
UNIVERSITI SAINS MALAYSIA

First Semester Examination
2016/2017 Academic Session

December 2016 / January 2017

EKC 336 – Chemical Reaction Engineering
[Kejuruteraan Tindak Balas Kimia]

Duration : 3 hours
[Masa : 3 jam]

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

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

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

Arahan: Jawab **SEMUA** (4) soalan.]

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

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

Answer ALL questions.

1. [a] A reaction has the stoichiometric equation $A + B \rightarrow 2C$. Determine the order of reaction.

[2 marks]

- [b] Experimental studies of a specific decomposition of A in a batch reactor using pressure units show exactly the same rate at two different temperatures:

$$-r_A = 2.3p_A^2 \text{ at } 400K$$

$$-r_A = 2.3p_A^2 \text{ at } 500K$$

$$\text{where, } -r_A = \left[\frac{\text{mol}}{\text{m}^3 \cdot \text{s}} \right], p_A = [\text{atm}]$$

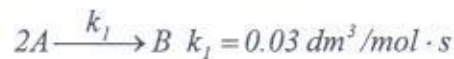
$$\text{Universal gas constant, } R = 82.06 \times 10^{-6} \frac{\text{m}^3 \cdot \text{atm}}{\text{mol} \cdot \text{K}}$$

Transform the rate expressions into concentration units and then evaluate the activation energy.

Note: The pressure is not excessive, so the ideal gas law can be applied.

[10 marks]

- [c] The irreversible liquid phase second order reaction:



is carried out in a *CSTR*. The entering concentration of A , C_{A0} , is 2 molar and the exit concentration of A , C_A is 0.1 molar. The entering and exiting volumetric flow rate is constant at 3 dm³/s. Calculate the corresponding reactor volume.

[8 marks]

- [d] Derive the differential and integral forms of design equations for plug flow reactor (*PFR*).

[5 marks]

Jawab SEMUA soalan.

1. [a] Satu tindak balas mempunyai persamaan stoikiometrik $A + B \rightarrow 2C$.
Tentukan tertib tindak balas.

[2 markah]

- [b] Kajian eksperimen penguraian spesifik A di dalam reaktor berkelompok menggunakan unit tekanan menunjukkan kadar yang sama pada dua suhu berbeza:

$$-r_A = 2.3p_A^2 \text{ pada } 400K$$

$$-r_A = 2.3p_A^2 \text{ pada } 500K$$

$$\text{di mana, } -r_A = \left[\frac{\text{mol}}{\text{m}^3 \cdot \text{s}} \right], p_A = [\text{atm}]$$

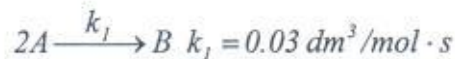
$$\text{Pemalar gas unggul, } R = 82.06 \times 10^{-6} \frac{\text{m}^3 \cdot \text{atm}}{\text{mol} \cdot \text{K}}$$

Tukarkan persamaan kadar ke dalam unit kepekatan dan seterusnya nilaikan tenaga pengaktifan.

Nota: Tekanan tidak melampau, jadi hukum gas unggul boleh digunakan.

[10 markah]

- [c] Tindak balas fasa cecair tertib kedua tidak berbalik:



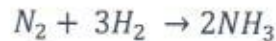
dijalankan di dalam CSTR. Kepekatan masuk A, C_{A0} , adalah 2 molar dan kepekatan keluar A, C_A adalah 0.1 molar. Kadar aliran volumetrik masuk dan keluar adalah malar pada $3 \text{ dm}^3/\text{s}$. Kirakan isipadu reaktor terbabit.

[8 markah]

- [d] Terbitkan persamaan rekabentuk pembezaan dan pengamiran untuk reaktor aliran berpalam (PFR).

[5 markah]

2. [a] The gas phase reaction



is to be carried out isothermally. The molar feed is 50% H_2 and 50% N_2 , at a pressure of 16.4 atm and 227°C.

- [i] Construct a complete stoichiometric table. [5 marks]
- [ii] What are the values of C_{A0} , δ and ϵ ? Calculate the concentrations of NH_3 and H_2 when $X_{H_2} = 0.6$. [6 marks]
- [iii] If the reaction is elementary with $k_{N_2} = 40 \text{ dm}^3/\text{mol.s}$. Write the rate of reaction solely as a function of conversion for :
- [iii].[i] A flow system
- [iii].[ii] A constant volume batch system. [4 marks]

- [b] Reactant A decomposes in a batch reactor.



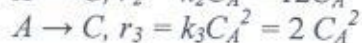
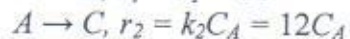
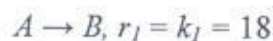
The decomposition of A in the reactor is measured at varying times with results shown in the following Table Q.1.[b]. Using fractional life method with $F = 0.8$, find a rate equation to represent the data.

[10 marks]

Table Q.1.[b].: Time-concentration data

Time, $t(s)$	0	20	40	60	120	180	300
Concentration $C_A(\text{mol/liter})$	10	8	6	5	3	2	1

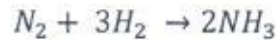
3. [a] A component A converts into B and C via three parallel reactions listed below:



where rates are in $\text{mol.L}^{-1}.\text{min}^{-1}$ and concentrations in mol.L^{-1} .

- [i] Plot the graph of the selectivity of C versus the concentration of A (C_A) in the range of 0 to 10 mol.L^{-1} . Suggest the strategy to maximize the selectivity of C . [10 marks]
- [ii] If you are the design engineer, do you recommend *PFR* or *CSTR*? Justify your recommendation. [5 marks]

2. [a] Tindak balas fasa gas



dijalankan secara isoterma. Suapan molar adalah 50% H_2 dan 50% N_2 , pada tekanan 16.4 atm dan 227°C.

[i] Bina jadual stoikiometrik yang lengkap.

[5 markah]

[ii] Apakah nilai C_{A0} , δ and ϵ ? Kirakan kepekatan NH_3 dan H_2 bila $X_{H_2} = 0.6$.

[6 markah]

[iii] Jika tindak balas adalah asas dengan $k_{N_2} = 40 \text{ dm}^3/\text{mol.s}$. Tulis kadar tindak balas sebagai fungsi penukaran untuk :

[iii].[i] Sistem aliran

[iii].[ii] Sistem kelompok isipadu malar.

[4 markah]

[b] Reaktan A terurai di dalam reaktor.



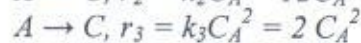
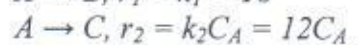
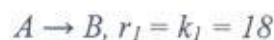
Penguraian A di dalam reaktor di ukur pada masa yang berbeza dengan keputusan ditunjukkan di dalam Jadual S.1.[b] berikut. Menggunakan kaedah hayat pecahan dengan $F = 0.8$, cari persamaan kadar untuk mewakili data.

[10 markah]

Jadual S.1.[b].: Data masa-kepekatan

Masa, $t(s)$	0	20	40	60	120	180	300
Kepekatan $C_A(\text{mol/liter})$	10	8	6	5	3	2	1

3. [a] Komponen A bertukar kepada B dan C melalui tiga tindak balas selari yang disenaraikan di bawah:



di mana kadar adalah dalam $\text{mol.L}^{-1}.\text{min}^{-1}$ dan kepekatan dalam mol.L^{-1} .

[i] Plotkan graf kememilihan C berbanding kepekatan A (C_A) dalam julat 0 - 10 mol.L^{-1} . Cadangkan strategi untuk memaksimumkan kememilihan C.

[10 markah]

[ii] Jika anda ialah jurutera reka bentuk, adakah anda mengesyorkan PFR atau CSTR? Jelaskan cadangan anda.

[5 markah]

[b] The concentration readings of a continuous response are summarized in Table Q.3.[b].

[i] Tabulate and plot the exit age distribution E .

[5 marks]

[ii] Calculate the mean residence time of fluid in the vessel t .

Table Q.3.[b]

Time t (min)	0	5	10	15	20	25	30	35
C_{pulse} (g/L)	0	6	10	10	8	4	2	0

[5 marks]

4. [a] A gas-phase decomposition is adiabatically conducted in a batch reactor. The decomposition reaction is shown be



The initial temperature is 300 K while the initial volume is 0.5 m³. The total pressure is constant at 500 kPa. The C_p values for A , R and S are 185.6, 104.7, and 80.9 J.mol⁻¹.K⁻¹ respectively. The enthalpy of reaction is -6280 J.(mol A)⁻¹. The reaction is first order with respect to A with $k_A = 10^{14} e^{-10,000/T} \text{ h}^{-1}$.

[i] Derive the material balance and energy balance equations in the simplest form for above reaction conducted in a batch reactor.

[8 marks]

[ii] Using the energy balance, determine and plot the temperature profile for the conversion range of 0.00 to 0.99. The step size should not be smaller than 0.2.

[6 marks]

[iii] Using the temperature in Q.4.[a][ii], determine the residence time to achieve a conversion of 0.99.

[4 marks]

[iv] Based on the calculation in [ii] and [iii], comment on the feasibility of this reaction in an adiabatic batch reactor.

[2 marks]

[b] The performance of a continuous flow reactor depends on the flow and mixing patterns to a great extent. Residence-time distribution (RTD) is usually used to analyze the performance of a real reactor.

[i] List 3 factors that cause the real reactors to deviate from ideal flow patterns.

[3 marks]

[ii] Name 2 types of RTD measurement.

[2 marks]

[b] Bacaan-bacaan kepekatan maklumbalas yang berterusan diringkaskan dalam Jadual S.3.[b].

[i] Jadual dan plotkan taburan umur keluar E.

[5 markah]

[ii] Kirakan masa mastautin min t bagi bendalir dalam bekas.

Jadual S.3.[b]

Time t (min)	0	5	10	15	20	25	30	35
C_{pulse} (g/L)	0	6	10	10	8	4	2	0

[5 markah]

4. [a] Suatu penguraian dalam fasa gas dijalankan secara adiabatik dalam reaktor kelompok. Tindak balas penguraian ditunjukkan seperti berikut.



Suhu awal ialah 300 K manakala isipadu awal adalah 0.5 m^3 . Jumlah tekanan adalah malar pada 500 kPa. Nilai C_p untuk A, R dan S ialah masing-masing 185.6, 104.7 dan $80.9 \text{ J.mol}^{-1}.\text{K}^{-1}$. Entalpi tindak balas ialah $-6280 \text{ J.(mol A)}^{-1}$. Tindak balas adalah tertib pertama terhadap A dengan $k_A = 10^{14} e^{-10,000/T} \text{ h}^{-1}$.

[i] Terbitkan imbalan jisim dan tenaga dalam bentuk yang paling ringkas untuk tindak balas di atas yang dijalankan dalam reaktor kelompok.

[8 markah]

[ii] Dengan menggunakan imbalan tenaga, tentukan dan plotkan lengkung suhu untuk pelbagai penukaran 0.00 hingga 0.99. Saiz langkah tidak boleh lebih kecil daripada 0.2.

[6 markah]

[iii] Menggunakan suhu yang dikira dalam soalan S.4.[a].[ii], tentukan masa mastautin untuk mencapai penukaran 0.99.

[4 markah]

[iv] Berdasarkan pengiraan dalam [ii] dan [iii], ulaskan mengenai kemungkinan tindak balas ini dalam reaktor kelompok adiabatik.

[2 markah]

[b] Prestasi bagi suatu reaktor aliran berterusan banyak bergantung kepada corak pengaliran dan pencampuran. Taburan masa mastautin (RTD) biasa digunakan untuk menganalisa prestasi reaktor sebenar.

[i] Senaraikan 3 faktor yang menyebabkan reaktor sebenar menyimpang daripada corak pengaliran unggul.

[3 markah]

[ii] Namakan 2 jenis pengukuran RTD.

[2 markah]