UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Kedua
Sidang Akademik 2004/2005

Mac 2005

EKC 334 – Analisis Reaktor Bermangkin & Operasi

Masa : 3 jam

Sila pastikan bahawa kertas peperiksaan ini mengandungi SEMBILAN muka surat yang bercetak sebelum anda memulakan peperiksaan ini.

Arahan: Jawab **EMPAT (4)** soalan. Jawab mana-mana **DUA (2)** soalan dari Bahagian A. Jawab mana-mana **DUA (2)** soalan dari Bahagian B.

Pelajar boleh menjawab semua soalan dalam Bahasa Malaysia. Jika pelajar ingin menjawab dalam Bahasa Inggeris, pelajar hendaklah menjawab sekurang-kurangnya SATU soalan dalam Bahasa Malaysia.

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Bahagian A: Jawab mana-mana DUA soalan.
Section A: Answer any TWO questions.

1. [a] Pengoksidaan etanol bermangkin berlaku seperti berikut:

$$C_2H_5OH + ½\ O_2 \rightarrow CH_3CH\ O + H_2O$$

Menggunakan mangkin tantalum oksida. Tindakbalas keseluruhan dipercayai berlaku menurut mekanisma di mana etanol terjerap pada satu jenis tapak, S_1, dan oksigen terjerap pada satu jenis tapak yang berbeza, S_2. Kedua-dua etanol dan O_2 melalui penjerapan pelerai pada sepasang tapak erapan (andaian ion logam), dengan etanol terlerai menjadi satu ion ethoxy dan satu proton. Jika diandaikan tindakbalas permukaan tapak duaan merupakan langkah mengehad kadar dan proton serta hidroksil terjerap yang masih lagi tertinggal ditukarkan kepada satu molekul air tak terjerap, terbitkan mekanisma dan hukum kadar untuk tindakbalas ini.

[15 markah]

[b] Pertimbangkan dua kes: (1) keluaran terjerap dengan kuat dan merencatkan tindak balas, dan (2) keluaran terjerap dengan amat lemah. Tuliskan hukum kadar bagi setiap kes?

[5 markah]

[c] Berikan takrifan mangkin dan kelaskan suatu proses bermangkin?

[5 markah]

1. [a] The catalytic ethanol oxidation proceeds according to

$$C_2H_5OH + ½\ O_2 \rightarrow CH_3CH\ O + H_2O$$

over a tantalum oxide catalyst. The overall reaction is believed to proceed by a mechanism in which ethanol is adsorbed on one type of site, S_1, and oxygen is adsorbed on a different type of site, S_2. Both ethanol and O_2 undergo dissociative adsorption on a pair of sorption sites (presumably metal ions), with the ethanol dissociating into an ethoxy ion and a proton. Assuming that the rate-limiting step is a dual-site surface reaction, and that the remaining adsorbed hydroxyl and proton are converted into a non-adsorbed molecule of water, derive the mechanism and the rate law for this reaction.

[15 marks]

[b] Consider two cases: (1) the product is strongly adsorbed and inhibits the reaction; and (2) the product is very weakly adsorbed. Write each the respective rate law?

[5 marks]

[c] Define a catalyst and classify a catalytic process?

[5 marks]

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2. [a] [i] Bagi tindakbalas bermangkin tertib sifar, jika faktor keberkesanan zarah mangkin ialah η, apakah faktor keberkesanan keseluruhan, Ω (di dalam sebutan η)? Berikan justifikasi kepada jawapan anda.

[5 markah]

[ii] Bagi satu mangkin pepejal, tindakbalas fasa gas A(*g*) → produk (s), jika fasa gas adalah A tulen dan modulus Thiele ialah 30, apakah nilai faktor keberkesanan keseluruhan? Terangkan secara ringkas.

[5 markah]

[b] Tindakbalas tertib pertama tak berbalik.

$$A \rightarrow B$$

sedang berlaku di mangkin berliang pada 8.2 atm di dalam sebuah reaktor yang disuap dengan A tulen. Kirakan modulus Thiele dan faktor keberkesanan?

Maklumat tambahan :

Kemeresapan berkesan : 0.53 sm^2/s
Luas permukaan mangkin berliang : 30 m^2/g mangkin
Ketumpatan pelet mangkin : 1.3 g/sm^3
Jejari pelet mangkin : 0.5 sm
$k = 2.035 \times 10^4\ m^3/m^2.s$

[10 markah]

[c] Takrifkan ungkapan-ungkapan berikut:

[i] Frekuensi pusingan balik

[ii] Serakan

[5 markah]

2. *[a]* *[i]* *For a zero-order catalytic reaction, if the catalyst particle efectiveness factor is η, what is the overall effectiveness factor, Ω (in terms of η)? Justify your answer.*

[5 marks]

[ii] *For a solid-catalyst, gas phase reaction A(g) → product(s), if the gas phase is pure A and the Thiele modulus is 30, what is the value of the overall effectiveness factor? Explain briefly.*

[5 marks]

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[b] The irreversible first order reaction

$$A \rightarrow B$$

is taking place in porous catalyst at 8.2 atm in a reactor to which only pure A is fed. Calculate the Thiele modulus and effectiveness factor?

Additional information :

Effective diffusivity : 0.53 cm^2/s
Surface area of porous catalyst : 30 m^2/g cat
Density of catalyst pellets : 1.3 g/cm^3
Radius of catalyst pellets : 0.5 cm
$k = 2.035 \times 10^4 m^3/m^2.s$

[10 marks]

[c] Define the following terms:

[i] Turnover frequency

[ii] Dispersion

[5 marks]

3. [a] Sebiji pelet mangkin bergaris pusat 0.5 sm terampai di dalam cecair. Kepekatan permukaan dan pukal, masing-masing adalah 0.5 M dan 2.0 M. Halaju cecair sistem bebas, U, adalah 0.2 m/s dan kelikatan kinematik, ν, adalah 4.2×10^{-7} m^2/s. Kemeresapan cecair bagi A ialah 9×10^{-11} m^2/s. Kirakan kadar tindakbalas bagi bahan tindak balas A per luas permukaan unit mangkin?

Persamaan-persamaan berguna:

$$Sh = 2 + 0.6\, Re^{1/2}\, Sc^{1/3}$$

$$Sh = \text{Nombor Sherwood} = \frac{k_c d_p}{D_{AB}}$$

Re = Nombor Reynolds

Sc = Nombor Schmidt

[10 markah]

[b] Terbitkan Sesuhu Langmuir bagi kes dua gas (A dan B) yang menjerap pada permukaan (tiada tindakbalas yang berlaku).

[10 markah]

[c] Takrifkan yang berikut :

[i] Reaktor buburan

[ii] Reaktor lapisan cucuran

[5 markah]

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3. [a] *A single catalyst pellet 0.5 cm in diameter suspended in a liquid. The surface and bulk concentration are 0.5 M and 2.0 M, respectively. The free-system liquid velocity, U, is 0.2 m/s and the kinematic viscosity, ν, is 4.2 x 10^{-7} m^2/s. The liquid diffusivity of A is 9 x 10^{-11} m^2/s. Calculate the rate of reaction for reactant A per unit surface area of catalyst?.*

Useful equations:

$$Sh = 2 + 0.6\,Re^{1/2}\,Sc^{1/3}$$

$$Sh = \text{Sherwood Number} = \frac{k_c d_p}{D_{AB}}$$

Re = Reynolds Number

Sc = Schmidt Number

[10 marks]

[b] *Derive the Langmuir Isotherm for the case of two gases (A and B) adsorbing onto a surface (no reaction occurs).*

[10 marks]

[c] *Define the following :*

[i] Slurry reactor

[ii] Trickle bed reactor

[5 marks]

Bahagian B: Jawab mana-mana DUA soalan.
Section B: Answer any TWO questions.

4. [a] Sekelompok pepejal sfera bersaiz seragam dirawat dengan gas di dalam persekitaran seragam. Pepejal telah ditukar untuk memberi keluaran tak berkeping menurut model teras mengecut (SCM). Bagi masa tindakbalas selama satu jam setengah penukaran adalah 88% dan penukaran (100%) akan lengkap di dalam dua jam. Apakah mekanisma yang mengawal kadar?

[10 markah]

[b] Suatu mangkin penghidrogenan disediakan dengan merendam zarah-zarah alumina (saiz jejaring 100 - 150) di dalam larutan berair $NiNO_3$. Selepas pengeringan dan penurunan, zarah-zarah mengandungi 7 %berat NiO. Mangkin ini kemudiannya dijadikan pelet silinder yang besar untuk kajian kadar. Ukuran-ukuran kesan bagi satu pelet adalah:

Jisim, g	3.15
Garispusat, mm	25
Ketebalan, mm	6
Isipadu, sm^3	3.22

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Zarah-zarah alumina mengandungi liang-liang mikro dan proses pempeletan memperkenalkan liang-liang makro yang mengelilingi zarah-zarah. Jika isipadu liang makro pelet ialah 0.645 sm^3 dan isipadu liang mikro ialah 0.40 sm^3/g zarah-zarah, kira:

[i] Ketumpatan pelet

[ii] Isipadu liang makro dalam sm^3/g

[iii] Pecahan lompang liang makro di dalam pelet

[iv] Pecahan lompang liang mikro di dalam pelet

[v] Pecahan pepejal

[vi] Ketumpatan zarah-zarah

[9 markah]

[c] Nyatakan ciri-ciri mangkin yang boleh diperolehi apabila menggunakan teknik-teknik berikut:

Kemikroskopan Elektron Imbasan (SEM)
Analisis Permeteran Graviti Haba (TGA)
Belauan Sinar-X (XRD)
Kaedah BET

[6 markah]

4. *[a] A batch of spherical solids of uniform size is treated by gas in a uniform environment. Solid is converted to give a nonflaking product according to the shrinking-core model (SCM). Conversion is 88% for a reaction time of one hour and the conversion (100%) will complete in two hours. What mechanism is rate controlling?*

[10 marks]

[b] A hydrogenation catalyst is prepared by soaking alumina particles (100 - 150 mesh size) in aqueous $NiNO_3$ solution. After drying and reduction, the particles contain about 7 wt% NiO. This catalyst is then made into large cylindrical pellets for rate studies. The gross measurements for one pellet are:

Mass, g	*3.15*
Diameter, mm	*25*
Thickness, mm	*6*
Volume, cm^3	*3.22*

The alumina particles contain micropores, and the pelletting process introduces macropores surrounding the particles. If the macropore volume of the pellet is 0.645 cm^3 and the micropore volume is 0.40 cm^3/g of particles, calculate:

[i] The density of the pellet

[ii] The macropore volume in cm^3/g

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[iii] The macropore void fraction in the pellet

[iv] The micropore void faction in the pellet

[v] The solid fraction

[vi] The density of the particles

[9 marks]

[c] State the catalyst properties that can be obtained using the following techniques:

Scanning Electron Microscopy (SEM)
Thermogravimetric analysis (TGA)
X-ray Diffraction (XRD)
BET method

[6 marks]

5. [a] Bagi tindakbalas zarah-bendalir yang berikut,

$$A(g) + bB\ (s) \rightarrow Produk$$

Andaikan masa yang diperlukan untuk tindakblas lengkap zarah silinder berjejari R_1, pada $T_1 = 527^{\circ}C$ dan tekanan separa P_{Ag_1}, adalah t_1.

Jika dicadangkan penggunaan zarah dengan saiz dua kali ganda (R_2) pada sepertiga tekanan separa (P_{Ag_2}), apakah suhu (T_2) yang diperlukan untuk mengekalkan nilai t_1 yang sama? Andaikan tindakbalas dikawal dengan model teras mengecut (SCM) dan $E_A/R = 10{,}000$ K.

[12 markah]

[b] Pertimbangkan penurunan pelet-pelet sfera bijih besi kecil (andaikan $\rho_{Bm} =$ 20 mol/L) oleh hidrogen pada 900 K dan 2 bar sebagai diwakili oleh model teras mengecut,

$$4H_2 + Fe_3O_4\ (s) = 4H_2O + 3Fe\ (s)$$

Tunjukkan samada kemungkinan rintangan saput gas akan bererti jika berbanding dengan rintangan lapisan abu pada penukaran tinggi ($X_B \rightarrow 1$). Bagi resapan H_2, andaikan $D = 1\ sm^2/s$ pada 300 K dan $D\ \alpha\ T^{1.5}$; andaikan juga yang $D_e = 0.03\ sm^2/s$ bagi resapan melalui lapisan abu. Bagi zarah jatuh bebas yang kecil, $k_{Ag} = D/R$.

[8 markah]

[c] Taburan komponen aktif di dalam zarah sokong boleh berada di dalam mod-mod yang berbeza. Lakarkan mod-mod tersebut dan nyatakan penggunaan mereka secara ringkas.

[5 markah]

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5. *[a]* *For the following fluid-particle reaction,*

$$A(g) + bB(s) \rightarrow Products$$

Suppose the time required for the complete reaction of cylindrical particles of radius R_1, at $T_1 = 527^oC$ and partial pressure P_{Ag_1}, is t_1.

If it is proposed to use particles of double the size (R_2) at one-third the partial pressure (P_{Ag_2}), what should be the temperature (T_2) to maintain the same value of t_1? Assume reaction is controler with the shrinking-core model (SCM), and, $E_A/R = 10,000$ K.

[12 marks]

[b] *Consider the reduction of relatively small spherical pellets of iron ore (assume $\rho_{Bm} = 20$ mol/L by hydrogen at 900K and 2 bar partial pressure, as represented by the shrinking-core model,*

$$4H_2 + Fe_3O_4(s) = 4H_2O + 3Fe(s)$$

Show whether gas-film resistance is likely to be significant in comparison with ash-layer resistance at relatively high conversion ($X_B \rightarrow 1$). For diffusion of H_2, assume $D = 1$ cm^2/s at 300 K and $D \alpha T^{1.5}$; assume also that $D_e = 0.03$ cm^2/s for diffusion through the ash layer. For relatively small, free-falling particle, $k_{Ag} = D/R$.

[8 marks]

[c] *The distribution of the active component in the support particle can be in different modes. Sketch these modes and briefly state their applications.*

[5 marks]

6. [a] Bagi tindakbalas pepejal-gas *A (g) + bB (s) → Produk, (s), (g)*, kirakan pepejal tertahan (W_B) yang diperlukan di dalam reaktor bagi $X_B = 0.80$, jika $F_{Bo} = 50$ kg/min dan $t_1 = 1.5$ j. Andaikan keadaan-keadaan berikut berlaku: zarah-zarah berbentuk sfera dan semuanya bersaiz sama, tindakbalas adalah tindakbalas permukaan tertib pertama dan model teras mengecut (SCM) digunakan dengan kawalan resapan lapisan abu.

[12 markah]

[b] Bagi tindakbalas dan andaian di bahagian [a], kecuali kawalan kadar tindak balas menggantikan kawalan resapan lapisan abu, andaikan suapan mengandungi 25% zarah-zarah bersaiz R yang mana $t_1 = 1.5$ j, 35% zarah-zarah bersaiz 2R, dan 40% zarah-zarah 3R. Apakah masa mastautin bagi zarah-zarah pepejal, $\bar{t}_B$, yang diperlukan untuk $\overline{X}_B = 0.80$?

[8 markah]

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[c] Apakah objektif utama di dalam penyediaan mangkin-mangkin tersokong? Nyatakan bagaimana mangkin-mangkin tersebut disediakan?

[5 markah]

6. *[a] For the gas-solid reaction A(g) + bB(s) → Products, (s), (g), calculate the solid holdup (W_B) required in a reactor for $X_B = 0.80$, if $F_{Bo} = 50$ kg/min and $t_l = 1.5$ h. Assume the following conditions applyings: the solid particles are in PF, the gas is uniform in composition, the particles are spherical and all of one size, the reaction is a first-order surface reaction, and the shrinking-core model (SCM) applies, with ash-layer-diffusion control.*

[12 marks]

[b] For the reaction and assumptions in part [a] , except that reaction-rate control replaces ash-layer-diffusion control, suppose the feed contains 25% of particles of size R for which $t_l = 1.5$ h, 35% of particles of size 2R, and 40% of particles of size 3R. What residence time of solid particles, $\bar{t}_B$, is required for $\overline{X}_B = 0.80$?

[8 marks]

[c] What is the main objective in the preparation of supported catalysts? State how these catalysts are prepared?

[5 marks]

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