UNIVERSITI SAINS MALAYSIA

Supplementary Semester Examination
Academic Session 2009/2010

June 2010

IEK 213 – MASS TRANSFER AND SEPARATION PROCESSES
[PROSES PEMINDAHAN JISIM DAN PROSES PEMISAHAN]

Duration: 3 hours
[Masa: 3 jam]

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

Answer **FIVE** questions. All questions can be answered in Bahasa Malaysia OR English.

In the event of any discrepancies, the English version shall be used.

*[Sila pastikan bahawa kertas peperiksaan ini mengandungi **EMPATBELAS** muka surat yang bercetak sebelum anda memulakan peperiksaan ini.*

*Jawab **LIMA** soalan. Semua soalan boleh dijawab dalam Bahasa Malaysia ATAU Bahasa Inggeris.*

Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah diguna pakai].

Answer any FIVE questions.

1. (a) For a tubular bowl centrifugal decanter used for settling of solid particles in liquid, the terminal velocity at a radius r is

$$u_t = \omega^2 r D_p^2(\rho_p - \rho)/18\mu$$

where $\omega^2 r$ is the acceleration.

The volumetric flow rate q_c for critical particle diameter D_{pc} can be given by

$$q_c = \omega^2 D_{pc}^2(\rho_p - \rho)[\pi b(r_2^2 - r_1^2)]/\{18\mu \ln [2r_2/(r_1 + r_2)]\}$$

(i) What is the expression for sigma Σ ?

(ii) What does Σ actually measure?

(40 marks)

(b) Ethanol vapor is being absorbed from a mixture of alcohol vapor and water vapor by means of a nonvolatile solvent in which alcohol is soluble but water is not. The temperature is 95^{o}C, and the total pressure is 760 mm Hg. The alcohol vapor can be considered to be diffusing through a film of alcohol-water vapor mixture 0.18 mm thick. The mole percent of the alcohol in the vapor at the outside of the film (bulk) is 78.8 percent, and that on the inside, next to the solvent (interface), is 9.75 percent. The diffusivity of the alcohol-water vapor mixture at 95^{o}C and 1 atm is 0.0791 m^2/h. Calculate the rate of diffusion of alcohol vapor in kilograms per hour if the area of the film is 10 m^2. The volume of a kmol gas at STP is 22.4 m^3. The molecular weight of alcohol is 46 kg/kmol.

$$PV = nRT$$

$$N_A = (D_{AB}\rho_M/b) \ln [(1 - y_{Ai})/(1 - y_A)]$$

where ρ_M = molar density; b = film thickness.

(60 marks)

2. A wet solid is to be dried from 30% to 11% moisture content (dry basis) under constant drying conditions. The initial weight of the solid is 150 kg, and the drying surface is 1 m^2/40 kg dry weight. The falling-rate period data are as follows:

W	0.20	0.18	0.16	0.14	0.12	0.10	0.09	0.08	0.07	0.064
10^3R	0.30	0.266	0.239	0.208	0.18	0.15	0.097	0.07	0.043	0.025

$R = - (ms/A)\, dW/dt$

$\int dX/(aX + b) = (1/a) \ln (aX + b)$

(a) Draw the drying rate curve (Rate vs moisture content) from moisture content from 35% to 6.4% (dry basis).

(b) Determine the time for drying.

(100 marks)

3. A plate and frame filter press was used to filter a slurry at constant pressure difference. After the 1800 s, a total of 8 m^3 filtrate was collected. After another 1800 s, an additional 3.5 m^3 filtrate was collected. Then filtration was stopped. Estimate the washing time in seconds if 2.3 m^3 of wash water are used. The resistance of the cloth can be neglected. The flow rate of washing water is one-quarter of the final filtration rate.

$$dV/dt = A^2(-\Delta p)/(\mu\alpha WV)$$
$$(V_2^2 - V_1^2)/2 = [A^2(-\Delta p)/(\mu\alpha W)](t_2 - t_1)$$

(100 marks)

4. A fractionating column is to be designed to separate 30,000 kg/h of a mixture of 45 mol % benzene with 55 mol % toluene into an overhead product containing 97 mol % benzene and a bottom product containing 4 mol % benzene. The molar latent heats of benzene and toluene are 7,360 and 7,960 cal/g-mol, respectively. The relative volatility of the benzene/toluene system α_{AB} is about 2.5. At 1 atm the boiling point of the feed is 95 ^oC. The average molecular weight of the feed is 85.8 g/g-mol.

(a) Calculate the equilibrium data (about 10 points) and construct the equilibrium curve.

(b) Determine the minimum number of theoretical trays.

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(c) Determine the minimum reflux ratio if the feed is

(i) at bubble point;
(b) a liquid at 20^{o}C (c_p = 0.44 cal/g.^{o}C)
(c) a mixture of two-thirds vapour and one-third liquid.

$y_A = \alpha_{AB}x_A/[1 + (\alpha_{AB} - 1)x_A]$
$q = 1 + c_{pL}(T_b - T_F)/\lambda$

(100 marks)

5. A liquid mixture of benzene-toluene is to be distilled in a fractionating tower at 101.3 kPa. The feed of 100 kg-mol/h is liquid and it contains 44 mol % benzene and 56 mol % toluene and enters at 327.6 K. The boiling temperature of the feed is T_b = 366.7 K. A distillate containing 95 mol % benzene and a bottoms containing 5 mol % benzene are to be obtained. The reflux ratio is 4:1. The average heat capacity of the feed is 159 kJ/(kg-mol.K) and the average latent heat is 32,099 kJ/kg-mol. Equilibrium data for this system are given in Table 1.

(a) Calculate the rates of distillate and bottoms in kg-mol/h.

(b) Determine the number of theoretical plates needed by McCabe-Thiele method.

(c) Determine the position of the feed plate.

Table 1. Equilibrium data for the benzene(A)-toluene system.

x_A	0.0	0.13	0.26	0.41	0.58	0.78	1.0
y_A	0.0	0.26	0.46	0.63	0.78	0.90	1.0

$y = - qx/(1-q) + x_F/(1-q)$
$q = 1 + c_{pL}(T_b - T_F)/\lambda$
$y_{n+1} = R_Dx_n/(R_D+1) + x_D/(R_D+1)$

(100 marks)

6. (a) A water vapor (A)-air (B) mixture at 1 atmospheric pressure has a percentage humidity of 15% at 135^{o}F. By using the humidity charts provided, find

(i) the humidity of the mixture;
(ii) the dew point;
(iii) the humid heat;
(iv) the humid volume;
(v) the saturation humidity;
(vi) the adiabatic saturation temperature;
(vii) the total enthalpy.

(50 marks)

(b) Discuss the two-film theory in mass transfer.

(20 marks)

(c) Discuss membrane separation technology.

(30 marks)

Jawab sebarang LIMA soalan.

1. (a) *Untuk satu penyiring empar mangkuk tubular yang digunakan untuk memendak zarah-zarah di dalam cecair, halaju terminal pada jejari r ialah*

$$u_t = \omega^2 r D_p^2 (\rho_p - \rho)/18\mu$$

di mana $\omega^2 r$ *adalah pecutan.*

Kadar aliran volumetrik q_c *bagi diameter zarah genting* D_{pc} *boleh diberikan sebagai*

$$q_c = \omega^2 D_{pc}^2 (\rho_p - \rho)[\pi b(r_2^2 - r_1^2)]/\{18\mu \ln [2r_2/(r_1 + r_2)]\}$$

(i) *Apakah ungkapan bagi sigma* Σ*?*

(ii) *Apakah sebenarnya diukur oleh* Σ*?*

(40 markah)

(b) *Wap ethanol diserap daripada suatu campuran wap alkohol dengan wap air dengan menggunakan satu pelarut takmeruap di mana alkohol itu melarut tetapi air tidak. Suhu ialah 95* ^oC *dan jumlah tekanan 760 mm Hg. Alkohol tersebut boleh dipertimbangkan meresap menerusi selapisan campuran air-alkohol tebalnya 0.18 mm. Peratus mol alkohol di dalam wap di luar lapisan (pukal) tersebut ialah 78.8 peratus, dan peratus molnya di antaramuka ialah 9.75 peratus. Keresapan campuran alkohol-air pada 95* ^oC *dan 1 atm ialah 0.0791* m^2/h*. Hitungkan kadar peresapan wap alkohol dalam unit kilogram sejam jika lapisan itu berkeluasan 10* m^2*. Isipadu bagi 1 kmol gas pada STP ialah 22.4* m^3*. Berat molekul bagi alkohol ialah 46 kg/kmol.*

$$PV = nRT$$

$$N_A = (D_{AB}\rho_M/b) \ln [(1 - y_{Ai})/(1 - y_A)]$$

di mana ρ_M *= ketumpatan molar;* b *= ketebalan lapisan.*

(60 markah)

2. *Satu pepejal basah akan dikeringkan dari 30% hingga 11% kandungan lembapan (dasar kering) di bawah keadaan pengeringan malar. Berat awal bagi pepejal ialah 150 kg, dan luas permukaan pengeringan ialah 1 m^2/40 kg berat kering. Data tempoh kadar-kejatuhan ialah seperti berikut:*

W	0.20	0.18	0.16	0.14	0.12	0.10	0.09	0.08	0.07	0.064
10^3R	0.30	0.266	0.239	0.208	0.18	0.15	0.097	0.07	0.043	0.025

$R = - (ms/A)\, dW/dt$

$\int dX/(aX + b) = (1/a) \ln (aX + b)$

(a) *Lukiskan lengkungan kadar pengeringan (Kadar lawan Kandungan lembapan) dari kandungan lembapan 35% hingga 6.4% (dasar kering).*

(b) *Tentukan masa untuk pengeringan.*

(100 markah)

3. *Satu penuras plat dan rangka digunakan menuras satu campuranlikat pada tekanan malar. Selepas 1800 s, sejumlah 8 m^3 turasan didapati. Selepas 1800 s tambahan, turasan tambahan sebanyak 3.5 m^3 diterima. Proses penurasan kemudian dihentikan. Tentukan masa pembasuhan dalam unit saat jika 2.3 m^3 air pembasuh digunakan. Rintangan kain turas boleh diabaikan. Kadar aliran air pembasuh ialah sesuku daripada kadar penurasan akhir.*

$$dV/dt = A^2(-\Delta p)/(\mu \alpha W V)$$

$$(V_2^2 - V_1^2)/2 = [A^2(-\Delta p)/(\mu \alpha W)](t_2 - t_1)$$

(100 markah)

4. *Satu menara penyulingan akan direkabentuk untuk memisahkan satu campuran yang mengandungi 45 mol % benzena dan 55 mol % toluena pada kadar 30,000 kg/h. Produk atas penyulingan mengandungi 97 mol % benzena manakala produk bawah mengandungi 4 mol % benzena. Haba pendam molar masing-masing bagi benzena dan toluena ialah 7,360 dan 7,960 cal/g-mol. Kemeruapan relatif bagi sistem benzena/toluena α_{AB} ialah 2.5. Pada 1 atm takat didih bagi larutan suapan ialah 95 ^oC. Berat molekul purata bagi larutan suapan ialah 85.8 g/g-mol.*

(a) *Hitungkan data keseimbangan (lebih kurang 10 titik) dan lukiskan lengkung keseimbangan.*

(b) *Tentukan bilangan minimum plat secara teori.*

(c) Tentukan nisbah refluks minimum jika larutan suapan adalah

(i) pada takat gelembung;
(ii) cecair pada 20 ^oC (c_p = 0.44 cal/g.^oC);
(iii) satu campuran yang mengandungi 2/3 wap dan 1/3 cecair.

$y_A = \alpha_{AB}x_A/[1 + (\alpha_{AB} - 1)x_A]$
$q = 1 + c_{pL}(T_b - T_F)/\lambda$

(100 markah)

5. *Satu campuran cecair benzena-toluena akan disuling di dalam satu menara penyulingan pada 101.3 kPa. Kadar suap cecair ialah 100 kg-mol/h dan mengandungi 44 mol % benzena dan 56 mol % toluena dan memasuki menara pada 327.6 K. Takat didih suap ialah T_b = 366.7 K. Hasil atas perlu mengandungi 95 mol % benzena dan hasil bawah mengandungi 5 mol % benzene. Nisbah refluks ialah 4:1. Muatan haba purata bagi suap ialah 159 kJ/(kg-mol.K) dan haba pendam purata ialah 32,099 kJ/kg-mol. Data keseimbangan bagi sistem ini diberi dalam Jadual 1.*

(a) Kirakan kadar hasil atas dan hasil bawah dalam unit kg-mol/h.

(b) Tentukan bilangan plat teoretis yang diperlu melalui kaedah McCabe-Thiele.

(c) Tentukan kedudukan plat suap.

Jadual 1 Data keseimbangan untuk sistem benzena(A)-toluena

x_A	0.0	0.13	0.26	0.41	0.58	0.78	1.0
y_A	0.0	0.26	0.46	0.63	0.78	0.90	1.0

$y = - qx/(1-q) + x_F/(1-q)$
$q = 1 + c_{pL}(T_b - T_F)/\lambda$
$y_{n+1} = R_Dx_n/(R_D+1) + x_D/(R_D+1)$

(100 markah)

6. *(a) Satu campuran wap air(A) dan udara (B) pada 1 atmosfera mempunyai peratus kelembapan 15% dan suhu 135^{o}F. Dengan menggunakan carta kelembapan, tentukan*

   (i) kelembapan campuran tersebut;
   (ii) takat embun;
   (iii) haba lembab;
   (iv) isipadu lembab;
   (v) kelembapan tepu;
   (vi) suhu tepu adiabatik;
   (vii) entalpi total.

   (50 marks)

   (b) Bincangkan teori dua-lapisan dalam pemindahan jisim.

   (20 marks)

   (c) Bincangkan teknologi pemisahan membran.

   (30 marks)