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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER III
SESSION 2013/2014

COURSE NAME	:	SEPARATION PROCESS TECHNOLOGY
COURSE CODE	:	DAK 21703
PROGRAMME	:	2 DAK
EXAMINATION DATE	:	AUGUST 2014
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **FOUR (4)** QUESTIONS ONLY

THIS QUESTION PAPER CONSISTS OF **ELEVEN (11)** PAGES

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Q1 (a) State both solute (component B) and carrier (component A) in each example below:

(i) Oil in a sunflower seed

(ii) Solid insoluble oxide containing Na_2CO_3

(iii) Decaffeinated coffee powder

(6 marks)

(b) A feed of 5436 kg/h of a 25 wt% solution of p-dioxane in water is to be separated continuously with 4806 kg/h of benzene. The distribution coefficient, K'_{DB} is 1.35. Assuming benzene and water are mutually insoluble, determine the percentage (%) of recoveries for the following alternative procedures:

(i) Two stage countercurrent cascade

(5 marks)

(ii) Three stage crosscurrent cascade

(5 marks)

(iii) If the loss due to unextracted p-dioxane is RM5/kg, calculate the loss for each procedures above

(4 marks)

(c) Sketch a solid-liquid extraction diagram complete with its four (4) streams symbolized by F, E, R, S and all its related components (A, B, and C)

(5 marks)

Q2 (a) State the best choice of device between a trayed and a packed column for the statements below:

(i) Column diameter is less than 2 ft

(ii) Column height is less than 20 ft and low pressure drop

(iii) Pressure drop above 200 psia and low liquid velocities

(iv) High degree of separation required

(8 marks)

(b) A feed gas to an absorber containing 17 mol% CO_2 and 83 mol% air, is to be absorbed in a 5.0-N solution of triethanolamine (or amine), containing 0.04 mol CO_2 per mole of amine solution. The column operates isothermally at 25^oC, and the exit liquid contains 87.4% of the CO_2 in the feed gas to the absorber, and if absorption is carried out in a six (6) theoretical plate column, use equilibrium data below to:

Table Q2 (b)

Equilibrium Data						
X	0.003	0.008	0.015	0.023	0.032	0.043
Y	0.01	0.02	0.03	0.04	0.05	0.06

Equilibrium Data					
X	0.055	0.068	0.083	0.099	0.12
Y	0.07	0.08	0.09	0.10	0.11

(i) State the value of X_0, Y_{N+1}, and Y_1

(3 marks)

(ii) Calculate the exit gas (top product) composition in terms of mol%

(4 marks)

(iii) Plot the equilibrium curve of Y versus X

(4 marks)

(iv) Determine the value of X_N from trial and error method, using the value of Y_{N+1}

(3 marks)

(v) Determine the moles of amine per mole of feed gas

(3 marks)

Q3 A stream feed of five hundred and forty lbmol/h of a mixture of 60 mol% benzene (LK-component x) and 40 mol% toluene (HK-component y) is to be separated to produce a liquid distillate and a liquid bottoms product of 90 mol% and 10 mol% benzene respectively. The feed enters the column at 1 atm with a molar percent vaporization equal to the distillate-to-feed ratio. Use the McCabe-Thiele method to compute:

(a) Minimum equilibrium stages, N_{min} using **Figure Q3 (a)** (7 marks)

(b) Minimum reflux ratio, R_{min} (8 marks)

(c) Number of equilibrium stages, N given that the reflux ratio, $R = 1.4R_{min}$ using **Figure Q3 (b)** (8 marks)

(d) The optimum feed-stage location based on the answer in Q3 (c) (2 marks)

Q4 (a) State the use of each equation below:

(i) Fenske equation (state one use only)

(ii) Underwood equations

(iii) Gilliland correlation

(iv) Kirkbide equation

(8 marks)

(b) A debutanizer as shown in **Figure Q4 (b)** is operated at a uniform operating pressure of 80 psia throughout the column. The distillate (top) temperature is 123°F and its bottoms temperature is 340°F.

(i) Determine the two key components (i, j)

(2 marks)

(ii) Tabulate the mole fraction for all components in distillate (x_D), and mole fraction for all components in bottoms (x_B)

(4 marks)

(iii) Calculate the relative volatility,α for component i and j, α_m using equilibrium data in **Table Q4 (b)**
(note that LK = i and HK = j)

(6 marks)

(iv) Estimate the minimum theoretical stages, N_{min} by Fenske equation

(3 marks)

(v) Determine the actual number of stages, N if its value is 2 times N_{min}

(2 marks)

Q5 A simple batch pot is used to separate methanol (CH_3OH) from water using batch distillation method. The pot is initially filled with W_0 = 50 moles of an 80 mol% methanol at atmospheric pressure of 1 atm. The solution is then distilled to obtain the desired distilled concentration (x_D) of 89.15% of methanol. Using trial and error from **Figure Q5 (a) and Figure Q5 (b)**, estimate at which value of D_{Total}, W_{final} and $x_{W\ final}$ yield the value of $x_D \approx 89.15\%$ when:

(a) The first guessed value of $x_{W\ final} = 0.60$

(8 marks)

(b) The second guessed value of $x_{W\ final} = 0.65$

(8 marks)

(c) A tabulated data of vapor pressure, P^s for a vapor-liquid mixture of water (H_2O) and methane (CH_4) at P = 2 atm and T = 20 and 80°C is as below:

T (°C)	P^s for H_2O (atm)	P^s for CH_4 (atm)
20	0.02307	3.76×10^4
80	0.4673	6.82×10^4

(i) Calculate the K-value and α for water over methane at 20°C

(3 marks)

(ii) Calculate the K-value and α for water over methane at 80°C

(3 marks)

(iii) Sketch a simple batch distillation (or Rayleigh distillation)

(3 marks)

Q6 (a) State four (4) points to compare an absorber with a stripper with the aid of suitable diagrams

(10 marks)

(b) For a stream of liquid comprising of component A and B:

(i) Express the relative volatility of A to B, $\alpha_{A,B}$ in terms of P^s and P

(ii) Express the relative volatility of A to B, $\alpha_{A,B}$ in terms of γ, P^s and P

(iii) Given that K = 0.55, rearrange the K-value equation so that Y is in the left side of the equation

(iv) Given that K = 0.45, rearrange the K-value equation so that X is in the left side of the equation

(12 marks)

(c) State three (3) parameters that can be determined from the McCabe-Thiele Method

(3 marks)

- END OF QUESTION –

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LIST OF FORMULA

$E = K'_{DB}S/F_A$

$K'_{DB} = Y_B / X_B$

$1 - X_B^{(n)} / X_B^{(F)} = 1 - 1 / (1 + E/N)^n$

$1 - X_B^{(R)} / X_B^{(F)} = 1 - 1 / (1 + E + E^N)$

$1 - X_B^{(R)} / X_B^{(F)} = Y_1 (S - RF_A) / F_B$

$Y_{N+1} = X_N (L'/V') + Y_1 - X_0 (L'/V')$

Y_{N+1} = mol B in / mol gas (A)

Y_1 = mol B out / mol gas (A)

X_N = mol B out / mol liq solvent (C)

X_0 = mol B in / mol liq solvent (C)

$y = Y / (1 + Y)$

$z_F (F) = x_D (D) + x_B (B)$

$F = D + B$

$q = 1 - (D/F)$

Absorber's slope operating line = L' / V'

McCabe Thiele's slope rectifying operating line = (R / R + 1)

McCabe Thiele's slope rectifying operating line (min reflux) = (R_{min} / R_{min} + 1)

McCabe Thiele's slope q-line = (q / q – 1)

normal slope, m = Δy / Δx

$\alpha_m = [(\alpha_{i,j})_N \times (\alpha_{i,j})_1]^{0.5}$

$N_{min} = \log [(x_{Di} / x_{Dj}) (x_{Bi} / x_{Bj})] \div \log \alpha_m$

$$\alpha_{i,j} = \frac{K_i}{K_j} \ or\ \alpha_{A,B} = \frac{K_A}{K_B}$$

$$W_{final} = W_0 \exp\left(-\int_{x0}^{x} \frac{dx}{y - x}\right) \ or\ W_{final} = W_0 \exp(-Area\ under\ the\ curve)$$

$$D_{total} = W_0 - W_{final}$$

$$x_D = \frac{W_0 x_0 - W_{final} x_{W\,final}}{D_{total}}$$

$$K_n = \frac{y_n}{x_n} = \frac{Y_n/(1 + Y_n)}{X_n/(1 + X_n)}$$

$$K = \frac{P^s}{P} \ or\ K = \frac{\gamma P^s}{P}$$

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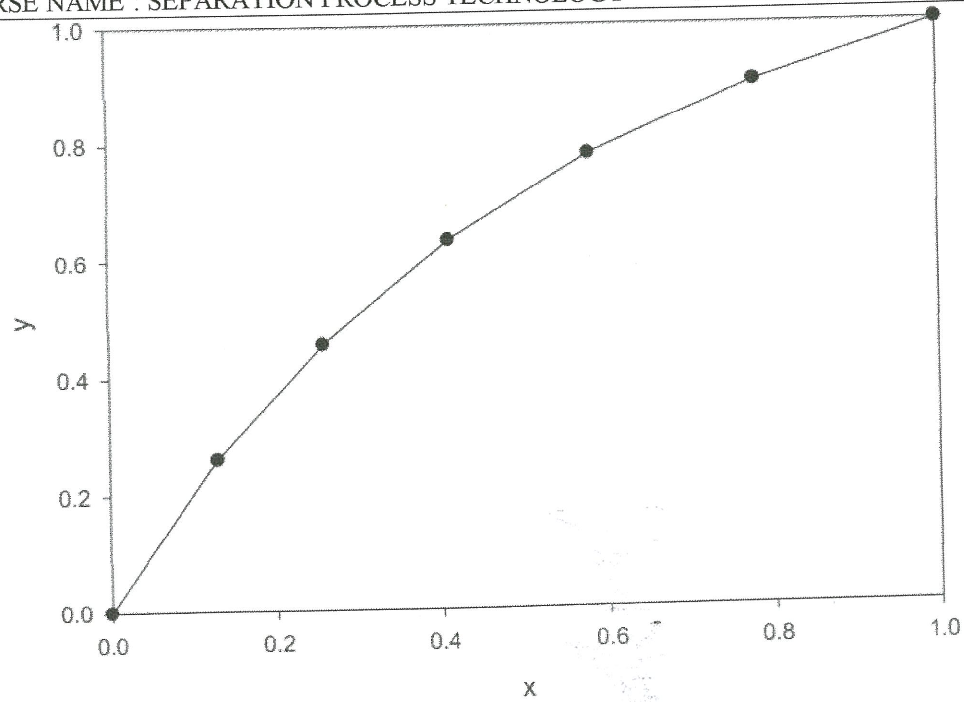

FIGURE Q3 (a)

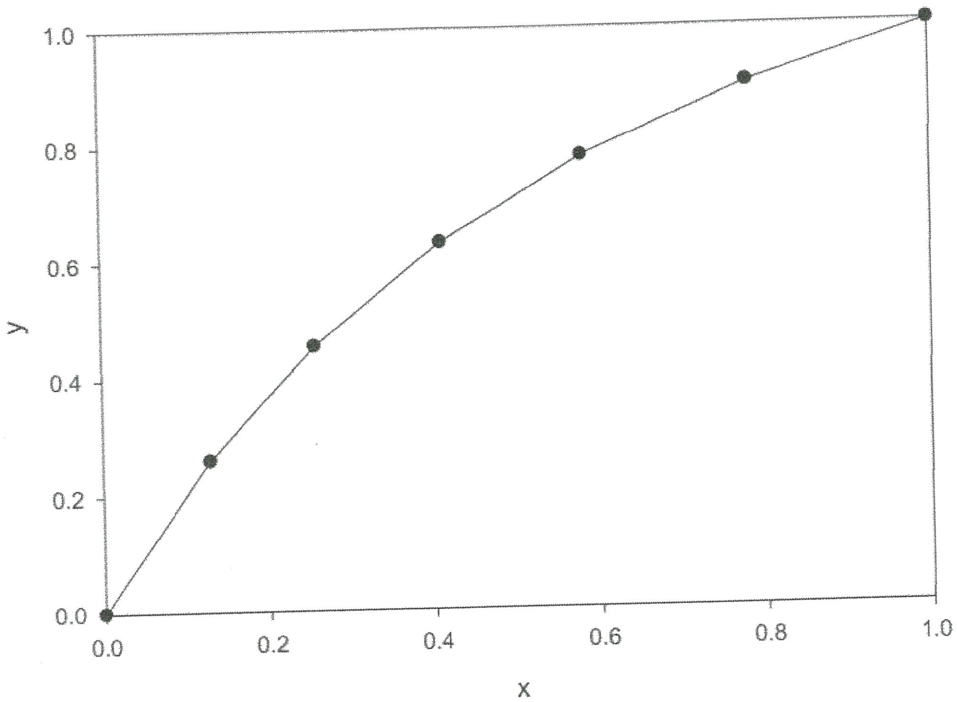

FIGURE Q3 (b)

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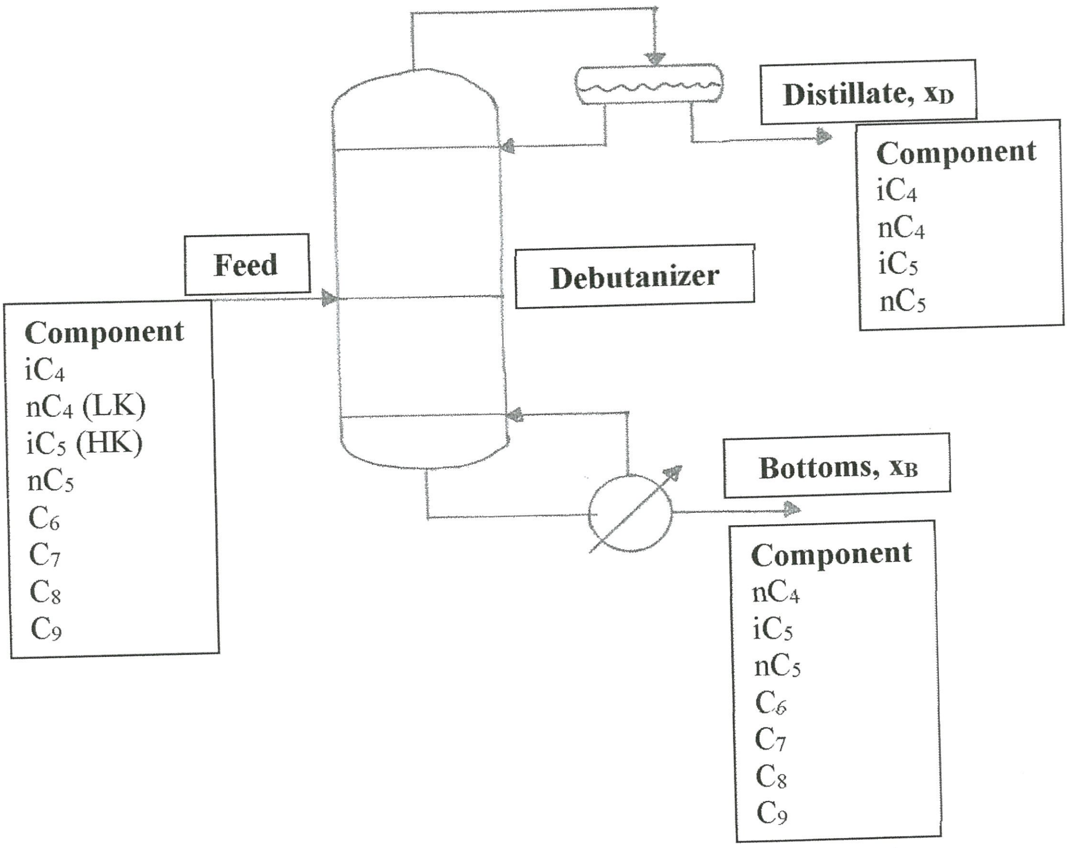

FIGURE Q4 (b)

TABLE Q4 (b)

Component	Distillate,D (lbmol/h)	Bottoms, B (lbmol/h)	K-value at 123°F (top, N)	K-value at 340°F (bottom, 1)
iC_4	12	~0		
nC_4 (LK)	450	6	1.04	5.21
iC_5 (HK)	13	23	0.496	3.61
nC_5	2	14		
C_6	~0	23		
C_7	~0	39		
C_8	~0	272		
C_9	~0	31		
	477	408		

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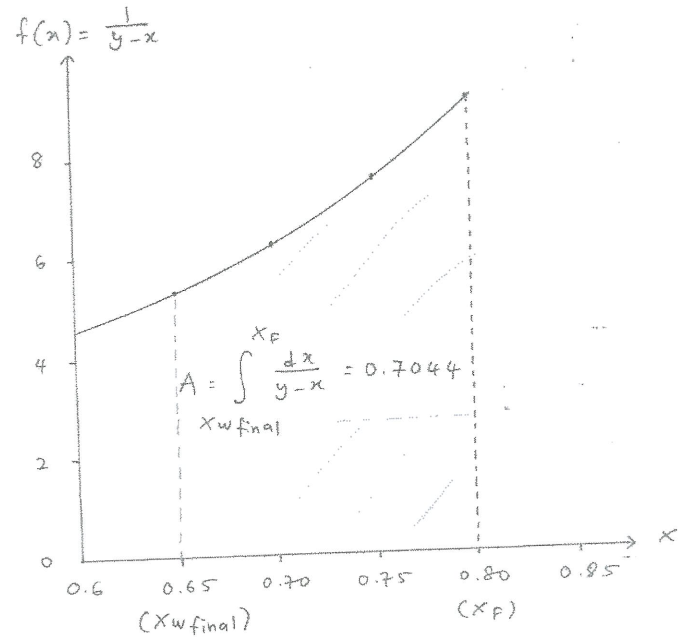

FIGURE Q5 (a)

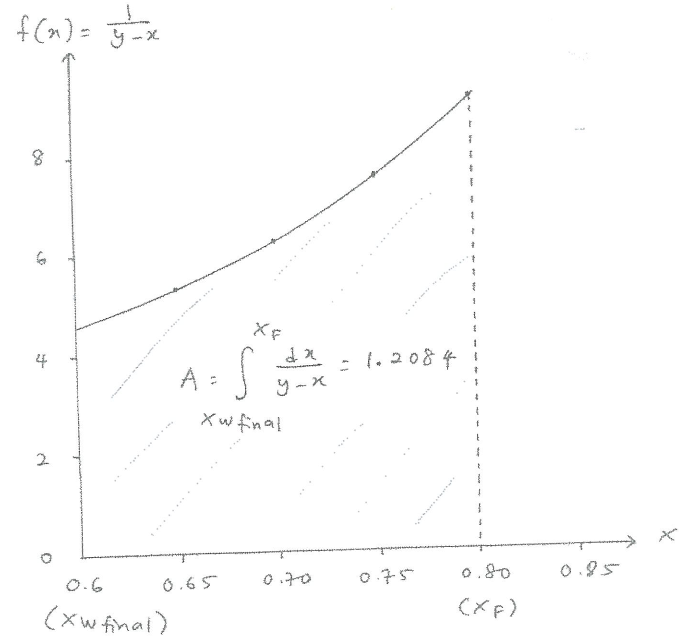

FIGURE Q5 (b)