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UNIVERSITI SAINS MALAYSIA

Second Semester Examination
2011/2012 Academic Session

June 2012

KFT 131 – Physical Chemistry I
[Kimia Fizik I]

Duration : 3 hours
[Masa : 3 jam]

Please check that this examination paper consists of NINETEEN pages of printed material.

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** (3) questions. Answer 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.

Appendix: Fundamental constants in physical chemistry.

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PART B

Answer any **THREE** (3) questions.
Only the first **Three** (3) questions answered in the answer book will be marked.

1. (a) For helium P_c = 2.26 atm and T_c = 5.21 K. Calculate the pressure exerted by 2.5 g of He in a 100 cm^3 vessel at 50 °C using

   (i) the ideal-gas law, the van der Waals equation and the virial equation.

   (Given that for He gas B = 12.0 cm^3 mol^{-1} and C = 112.73 cm^6 mol^{-2} at 273 K, and B = 11.3 cm^3 mol^{-1} and C = 98.07 cm^6 mol^{-2} at 373 K)

   (ii) Which method gives the closest answer to the observed pressure of 174 atm? Comment on your answer.

   (12 marks)

   (b) Define the collision flux. Ultra-high vacuum studies typically use pressures on the order of 10^{-10} torr. How many collisions occur with 1 cm^2 cross-section area of an ultra-high vacuum chamber at this pressure and at T = 298.15 K in one nanosecond? (Assume that the gas is air and has an average molecular weight of 29 g mol^{-1})

   (8 marks)

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

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

is 1.008 x 10^{-14} at 25 ^oC. 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 25 ^oC and pH≈ 7. The density of pure water is 1.0 g cm^{-3}. Calculate the rate constants, k_1 and k_2 of the reactions.

(10 marks)

3 (a) The total pressure, P_{tot}, for the following reaction:

$$SO_2Cl_2(g) \rightarrow SO_2(g) + Cl_2(g)$$

was measured as a function of time.

Time /min	0	180	360	540	720	900
P_{tot} / atm	0.1093	0.1460	0.1703	0.1865	0.1973	0.2044

Determine the order and the rate constant for this reaction.

(10 marks)

(b) For the reaction

$$H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(c),$$

the standard enthalpy change at 100 ^oC is -285.851 kJ mol^{-1}. Calculate the enthalpy of formation for water at 300 ^oC given the following information:

$$\bar{C}_p(H_2O,g) = 30.12 + (11.72x10^{-3})T + (1.130x10^{-6})T^2 \ J\,K^{-1}\,mol^{-1}$$
$$\bar{C}_P(H_2,g) = 29.29 - (0.837x10^{-3})T + (2.092x10^{-6})T^2 \ J\,K^{-1}\,mol^{-1}$$
$$\bar{C}_p(O_2,g) = 25.52 + (13.81x10^{-3})T - (4.184x10^{-6})T^2 \ J\,K^{-1}\,mol^{-1}$$

The enthalpy of vaporisation for water at 100 ^oC is 40.656 kJ mol^{-1}.

(10 marks)

4. Five moles of an ideal gas ($\bar{C}_V = \frac{3}{2}R$) at 240 K and 10 atm (state *i*) are compressed adiabatically to 300 K and 20 atm (state *f*).

(a) Devise a path consisting of two steps, one of which must be an isochoric process, to return to the initial state. Indicate states *i* and *f*, and the proposed path on a PV diagram.

(4 marks)

(b) Determine q, w, ΔU and ΔH for the proposed path.

(10 marks)

(c) Is it possible for the ideal gas to be compressed reversibly and adiabatically from state *i* to state *f* ?

(6 marks)

APPENDIX **UNIVERSITI SAINS MALAYSIA**
School of Chemical Sciences

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		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	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		Useful relation	Unit relations	
1 eV	1.60218 x 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 x 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		

TERJEMAHAN

Sila pastikan bahawa kertas peperiksaan ini mengandungi SEMBILAN BELAS muka surat bahan bercetak.

Arahan:

BAHAGIAN A (40 markah, mengandungi 25 soalan objektif (MCQ), **perlu dijawab dalam masa 1 jam pertama di dalam borang jawapan OMR yang disediakan. Borang OMR akan dikutip 1 jam selepas peperiksaan bermula.**

BAHAGIAN B (60 markah), mengandungi soalan bertulis. Jawab hanya **TIGA** (3) soalan sahaja. Jawab setiap 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

Jawab **TIGA** (3) soalan.
Hanya **TIGA** (3) jawapan yang pertama akan diperiksa.

1. (a) Bagi helium, P_c = 2.26 atm dan T_c = 5.21 K. Kirakan tekanan yang dikenakan oleh 2.5 g He dalam sebuah bekas berisipadu 100 cm^3 pada 50 °C dengan menggunakan

(i) Hukum gas unggul, persaman van der Waals dan persamaan virial.

(Diberikan bahawa bagi gas He, B = 12.0 cm^3 mol^{-1} dan C = 112.73 cm^6 mol^{-2} pada 273 K, dan B = 11.3 cm^3 mol^{-1} dan C = 98.07 cm^6 mol^{-2} pada 373 K)

(ii) Kaedah manakah memberikan jawapan yang paling dekat dengan nilai tekanan sebenar 174 atm? Berikan komen ke atas jawapan anda.

(12 markah)

(b) Takrifkan pelanggaran fluks. Kajian vakum ultra-tinggi biasanya menggunakan tekanan pada 10^{-10} Torr. Berapa banyakkah pelanggaran yang berlaku ke atas 1 cm^2 keluasan keratan rentas vakum ultra-tinggi pada tekanan ini dan T = 298.15 K dalam masa satu nanosaat? (Anggapkan bahawa gas itu ialah udara dan berat molekul purata gas adalah 29 g mol^{-1})

(8 markah)

2. Pemalar swa-pengionan, K_w, bagi air:

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

adalah 1.008 x 10^{-14} pada 25 ^oC. 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 dan k_2.

(10 markah)

(b) Selepas lompatan suhu, tindak balas itu kembali kepada keseimbangan dengan masa pengenduran 37 μs pada 25 ^oC dan pH ≈ 7. Ketumpatan air tulen adalah 1.0 g cm^{-3}. Kiralah pemalar kadar, k_1 dan k_2 bagi tindak balas itu.

(10 markah)

3 (a) Tekanan total, P_{tot} , bagi tindak balas yang berikut:

$$SO_2Cl_2(g) \rightarrow SO_2(g) + Cl_2(g)$$

telah disukat terhadap masa.

Masa /min	0	180	360	540	720	900
P_{tot} / atm	0.1093	0.1460	0.1703	0.1865	0.1973	0.2044

Tentukan tertib dan pemalar kadar bagi tindak balas ini.

(10 markah)

(b) Bagi tindak balas

$$H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(c),$$

perubahan entalpi piawai pada 100 ^oC adalah -285.851 kJ mol^{-1}. Kirakan entalpi pembentukan bagi air pada 300 ^oC diberikan maklumat berikut:

$$\bar{C}_p(H_2O,g) = 30.12 + (11.72x10^{-3})T + (1.130x10^{-6})T^2 \ J\,K^{-1}\,mol^{-1}$$
$$\bar{C}_P(H_2,g) = 29.29 - (0.837x10^{-3})T + (2.092x10^{-6})T^2 \ J\,K^{-1}\,mol^{-1}$$
$$\bar{C}_p(O_2,g) = 25.52 + (13.81x10^{-3})T - (4.184x10^{-6})T^2 \ J\,K^{-1}\,mol^{-1}$$

Entalpi pengewapan air pada 100 ^oC adalah 40.656 kJ mol^{-1}.

(10 markah)

4. Lima mol gas unggul ($\bar{C}_V = \frac{3}{2}R$) pada 240 K dan 10 atm (keadaan *i*) dimampatkan secara adiabatik ke 300 K dan 20 atm (keadaan *f*).

(a) Cari suatu lintasan yang terdiri daripada dua langkah, satu daripadanya mestilah proses isokorik, untuk kembali ke keadaan awal. Tunjukkan keadaan *i* dan *f*, dan lintasan yang dicadangkan pada rajah PV.

(4 markah)

(b) Tentukan q, w, ΔU dan ΔH bagi lintasan yang dicadangkan itu.

(10 markah)

(c) Adakan mungkin bagi gas unggul itu dimampatkan secara adiabatik dan berbalik dari keadaan *i* ke keadaan *f* ?

(6 markah)

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