorption

Overall material balance

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

A balance around dashed-line

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

APPENDIX C

A.3-18 Henry's Law Constants for Gases in Water ($H \times 10^{-4}$)*

T											
K	$^{\circ}C$	CO_2	CO	C_2H_6	C_2H_4	He	H_2	H_2S	CH_4	N_2	O_2
273.2	0	0.0728	3.52	1.26	0.552	12.9	5.79	0.0268	2.24	5.29	2.55
283.2	10	0.104	4.42	1.89	0.768	12.6	6.36	0.0367	2.97	6.68	3.27
293.2	20	0.142	5.36	2.63	1.02	12.5	6.83	0.0483	3.76	8.04	4.01
303.2	30	0.186	6.20	3.42	1.27	12.4	7.29	0.0609	4.49	9.24	4.75
313.2	40	0.233	6.96	4.23		12.1	7.51	0.0745	5.20	10.4	5.35

* $p_A = Hx_A$, p_A = partial pressure of A in gas in atm, x_A = mole fraction of A in liquid, H = Henry's law constant in atm/mole frac.

Source: National Research Council, *International Critical Tables*, Vol. III. New York: McGraw-Hill Book Company, 1929.