
UNIVERSITI SAINS MALAYSIA

Peperiksaan Kursus Semasa Cuti Panjang
Sidang Akademik 2006/2007

June 2007

KFT 131 – Physical Chemistry I
[Kimia Fizik I]

Duration: 3 hours
[Masa : 3 jam]

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

Instructions: Answer **FIVE** (5) questions. Section A is **COMPULSORY**. Answer any **TWO** (2) questions from Section B. All questions carry the same marks. You may answer a question either in Bahasa Malaysia or in English.

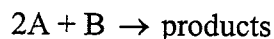
Appendix: Fundamental Constants in Physical Chemistry

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SECTION AAnswer **ALL** questions.

1. (a) The initial rates of the following reaction



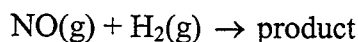
were determined under various initial concentrations of the reactants, $[A]_0$ and $[B]_0$.

Experiment	$[A]_0/\text{mol dm}^{-3}$	$[B]_0/\text{mol dm}^{-3}$	$-\frac{d[B]}{dt}/\text{mol dm}^{-3}\text{s}^{-1}$
1	0.10	0.10	0.25
2	0.20	0.10	0.50
3	0.10	0.20	0.25

Determine the order of the reaction for each reactant.

(8 marks)

- (b) For the following reaction at 1100 K,



The following half-life data were obtained for the initial pressure, P_0 , of each reactant, where $P_0(\text{NO}) = P_0(\text{H}_2)$.

$t_{1/2}/\text{s}$	81	102	140	224
P_0/Torr	354	341	288	202

Determine the overall order of the reaction.

(12 marks)

2. (a) Consider a dimerization reaction in the gaseous phase,
- $2A(\text{g}) \rightarrow B(\text{g})$
- . Given that the enthalpy change of the reaction can be represented by the following quadratic function of temperature:

$$\Delta H = \alpha T^2 + \beta T + \gamma \text{ kJ mol}^{-1}$$

where α , β and γ are constants.

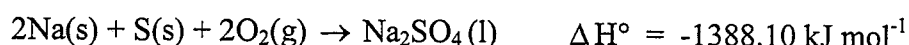
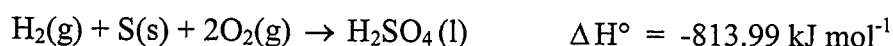
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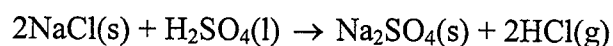
- (i) Obtain an expression for ΔC_p of the reaction as a function of T.
- (ii) Determine the \bar{C}_p of B(g) as a function of T if the \bar{C}_p of A(g) is $20.784 \text{ J K}^{-1} \text{ mol}^{-1}$.

(10 marks)

- (b) The enthalpy changes of the following reactions at 25°C are:



From these data, find the heat of reaction at constant volume at 25°C for the process.



(10 marks)

3. (a) A perfect gas undergoes isothermal compression, which reduces its volume by 2.20 L. If the final pressure and volume of the gas are $3.78 \times 10^3 \text{ Torr}$ and 4.65 L, respectively, calculate the original pressure.

(3 marks)

- (b) The critical constants of methane are $P_c = 46.5 \text{ atm}$, $T_c = 200.6 \text{ K}$ and $V_c = 148 \text{ cm}^3 \text{ mol}^{-1}$. Calculate the van der Waals parameters and estimate the radius of the methane molecules.

(7 marks)

- (c) A vessel of volume 2.0 dm^3 contains 2.0 mol H_2 and 1.0 mol N_2 at 273.15 K . Calculate;

- (i) the mole fraction of each component,
- (ii) the partial pressure,
- (iii) numbers of molecules present, and
- (iv) the relative speed of the gas molecules.

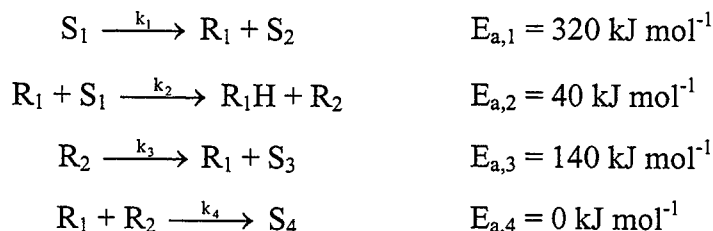
(10 marks)

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SECTION B

Answer any **TWO** questions.

4. A chain mechanism for the thermal decomposition of an organic compound is



where R represents a highly reactive radical and S represents a stable molecule.

- (a) Prove that the rate equation for this long-chain organic compound is

$$-\frac{d[S_1]}{dt} = \left(\frac{k_1 k_2 k_3}{2k_4} \right)^{1/2} [S_1]$$

(12 marks)

- (b) What is the value of the activation energy for the overall reaction?

(8 marks)

5. (a) For an ideal gas undergoing a reversible adiabatic process, derive the following equation:

$$\frac{T_1}{T_2} = \left(\frac{P_1}{P_2} \right)^{(\gamma-1)/\gamma}$$

where $\gamma = C_p / C_v$

(10 marks)

- (b) Five moles of hydrogen gas at 273 K and 1 atm are compressed adiabatically and reversibly to 10 L. Assuming that hydrogen behaves as an ideal gas, calculate

- (i) the final pressure and temperature of the gas, and

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(ii) work done in the process.

 $(\gamma = 1.4)$

(10 marks)

6. (a) A gas is found to obey the following equation of state:

$$P = \frac{RT}{V-b} - \frac{a}{V}$$

where a and b are constants. Determine whether this gas has a critical point; if it does, express the critical constants in terms of a and b . If it does not, explain how you determine this. What is the implication if the gas does not have a critical point?

(10 marks)

(b) A substance of molar mass, $M = 83.80 \text{ g mol}^{-1}$, has a vapor pressure of $1 \times 10^5 \text{ Pa}$ at $25 \text{ }^\circ\text{C}$. Determine the mass of the substance that will effuse from a Knudsen cell in 2 hours through a hole of 0.1 cm diameter.

(10 marks)

7. (a) Prove that the coefficient of thermal conductivity, κ , is equal to

$$\frac{1}{3} \lambda v C_{v,m} [A]$$

(10 marks)

(b) Two sheets of copper of area 1.25 m^2 are separated by 10 cm . What is the rate of transfer of heat from the warm sheet ($45 \text{ }^\circ\text{C}$) to the cold sheet ($-10 \text{ }^\circ\text{C}$)? The experimental value for κ is $0.0163 \text{ J K}^{-1} \text{ m}^{-1} \text{ s}^{-1}$.

(6 marks)

(c) Differentiate diffusion from effusion and state the laws associated with each of these processes.

(4 marks)

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General data and fundamental constants

Quantity	Symbol	Value	Power of ten	Units
Speed of light	c	2.99792458	10^8	m s^{-1}
Elementary charge	e	1.602176	10^{-19}	C
Faraday constant	$F=N_Ae$	9.64853	10^4	C mol^{-1}
Boltzmann constant	k	1.38065	10^{-23}	J K^{-1}
Gas constant	$R=N_Ak$	8.31447		$\text{J K}^{-1} \text{mol}^{-1}$
		8.31447	10^{-2}	$\text{L bar K}^{-1} \text{mol}^{-1}$
		8.20574	10^{-2}	$\text{L atm K}^{-1} \text{mol}^{-1}$
		6.23637	10	$\text{LTorr K}^{-1} \text{mol}^{-1}$
Planck constant	h	6.62608	10^{-34}	J s
	$\hbar = h/2\pi$	1.05457	10^{-34}	J s
Avogadro constant	N_A	6.02214	10^{23}	mol^{-1}
Standard acceleration of free fall	g	9.80665		m s^{-2}

Conversion factors**Useful relation****Unit relations**

1 eV	$1.60218 \times 10^{-19} \text{ J}$ $96.485 \text{ kJ mol}^{-1}$	2.303 RT/F $= 0.0591 \text{ V at } 25^\circ\text{C}$	Energy	$1 \text{ J} = 1 \text{ kg m}^2 \text{ s}^{-2}$ $= 1 \text{ A V s}$
	8065.5 cm^{-1}		Force	$1 \text{ N} = 1 \text{ kg m s}^{-2}$
1 cal	4.184 J		Pressure	$1 \text{ Pa} = 1 \text{ N m}^{-2}$ $= 1 \text{ kg m}^{-1} \text{ s}^{-2}$ $= 1 \text{ J m}^{-3}$
1 atm	101.325 kPa 760 Torr			
1 cm^{-1}	$1.9864 \times 10^{-23} \text{ J}$		Charge	$1 \text{ C} = 1 \text{ A s}$
1 \AA	10^{-10} m		Potential difference	$1 \text{ V} = 1 \text{ J C}^{-1}$ $= 1 \text{ kg m}^2 \text{ s}^{-3} \text{ A}^{-1}$
1 L atm	101.325 J			

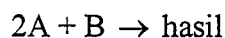
Atomic Weights

Al	26.98	C	12.01	Fe	55.85	P	30.97
Sb	121.76	Cs	132.92	Kr	83.80	K	39.098
Ar	39.95	Cl	35.45	Pb	207.2	Ag	107.87
As	74.92	Cr	51.996	Li	6.941	Na	22.99
Ba	137.33	Co	58.93	Mg	24.31	S	32.066
Be	9.012	Cu	63.55	Mn	54.94	Sn	118.71
Bi	208.98	F	18.998	Hg	200.59	W	183.84
B	10.81	Au	196.97	Ne	20.18	Xe	131.29
Br	79.90	He	4.002	Ni	58.69	Zn	65.39
Cd	112.41	H	1.008	N	14.01		
Ca	40.078	I	126.90	O	15.999		

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BAHAGIAN AJawab **SEMUA** soalan

1. (a) Kadar awal bagi tindak balas



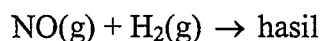
telah ditentukan pada beberapa kepekatan awal bahan tindak balas, $[A]_0$ dan $[B]_0$.

Eksperimen	$[A]_0/\text{mol dm}^{-3}$	$[B]_0/\text{mol dm}^{-3}$	$-\frac{d[B]}{dt}/\text{mol dm}^{-3}\text{s}^{-1}$
1	0.10	0.10	0.25
2	0.20	0.10	0.50
3	0.10	0.20	0.25

Tentukan tertib tindak balas bagi setiap bahan tindak balas

(8 markah)

- (b) Bagi tindak balas yang berikut pada 1100 K,



data setengah-hayat, $t_{1/2}$, diperoleh untuk tekanan awal, P_0 , bagi setiap bahan tindak balas, $P_0(\text{NO}) = P_0(\text{H}_2)$.

$t_{1/2}/\text{s}$	81	102	140	224
P_0/Torr	354	341	288	202

Tentukan tertib keseluruhan bagi tindak balas tersebut.

(12 markah)

2. (a) Pertimbangkan suatu tindak balas pendimeran fasa gas,
- $2A(\text{g}) \rightarrow B(\text{g})$
- . Diberikan bahawa perubahan entalpi bagi tindak balas tersebut dapat diwakili dengan fungsi kuadratik suhu yang berikut:

$$\Delta H = \alpha T^2 + \beta T + \gamma \text{ kJ mol}^{-1}$$

dengan α , β dan γ adalah pemalar.

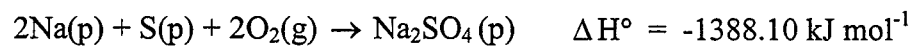
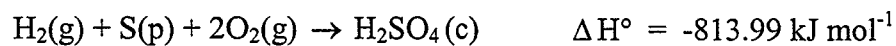
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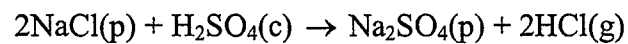
- (i) Dapatkan suatu ungkapan untuk ΔC_p bagi tindak balas ini sebagai fungsi T.
- (ii) Tentukan \bar{C}_p bagi B(g) sebagai fungsi T jika \bar{C}_p bagi A(g) adalah $20.784 \text{ J K}^{-1} \text{ mol}^{-1}$.

(10 markah)

- (b) Perubahan entalpi bagi tindak balas yang berikut pada 25°C adalah:



Berdasarkan data ini, kirakan haba tindak balas pada isipadu tetap pada 25°C bagi tindak balas.



(10 markah)

3. (a) Satu gas unggul melalui proses pemampatan isoterma yang mengakibatkan penurunan isipadu sebanyak 2.20 L. Sekiranya tekanan akhir dan isipadu akhir gas tersebut adalah masing-masing 3.78×10^3 Torr dan 4.65 L, kiralah tekanan asalnya.
- (b) Pemalar kritikal metana adalah $P_c = 46.5 \text{ atm}$, $T_c = 200.6 \text{ K}$ dan $V_c = 148 \text{ cm}^3 \text{ mol}^{-1}$. Kiralah parameter van der Waals dan anggarkan jejari bagi molekul metana.
- (c) Suatu bekas dengan isipadu 2.0 dm^3 mengandungi 2.0 mol H_2 dan 1.0 mol N_2 pada suhu 273.15 K . Kira;
- pecahan mol setiap komponen,
 - tekanan separa,
 - bilangan molekul yang ada, dan
 - halaju purata molekul gas tersebut.

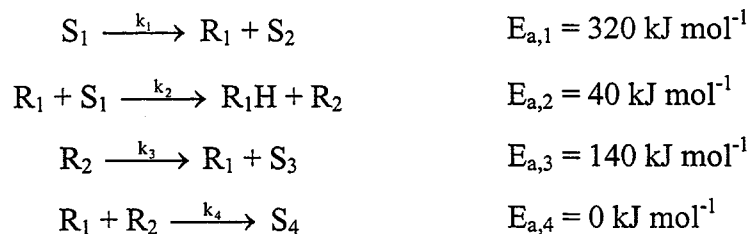
(10 markah)

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BAHAGIAN B

Jawab sebarang **DUA** soalan

4. Suatu mekanisme berantai untuk penguraian termal bagi sebatian organik ialah



Simbol R mewakili suatu radikal yang sangat reaktif dan S ialah molekul stabil.

- (a) Tunjukkan bahawa persamaan kadar bagi sebatian organik berantai panjang ialah

$$-\frac{d[S_1]}{dt} = \left(\frac{k_1 k_2 k_3}{2k_4} \right)^{1/2} [S_1]$$

(12 markah)

- (b) Berapakah nilai tenaga pengaktifan keseluruhan bagi tindak balas tersebut?

(8 markah)

5. (a) Bagi suatu gas unggul yang mengalami suatu proses adiabatik berbalik, terbitkan persamaan berikut:

$$\frac{T_1}{T_2} = \left(\frac{P_1}{P_2} \right)^{\frac{\gamma-1}{\gamma}}$$

dengan $\gamma = \frac{C_p}{C_v}$

(10 markah)

- (b) Lima mol gas hidrogen pada 273 K dan 1 atm dimampatkan secara adiabatik dan berbalik ke isipadu 10 L. Dengan menganggap bahawa hidrogen berkelakuan sebagai gas unggul, kirakan

- (i) tekanan dan suhu akhir bagi gas itu, dan

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(ii) kerja yang dibuat dalam proses itu.

$$(\gamma = 1.4)$$

(10 markah)

6. (a) Suatu gas didapati mematuhi persamaan keadaan berikut;

$$P = \frac{RT}{V-b} - \frac{a}{V}$$

dimana a dan b adalah pemalar. Tentukan sama ada gas ini mempunyai takat kritikal; sekiranya ya, nyatakan pemalar kritikal dalam sebutan a dan b . Sekiranya tidak, jelaskan bagaimana anda menentukannya. Apakah implikasinya jika gas tersebut tidak mempunyai takat kritikal?

(10 markah)

(b) Suatu bahan dengan jisim molar, $M = 83.80 \text{ g mol}^{-1}$, mempunyai tekanan wap $1 \times 10^5 \text{ Pa}$ pada $25 \text{ }^\circ\text{C}$. Tentukan jisim bahan yang akan mengefusi dari satu sel Knudsen dalam masa 2 jam melalui suatu lubang berdiameter 0.1 cm .

(10 markah)

7. (a) Buktikan koefisien kekonduksian termal, κ , adalah bersamaan dengan

$$\frac{1}{3} \lambda v C_{v,m} [A]$$

(10 markah)

(b) Dua lapisan kuprum dengan luas permukaan 1.25 m^2 dipisahkan dengan jarak 10 cm . Berapakah kadar pemindahan haba dari lapisan panas ($45 \text{ }^\circ\text{C}$) ke lapisan sejuk ($-10 \text{ }^\circ\text{C}$)? Nilai eksperimen bagi κ adalah $0.0163 \text{ JK}^{-1} \text{ m}^{-1} \text{ s}^{-1}$.

(6 markah)

(c) Bezakan pembauran dari efusi dan nyatakan hukum-hukum yang berkaitan dengan proses tersebut.

(4 markah)

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