UNIVERSITI SAINS MALAYSIA

First Semester Examination
2009/2010 Academic Session

November 2009

EKC 511 – Advanced Separation Process

Duration : 3 hours

Please check that this examination paper consists of FIVE pages of printed material before you begin the examination.

Instruction: Answer **ALL** **(4)** questions.

Answer ALL (4) questions.
Jawab SEMUA soalan.

1. A feed of ethanol-water containing 50 wt.% ethanol is to be distilled at 101.32 kPa pressure to give a distillate containing 85 wt.% ethanol and a bottom product containing 2 wt.% ethanol. The distillate is fed to the pervaporation unit in order to increase the ethanol concentration of an ethanol-water mixture.

[a] Draw an appropriate schematic diagram and suggest a suitable membrane material for this particular system.

[5 marks/markah]

[b] A typical pervaporation membrane operates at $T_p = T_{out} = 30^oC$ where the selectivity of water compared to ethanol is 67, the feed rate is 1000 kg/h and the flux is 0.035 kg/m^2·h. If a cut, $\theta' = 0.085$ is used, find:

[i] Permeate mole fraction

[ii] Outlet liquid mole fraction

[iii] Feed inlet temperature

[iv] Membrane area

[v] Is the process feasible?

[20 marks/markah]

Data given:

Heat capacity of water = 4.18 kJ/kg·K
Heat capacity of ethanol = 2.73 kJ/kg·K
Latent heat of water = 2259 kJ/kg
Latent heat of ethanol = 839 kJ/kg

Useful formula:

$$y_p = \frac{\alpha_{AB} x_{out}}{1 + (\alpha_{AB} - 1) x_{out}}$$

$$y_p = \frac{-(1-\theta') x_{out}}{\theta'} + \frac{x_{in}}{\theta'}$$

$$T_{in} = T_{out} + \frac{\theta' \lambda_p}{C_{PL,in}}$$

2. [a] State the difference between sorption and adsorption? What make carbon nanotubes as good adsorbents?

[7 marks/markah]

[b] A 30 cm height laboratory column is packed with activated carbon particles having an average diameter of 0.12 mm. At a superficial velocity of 10 cm/min, the breakthrough curve is measured for a step input of solute. The column was initially clean. The center of the symmetrical breakthrough curve exits at 36.2 minutes while the width (measured from 0.05 c_F to 0.95 c_F) is 3.2 minutes. Assume pore diffusion controls and isotherm has a Langmuir type shape.

[i] What is the value of L_{MTZ} in the column?

[ii] If we want to design a large-scale column with 0.85 fraction of the bed used, how high should this column be? The average particle diameter will be 1 mm. The superficial velocity will be 12 cm/min. Assume ε_e is same in both columns.

[iii] What is t_{br} (c_{out} = 0.05 c_F)?

[18 marks/markah]

3. 1000 kmol/h of a feed mixture (F) of two components A and B containing 0.8 mol fraction of A is to be separated into a stream W_2 containing 0.95 mole fraction of A and a residual stream W_1 of mole fraction of 0.05 of A. Equilibrium data of the mixture is given in Table Q.3.1. A two column distillation process is used for separation as shown in Figure Q.3.1. Feed enters column 2. The distillate in column 2 is condensed and fed to a separator. The distillate from column 1 is also fed to the separator after condensation. Due to heterogeneity of the distillate mixture, the condensate separates into two phases P and Q s of mole fraction 0.3 and 0.85 of A respectively. The vapour streams V_1 and V_2 leaving the columns 1 and 2 are having mole fractions of 0.7 and 0.75 respectively.

1000 kmol/j suatu campuran suapan (F) dua komponen A dan B yang mengandungi 0.8 pecahan mol A akan dipisahkan kepada suatu aliran W_2 yang mengandungi 0.95 pecahan mol A dan suatu aliran baki W_1 dengan pecahan mol 0.05 A. Data keseimbangan campuran diberikan dalam Jadual S.3.1. Suatu proses penyulingan dua turus digunakan bagi pemisahan yang ditunjukkan dalam Rajah S.3.1. Suapan memasuki turus 2. Sulingan dalam turus 2 dipeluwap dan disuapkan ke sebuah pemisah. Sulingan dari turus 1 juga disuapkan ke pemisah tersebut selepas pemeluwapan. Disebabkan oleh keheterogenan campuran suligan, peluwap tersebut terpisah kepada dua fasa P dan Q dengan pecahan mol A masing-masing ialah 0.3 dan 0.85. Aliran wap V_1 dan V_2 yang keluar dari turus 1 dan 2 masing-masing mempunyai pecahan mol 0.7 dan 0.75.

Estimate:
Anggarkan:

[a] the flow rates of W_1, W_2, P, Q , V_1 and V_2 in kmol/h.
kadar aliran W_1, W_2, P, Q , V_1 dan V_2 dalam kmol/j.

[10 marks/markah]

[b] the number of theortical stages in column 1
bilangan peringkat teori dalam turus 1.

[15 marks/markah]

Mole fraction of A in vapour *Pecahan mol A dalam wap*	0	0.245	0.397	0.52	0.534	0.605	0.654	0.693	0.739
Mole fraction of A in liquid *Pecahan mol A dalam cecair*	0	0.049	0.1	0.161	0.173	0.232	0.288	0.358	0.487
Mole fraction of A in vapour *Pecahan mol A dalam wap*	0.758	0.758	0.758	0.758	0.8	0.82	0.832	0.883	1
Mole fraction of A in liquid *Pecahan mol A dalam cecair*	0.551	0.58	0.628	0.8	0.927	0.986	0.993	0.996	1

Table 3.1
Jadual 3.1

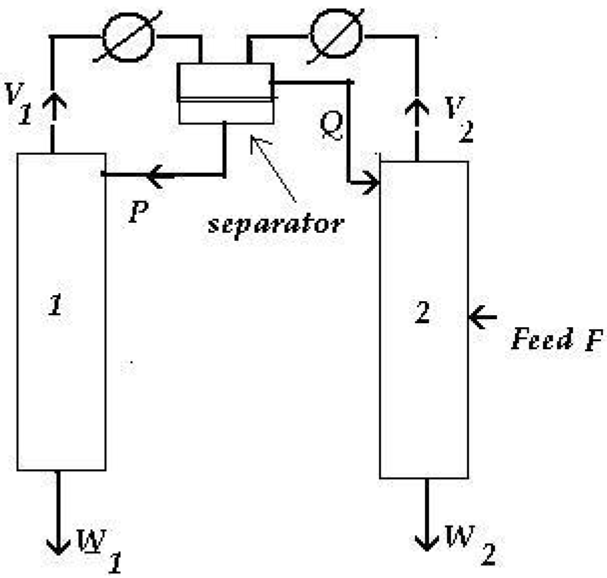


Figure 3.2
Rajah 3.2

4. [a] Critical properties of three fluids are shown in Table Q.4. A solute X has similar solubility properties in all three solvents under supercritical conditions. Discuss the relative advantages and disadvantages of application of these fluids in supercritical fluid extraction of X.

Sifat-sifat genting tiga bendalir ditunjukkan dalam Jadual S.4. Suatu bahan larut X mempunyai sifat-sifat keterlarutan yang sama dalam ketiga-tiga pelarut di bawah keadaan supergenting. Bincangkan kelebihan-kelebihan dan kekurangan-kekurangan relatif penggunaan bendalir-bendalir ini dalam penyairan bendalir supergenting X.

[6 marks/markah]

	T_c(K)	P_c(MPa)	μ (10^{-30}Cm)
Water *Air*	647.3	22.12	6
Carbon Dioxide *Karbon Dioksida*	304.2	7.38	0.0
Ammonia *Amonia*	405.6	11.35	5

Table Q.4.
Jadual S.4.

[b] Discuss the use ionic fluids vs. supercritical CO_2 in extraction.

Bincangkan penggunaan bendalir ion melawan CO_2 supergenting dalam penyairan.

[6 marks/markah]

[c] The P-x diagram for oleic acid-ethylene system is shown in Figure Q.4.
Gambarajah P-x bagi sistem asid oleik-etilena ditunjukkan dalam Rajah S.4.

[i] What is the solubility of oleic acid in ethylene at 25 MPa and 125^{o}C ?
Apakah keterlarutan asid oleik dalam etilena pada 25 MPa dan 125^{o}C?

[5 marks/markah]

[ii] Mark the desired point on the attached P-x Diagram for supercritical extraction.

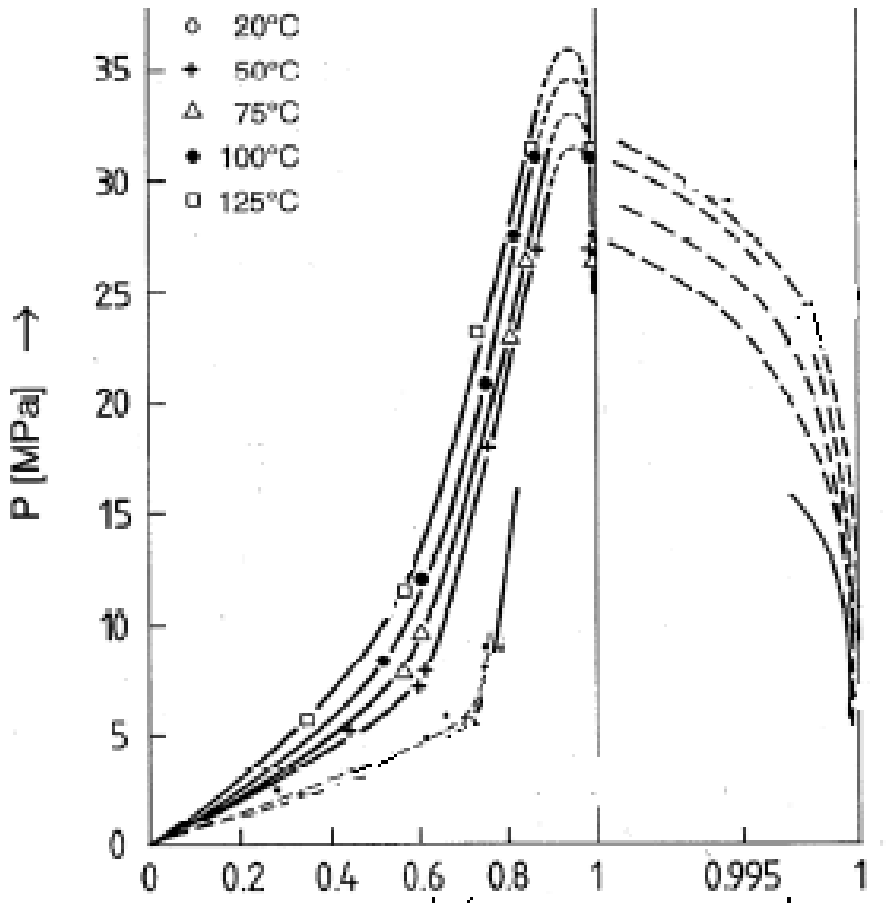
Tandakan titik yang diinginkan pada Gambarajah P-x yang dilampirkan untuk penyairan supergenting.

[2 marks/markah]

[iii] If the regeneration pressure and temperature are reduced to 15 MPa and 100^{o}C respectively, estimate the amount of oleic acid that can be recovered for 100 moles of ethylene.

Jika tekanan dan suhu penjanaan semula masing-masing dikurangkan kepada 15 MPa dan 100^{o}C, anggarkan jumlah asid oleik yang boleh dipulihkan bagi 100 mol etilena.

[6 marks/markah]



$X_{oleic\ acid}$ *(moles of oleic acid/mle of ethylene)*

P,x-diagram of oleic acid – ethylene

Figure Q.4.1
Rajah S.4.1.

[Attached this sheet with answer to question 4]
[Lampirkan kertas soalan ini dengan jawapan soalan 4]

- ooo O ooo -