UNIVERSITI SAINS MALAYSIA

Second Semester Examination
2009/2010 Academic Session

April/May 2010

KFT 131 – Physical Chemistry I
[Kimia Fizik I]

Duration : 3 hours
[Masa : 3 jam]

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

Instructions:

PART A (40 marks), comprising 25 multiple-choice questions (MCQ), **has to be answered within one hour of the examination on the OMR forms provided. The completed OMR forms will be collected one hour after the commencement of the examination.**

PART B (60 marks) consists of essay-type questions. Answer any **THREE** questions only, beginning the answer to each question on a new page.

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

Ensure that your OMR form is complete [with your index number, course code, answers to the questions]. Use only a 2B pencil on your OMR form.

Submit the answer scripts and question paper to the invigilator before you leave the examination hall at the end of the examination.

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

PART B

This section has FOUR questions.
Answer any THREE questions.

1. (a) For two gases at the same temperature and pressure, prove that

$$\frac{\lambda_A}{\lambda_B} = \frac{\eta_A\, M_B^{1/2}}{\eta_B\, M_A^{1/2}}$$

(4 marks)

(b) A sample of mercury is heated in an oven maintained at 380 K. A vapour pressure of 152 kPa is recorded at this temperature. An atomic beam of mercury is then released into a vacuum through a small slit of dimensions 1.0 cm by 1.0 x 10^{-3} cm. What is the rate of mass loss (in mg s^{-1}) of mercury in this process?

(6 marks)

(c) (i) Sketch a graph that depicts the Maxwell distribution of molecular speeds for a gas at two different temperatures. Label the most probable speed, υ_{mp}, mean speed, $\langle\upsilon\rangle$ and root-mean-square speed, υ_{rms}, on one of the curves.

(ii) For a certain gas, calculate the ratio of the fraction of molecules that has the υ_{mp} at 100 °C in a range $\Delta\upsilon$, to the fraction that has υ_{mp} at 25 °C in the same range.

Given: $G(\upsilon) = 4\pi\upsilon^2 \left(\frac{M}{2\pi RT}\right)^{\frac{3}{2}} e^{-\frac{M\upsilon^2}{2RT}}$

(10 marks)

2. The equilibrium constant, K_w, for the self-ionisation of water:

$$H_2O\,(aq) \underset{k_2}{\overset{k_1}{\rightleftharpoons}} H^+\,(aq) + OH^-\,(aq)$$

is 1.008 x 10^{-14} at 298 K. The forward reaction is first-order and the reverse is second-order overall.

(a) Derive the relaxation time, τ, as a function of the rate constants, k_1 and k_2.

(10 marks)

(b) After a temperature–jump, the reaction returns to equilibrium with a relaxation time of 37 μs at 298 K and pH ≈ 7. The molar concentration of pure water is 55.6 mol dm^{-3}. Calculate the rate constants, k_1 and k_2 of the reactions.

(10 marks)

3. (a) The following half-life, $t_{½}$, data are obtained for the decomposition of $N_2O(g)$ at various initial pressure, P_o, at 1030 K.

P_o / atm	0.474	0.382	0.183	0.0691
$t_{½}$ / s	212	255	470	860

Determine the order and the rate constant of the reaction using the half-life method.

(10 marks)

(b) Given that ΔH^o_{298} = - 1655 kJ mol^{-1} for the following reaction:

$$2FeS_2(s) + 5½O_2(g) \rightarrow Fe_2O_3(s) + 4SO_2(g)$$

Calculate the standard enthalpy of formation of $FeS_2(s)$ at 300 °C from the following data at 25 °C. Assume that the heat capacities are independent of temperature.

Substance	Fe(s)	$FeS_2(s)$	$Fe_2O_3(s)$	S(rhombic)	$SO_2(g)$
$\Delta_f H^o$/ kJ mol^{-1}			- 824.2		- 296.81
C_p/R	3.02	7.48		2.72	

(10 marks)

4. (a) Explain clearly what is meant by a thermodynamically reversible process.

(3 marks)

(b) Initially, the volume and pressure of 0.1 mol of methane gas are 2.90 L and 1 atm, respectively. The gas is allowed to expand adiabatically and reversibly to a pressure of 0.1 atm. Assume that the gas behaves ideally and the value of C_p/C_v is 1.31.

(i) What is the final temperature of the gas?
(ii) Calculate q, w, ΔU and ΔH in joule (J) for the process.
(iii) Could the process be carried out isothermally?
(iv) Suggest an alternative path to attain the same final state. Sketch both paths in a PV diagram.

(17 marks)

TERJEMAHAN

<u>Arahan</u>:

<u>BAHAGIAN A</u> (40 markah) mengandungi 25 soalan berbentuk objektif (MCQ), **perlu dijawab dalam masa satu jam pertama di dalam borang jawapan OMR yang disediakan. Borang OMR akan dikutip satu jam selepas peperiksaan bermula.**

<u>BAHAGIAN B</u> (60 markah) mengandungi soalan bertulis. Jawab **TIGA** soalan sahaja. Jawab tiap-tiap soalan di muka surat yang baru.

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

Pastikan borang OMR diisi dengan lengkap [nombor angka giliran, kod kursus, jawapan]. Gunakan hanya pensil 2B bagi borang OMR.

Sila serahkan buku jawapan dan kertas soalan ini kepada Pengawas sebelum anda keluar dari dewan peperiksaan.

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

BAHAGIAN B

Bahagian ini mengandungi EMPAT soalan.
Jawab sebarang TIGA soalan.

1. (a) Bagi dua gas pada suhu dan tekanan yang sama, buktikan bahawa

$$\frac{\lambda_A}{\lambda_B} = \frac{\eta_A M_B^{1/2}}{\eta_B M_A^{1/2}}$$

(4 markah)

(b) Suatu sampel raksa dipanaskan di dalam sebuah oven yang ditetapkan suhunya pada 380 K. Tekanan wap sebanyak 152 kPa telah direkodkan pada suhu ini. Suatu alur atom raksa kemudiannya dilepaskan ke dalam vakum melalui satu celahan kecil berukuran 1.0 cm dan 1.0×10^{-3} cm. Apakah kadar kehilangan jisim raksa (dalam mg s^{-1}) dalam proses ini?

(6 markah)

(c) (i) Lakarkan graf yang menunjukkan taburan laju molekul Maxwell bagi suatu gas pada dua suhu berbeza. Labelkan laju paling mungkin, υ_{mp}, laju purata, $\langle \upsilon \rangle$ dan laju punca-purata-kuasadua, υ_{rms}, pada salah satu keluk tersebut.

(ii) Bagi suatu gas tertentu, hitung nisbah pecahan molekul yang mempunyai υ_{mp} pada 100 °C dalam julat $\Delta\upsilon$, dengan pecahan yang mempunyai υ_{mp} pada 25 °C dalam julat yang sama.

Diberi: $G(\upsilon) = 4\pi\upsilon^2 \left(\frac{M}{2\pi RT}\right)^{\frac{3}{2}} e^{-\frac{M\upsilon^2}{2RT}}$

(10 markah)

2. Pemalar keseimbangan, K_w, untuk swa-pengionan air:

$$H_2O\,(ak) \underset{k_2}{\overset{k_1}{\rightleftharpoons}} H^+\,(ak) + OH^-\,(ak)$$

ialah 1.008×10^{-14} pada 298 K. Tindak balas ke hadapan adalah bertertib pertama dan tindak balas ke belakang adalah bertertib kedua.

(a) Terbitkan masa pengenduran, τ, sebagai fungsi pemalar kadar, k_1 and k_2.

(10 markah)

(b) Selepas lompatan suhu, tindak balas itu kembali kepada keseimbangan dengan masa pengenduran 37 μs pada 298 K dan pH $\approx$ 7. Kepekatan molar air tulen ialah 55.6 mol dm^{-3}. Kiralah pemalar kadar, k_1 dan k_2 bagi tindak balas tersebut.

(10 markah)

3. (a) Data setengah-hayat, $t_{½}$, yang berikut diperoleh bagi penguraian N_2O(g) pada perbagai tekanan awal, P_o, pada 1030 K.

P_o / atm	0.474	0.382	0.183	0.0691
$t_{½}$ / s	212	255	470	860

Tentukan tertib dan pemalar kadar bagi tindak balas ini dengan menggunakan kaedah setengah hayat.

(10 markah)

(b) Diberikan bahawa ΔH^o_{298} = - 1655 kJ mol^{-1} bagi tindak balas berikut:

$$2FeS_2(p) + 5½O_2(g) \rightarrow Fe_2O_3(p) + 4SO_2(g)$$

Kirakan entalpi pembentukan piawai bagi FeS_2(p) pada 300 ^{o}C dari data berikut pada 25 ^{o}C. Andaikan bahawa muatan haba tidak bergantung kepada suhu.

Zat	Fe(p)	FeS_2(p)	Fe_2O_3(p)	S(rombik)	SO_2(g)
$\Delta_f H^o$/ kJ mol^{-1}			- 824.2		- 296.81
C_p/R	3.02	7.48		2.72	

(10 markah)

4. (a) Terangkan dengan jelas apakah yang dimaksudkan dengan proses berbalik secara termodinamik.

(3 markah)

(b) Pada awalnya, isipadu dan tekanan bagi 0.1 mol gas metana masing-masing adalah 2.90 L dan 1 atm. Gas itu dibenarkan mengembang secara adiabatik dan berbalik ke tekanan 0.1 atm. Andaikan bahawa gas tersebut bersifat unggul dan nilai C_p/C_v adalah 1.31.

(i) Apakah suhu akhir gas tersebut?
(ii) Kirakan q, w, ΔU dan ΔH dalam unit joule (J) bagi proses tersebut.
(iii) Bolehkah proses tersebut dilakukan secara isotermal?
(iv) Cadangkan suatu lintasan alternatif untuk mencapai keadaan akhir yang sama. Lakarkan kedua-dua lintasan itu dalam suatu rajah PV.

(17 markah)

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Appendix: Fundamental constants in physical chemistry.

APPENDIX **UNIVERSITI SAINS MALAYSIA**

School of Chemical Sciences

General data and fundamental constants

Quantity	Symbol	Value	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	$J\ K^{-1}\ mol^{-1}$
		8.31447×10^{-2}	$L\ bar\ K^{-1}\ mol^{-1}$
		8.20574×10^{-2}	$L\ atm\ K^{-1}\ mol^{-1}$
		6.23637×10^{1}	$LTorr\ K^{-1}\ mol^{-1}$
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

1 eV	1.60218×10^{-19} J 96.485 kJ mol^{-1}	2.303 RT/F = 0.0591 V at 25 ^{o}C	Energy	1 J = 1 kg $m^2\ s^{-2}$ = 1 A V s
	8065.5 cm^{-1}		Force	1 N = 1 kg m s^{-2}
1 cal 1 atm	4.184 J 101.325 kPa 760 Torr		Pressure	1 Pa = 1 N m^{-2} = 1 kg $m^{-1}\ s^{-2}$ = 1 J m^{-3}
1 cm^{-1}	1.9864×10^{-23} J		Charge	1 C = 1 A s
1 Å 1 L atm	10^{-10} m 101.325 J		Potential difference	1 V = 1 J C^{-1} = 1 kg $m^2\ s^{-3}\ A^{-1}$
1 Poise			Viscosity	1 P = 0.1 kg $m^{-1}\ s^{-1}$

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		