UNIVERSITI SAINS MALAYSIA

First Semester Examination
Academic Session 2008/2009

November 2008

EKC 217 – Mass Transfer
[Pemindahan Jisim]

Duration : 3 hours
[Masa : 3 jam]

Please check that this examination paper consists of SEVEN pages of printed material and ONE page of Appendix before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi TUJUH muka surat yang bercetak dan SATU muka surat Lampiran sebelum anda memulakan peperiksaan ini.]

Instructions: Answer any **FOUR** (4) questions.

*[**Arahan:** Jawab mana-mana **EMPAT** (4) soalan.]*

You may answer the question either in Bahasa Malaysia or in English.

[Anda dibenarkan menjawab soalan sama ada dalam Bahasa Malaysia atau Bahasa Inggeris.]

Answer any FOUR questions.
Jawab mana-mana EMPAT soalan.

1. [a] Ammonia is absorbed in water from a mixture with air using a column operating at 1.2 atm and 350 K. The resistance to transfer can be regarded as lying entirely within the gas phase. At a point in the column, the partial pressure of the ammonia is 6.6 kN/m^2. The back pressure at the water interface is negligible and the resistance to transfer can be regarded as lying in a stationary gas film 1 mm thick. If the diffusivity of ammonia in air at 0° C and 1 atm is 0.216 cm^2/s, what is the transfer rate per unit area at that point in the column? If the gas is compressed to 200 kN/m^2 pressure, how would the transfer rate be altered? The relationship of diffusivity with temperature and pressure is $D_{AB} \alpha T^{1.75} \times \frac{1}{P}$.

Amonia telah diserap ke dalam air daripada suatu campuran bersama udara dengan menggunakan turus yang beroperasi pada 1.2 atm dan 350 K. Rintangan pemindahan berlaku dalam fasa gas. Pada suatu titik di dalam turus, tekanan separa amonia ialah 6.6 kN/m^2. Tekanan balik pada antara muka air diabaikan dan rintangan pemindahan berlaku dalam saput gas pegun berketebalan 1 mm. Jika kemeresapan amonia dalam air pada 0 ℃ dan 1 atm ialah 0.216 cm^2/s, apakah kadar pemindahan per unit keluasan pada titik itu dalam turus? Sekiranya gas dimampatkan ke tekanan 200 kN/m^2, bagaimanakah kadar pemindahan berubah? Hubungkait antara kemeresapan dengan suhu dan tekanan ialah $D_{AB} \alpha T^{1.75} \times \frac{1}{P}$.

[13 marks/markah]

[b] An ethanol (*A*)-water (*B*) solution in the form of a stagnant film 5.0 mm thick at 300 K is in contact at one surface with an organic solvent, in which ethanol is soluble and water is insoluble. At point 1, the concentration of ethanol is 25.7 wt% and the solution density is ρ_1 = 972.8 kg/m^3. At point 2, the concentration of ethanol is 5.5 wt% and ρ_2 = 988.1 kg/m^3. The diffusivity of ethanol at 300 K is 0.740 × 10^{-9} m^2/s. Calculate the steady-state flux N_A.

Larutan etanol (A)-air (B) dalam keadaan saput pegun berketebalan 5 mm pada 300 K adalah bersentuhan dengan pelarut organik pada satu permukaan. Etanol bersifat boleh larut dan air tidak boleh larut. Pada titik 1, kepekatan etanol ialah 25.7 % berat dan ketumpatan larutan ialah ρ_1 = 972.8 kg/m^3. *Pada titik 2, kepekatan etanol ialah 5.5% berat dan* ρ_2 = 988.1 kg/m^3. *Kemeresapan etanol pada 300 K ialah 0.740 × 10^{-9} m^2/s. Kirakan fluks,* N_A *pada keadaan mantap.*

Data given: Molecular weight of ethanol = 46.05 g/mole
Molecular weight of water = 18.02 g/mole
Use basis of 100 kg of solution.

Data diberi: *Jisim molekul etanol = 46.05 g/mol*
Jisim molekul air = 18.02 g/mol
Gunakan asas 100 kg larutan.

[12 marks/markah]

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2. [a] Write short notes on volatility and relative volatility. Explain the influence of relative volatility on the separation of a binary mixture by distillation.

Tuliskan nota ringkas mengenai kemeluwapan dan kemeluwapan relatif. Terangkan pengaruh kemeluwapan relatif ke atas pemisahan campuran binari dengan menggunakan penyulingan.

[7 marks/markah]

[b] A continuous fractionating column is required to separate a mixture containing 0.65 mole fraction of n-heptane (C_7H_{16}) and 0.35 mole fraction of n-octane (C_8H_{18}) into products of 99 mole % purity. The column is to operate at a pressure of 101.3 kN/m^2 with a vapor velocity of 0.75 m/s. The feed is all liquid at its boiling point, and is supplied to the column at 2.5 kg/s. The boiling point at the top of the column may be taken as 372 K and the equilibrium data are:

Suatu turus pemeringkatan berterusan dikehendaki memisahkan campuran yang mengandungi 0.65 pecahan mol n-heptana (C_7H_{16}) dan 0.35 pecahan mol n-oktana (C_8H_{18}) kepada produk-produk berketulenan 99% mol. Turus beroperasi pada tekanan 101.3 kN/m^2 dengan halaju wap 0.75 m/s. Suapan adalah cecair pada titik didih dan dibekalkan ke turus pada kadar 2.5 kg/s. Titik didih pada bahagian atas turus ialah 372 K dan data keseimbangan adalah:

y = mole fraction of heptane in vapor *Pecahan mol heptana dalam wap*	x = mole fraction of heptane in liquid *Pecahan mol heptana dalam cecair*
0.96	0.92
0.91	0.82
0.83	0.69
0.74	0.57
0.65	0.46
0.50	0.32
0.37	0.22
0.24	0.13

Calculate the following:

Kirakan yang berikut:

[i] moles per hour of distillate and bottom

bilangan mol per jam bagi sulingan dan produk bawah

[4 marks/markah]

[ii] minimum reflux ratio, R_m

nisbah refluks minimum, R_m

[4 marks/markah]

[iii] the diameter of the column if the reflux ratio used is twice the minimum.

diameter turus sekiranya nisbah refluks yang digunakan adalah dua kali ganda nilai minimum.

[10 marks/markah]

...4/-

3. [a] A continuous rectifying column treats a mixture consisting of 30% of benzene by weight and 70% of toluene by weight at the rate of 6 kg/s, and separates it into 97% by weight of benzene in the top product and 98% by weight toluene in the bottom product. The feed is liquid at its boiling point.

Suatu turus penulenan berterusan mengandungi campuran yang terdiri daripada 30% berat benzena dan 70% berat toluena pada kadar 6 kg/s. Campuran dipisahkan kepada 97% berat benzena dalam produk atas dan 98% berat toluena dalam produk bawah. Suapan adalah cecair pada titik didih.

[i] Calculate the weights of top and bottom products per unit time.

Kirakan berat produk-produk atas dan bawah per unit masa.

[5 marks/markah]

[ii] If a reflux ratio of 3.5 to 1 is employed, how many plates are required in the column?

Jika nisbah refluks 3.5 kepada 1 digunakan, berapakah bilangan plat yang diperlukan dalam turus?

[7 marks/markah]

[iii] What is the actual number of plates if the plate efficiency is 70%?

Apakah bilangan plat sebenar jika kecekapan plat ialah 70%?

[1 mark/markah]

The relation between the mole fraction of benzene in liquid and in vapor is given below:

Hubungan antara pecahan mol benzena dalam cecair dan wap diberi seperti di bawah:

Mole fraction of benzene in liquid *Pecahan mol benzena dalam cecair*	Mole fraction of benzene in vapor *Pecahan mol benzena dalam wap*
0.1	0.22
0.2	0.38
0.3	0.51
0.4	0.63
0.5	0.70
0.6	0.78
0.7	0.85
0.8	0.91
0.9	0.96

Molecular weight of benzene = 78 g/mole
Molecular weight of tolune = 92 g/mole

Jisim molekul benzena = 78 g/mol
Jisim molekul toluena = 92 g/mol

...5/-

[b] With the help of a diagram, derive an expression relating overall mass transfer coefficient to gas and liquid phase mass transfer coefficients. Show that the absorption of solute A from an inert gas into a liquid absorbent is "gas phase controlling" provided that solute A is very soluble in the liquid phase. You may assume the system is dilute and start by expressing the molar flux of solute A using gas/liquid phase mass transfer coefficient and overall mass transfer coefficient. Define all symbols used.

Dengan menggunakan bantuan gambarajah, terbitkan persamaan yang mengaitkan pekali keseluruhan pemindahan jisim dengan pekali pemindahan jisim fasa gas/cecair. Tunjukkan bahawa penyerapan bahan larut A daripada gas lengai ke dalam cecair bahan penyerap adalah "kawalan fasa gas" sekiranya bahan larut A adalah sangat larut di dalam fasa cecair. Anda boleh membuat anggapan bahawa sistem adalah cair dan mula dengan membuat ungkapan bagi fluk molar bahan larut A dengan menggunakan pekali pemindahan jisim fasa gas/cecair dan pekali keseluruhan pemindahan jisim. Takrifkan semua simbol yang digunakan.

[12 marks/markah]

4. A coal gas is to be freed of its light oil by scrubbing with wash oil as an absorbent and the light oil recovered by stripping the resulting solution with steam. The details of the absorber and stripper are as follows:

Kandungan minyak ringan dalam suatu gas arang perlu disingkirkan dengan menggahar gas tersebut dengan minyak pembersih sebagai bahan penyerap dan minyak ringan tersebut dipulihkan kembali dengan melucut larutan yang terhasil dengan stim. Maklumat lanjut penyerap dan pelucut adalah seperti berikut:

Absorber

Gas in, 0.25 m^3/s at 26°C and 1.07×10^5 N/m^2 containing 2.0% by volume of light oil vapors. The light oil will be assumed to be entirely benzene and a 95% removal is required. The wash oil is to enter at 26°C, containing 0.005 mole fraction benzene and has an average molecular weight of 260. An oil circulation rate of 1.5 times the minimum is to be used. Wash oil-benzene solutions are ideal. The temperature will be constant at 26°C and pressure at 1.07×10^5 N/m^2.

Penyerap

Gas suapan, 0.25 m^3/s pada 26 ℃ dan 1.07×10^5 N/m^2 mengandungi 2.0% (isipadu) wap minyak ringan. Minyak ringan tersebut boleh dianggap benzena sepenuhnya dan penyingkiran 95% adalah dikehendaki. Minyak pembersih memasuki turus penyerap pada 26 ℃, mengandungi 0.005 pecahan mol benzena dengan purata jisim molekul 260. Kadar kitaran minyak yang akan digunakan adalah 1.5 kali nilai minimum. Suhu turus adalah tetap pada 26 ℃ dan tekanan pada 1.07×10^5 N/m^2.

Stripper

The solution from the absorber is to be heated to 120°C and will enter the stripper at 1 standard atm pressure. Stripping steam will be at standard atmospheric pressure, superheated to 122°C. The debenzolized oil, 0.005 mole fraction benzene, is to be cooled to 26°C and returned to the absorber. A steam rate of 1.5 times the minimum is to be used. The temperature of the stripper will be constant at 122°C and pressure constant at 101.33 kN/m^2.

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Pelucut

Larutan daripada penyerap akan dipanaskan ke 120℃ dan akan disuapkan ke dalam pelucut pada tekanan piawai 1 atm. Stim pelucut adalah pada tekanan atmosfera piawai dan dipanaslampau ke 122℃. Minyak yang telah dinyahbenzenakan, mengandungi 0.005 pecahan mol benzena, akan disejukkan ke 26℃ dan dikembalikan ke dalam penyerap. Kadar kitaran stim yang akan digunakan adalah 1.5 kali nilai minimum. Suhu pelucut adalah tetap pada 122℃ dan tekanan tetap pada 101.33 kN/m^2.

Using the ghaphical method, compute the oil-circulation rate and the steam rate required. Assume that the system complies to Raoult's and Dalton's Laws.

Dengan menggunakan kaedah graf, kirakan kadar kitaran minyak dan stim yang diperlukan. Anggap bahawa sistem mematuhi Hukum-hukum Raoult dan Dalton.

Additional Data Given

Vapor pressure of benzene at 26°C is 13,330 N/m^2
Vapor pressure of benzene at 122°C is 319,900 N/m^2
Gas constant, R = 8.3145 m^3 Pa mol^{-1} K^{-1}
All system operating using counter current configuration.

Data tambahan

Tekanan wap benzena pada 26℃ adalah 13,330 N/m^2
Tekanan wap benzena pada 122℃ adalah 319,900 N/m^2
Pemalar gas, R = 8.3145 m^3 Pa mol^{-1} K^{-1}
Semua sistem beroperasi pada konfigurasi berlawanan arus.

[25 marks/markah]

5. [a] Describe the following terms normally used in liquid-liquid extraction:

[i] Extract phase
[ii] Tie Line
[iii] Plait Point

Terangkan istilah berikut yang biasa digunakan dalam proses penyarian cecair-cecair:

[i] Fasa ekstrak
[ii] Garis 'Tie'
[iii] Titik 'Plait'

[6 marks/markah]

[b] Discuss the differences between liquid-liquid extraction and distillation.

Bincangkan perbezaan di antara penyarian cecair-cecair dan penyulingan.

[4 marks/markah]

[c] Seeds containing 30% by weight of oil are extracted in a counter current plant and 95% of the oil is recovered in a solution containing 50% by weight of oil. If the seeds are extracted with fresh solvent and 1 kg of solution is removed in the underflow in association with every 2 kg of insoluble matter, how many ideal stages are required. Solve using the right triangular diagram.

Bijirin yang mengandungi 30% berat minyak akan disarikan dengan menggunakan loji berlawanan arus. 95% minyak akan dipulihkan di dalam larutan yang mengandungi 50% berat minyak. Sekiranya bijirin disarikan dengan menggunakan pelarut segar dan 1 kg larutan dikeluarkan di aliran bawah bersama-sama setiap 2 kg bahan tak larut, berapakah peringkat unggul yang diperlukan. Selesaikan masalah ini dengan menggunakan gambarajah segitiga tepat.

[15 marks/markah]

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Appendix
Lampiran

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 × 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 1 ft^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 × 10^5 dynes
Pressure	1 atm = 1.01325 × 10^5 N/m^2 (Pa) = 101.325 kPa = 1.01325 bars = 1.01325 × 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 × 10^{-7} kW·h = 0.23901 cal = 0.7376 ft-lb_f = 9.486 × 10^{-4} Btu
Power	1 W = 1 J/s = 0.23901 cal/s = 0.7376 ft·lb_f/s = 9.486 × 10^{-4} Btu/s = 1.341 × 10^{-3} hp

Example: The factor to convert grams to lb_m is $\left(\frac{2.20462\ lb_m}{1000\ g}\right)$

THE GAS CONSTANT

8.314 m^3·Pa/mol·K
0.08314 liter·bar/mol·K
0.08206 liter·atm/mol·K
62.36 liter·mm Hg/mol·K
0.7302 ft^3·atm/lb-mole·°R
10.73 ft^3·psia/lb-mole·°R

8.314 J/mol·K
1.987 cal/mol·K
1.987 Btu/lb-mole·°R