UNIVERSITI SAINS MALAYSIA

Final Examination
2015/2016 Academic Session

May/June 2016

JIK 223 – Physical Chemistry I
[Kimia Fizik I]

Duration : 3 hours
[Masa : 3 jam]

Please ensure that this examination paper contains **ELEVEN** printed pages before you begin the examination.

Answer **FIVE** questions. Answer the questions in English. You may also answer the questions in Bahasa Malaysia, but not a mix of both languages.

All answers must be written in the answer booklet provided.

Each question is worth 20 marks and the mark for each sub question is given at the end of that question.

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

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

*Jawab **LIMA** soalan. Jawab soalan-soalan dalam Bahasa Inggeris. Anda juga dibenarkan menjawab soalan dalam Bahasa Malaysia, tetapi campuran antara kedua-dua bahasa ini tidak dibenarkan.*

Setiap jawapan mesti dijawab di dalam buku jawapan yang disediakan.

Setiap soalan bernilai 20 markah dan markah subsoalan diperlihatkan di penghujung subsoalan itu.

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

Answer **FIVE** questions.
*Jawab **LIMA** soalan.*

1. (a) Two ideal gas systems undergo reversible expansion starting from the same pressure (*P)* and volume (*V)*. At the end of the expansion, the two systems have the same volume. The pressure in the system that has undergone adiabatic expansion is lower than that in the system that has undergone isothermal expansion. Explain this result without using equations.

Dua sistem gas unggul mengalami pengembangan berbalik bermula dari tekanan (P) dan isipadu (V) yang sama. Pada akhir pengembangan, kedua-dua sistem ini mempunyai isipadu yang sama. Tekanan di dalam sistem yang mengalami pengembangan adiabatik adalah lebih rendah berbanding dengan sistem yang mengalami pengembangan isotermal. Terangkan keadaan ini tanpa menggunakan persamaan.

(5 marks/*markah*)

(b) Calculate ΔS, ΔS_{total}, and $\Delta S_{surroundings}$ when the volume of 85.0 g of CO initially at 298 K and 1.00 bar increases by a factor of three in an

(i) adiabatic reversible expansion
(ii) expansion against $P_{external} = 0$
(iii) isothermal reversible expansion

Take $C_{p,m}$ to be constant at the value 29.14 J mol^{-1} K^{-1} and assume ideal gas behaviour. State whether each process is spontaneous. The temperature of surroundings is 298 K.

Kirakan ΔS, $\Delta S_{keseluruhan}$, dan $\Delta S_{persekitaran}$ apabila isipadu 85.0 g CO awalnya pada 298 K dan 1.00 bar meningkat 3 kali ganda dalam

(i) pengembangan adiabatik berbalik
(ii) pengembangan kepada $P_{luar} = 0$
(iii) pengembangan isothermal berbalik

Ambil $C_{p,m}$ sebagai tetap pada nilai 29.14 J mol^{-1} K^{-1} dan andaikan gas CO adalah unggul. Nyatakan sama ada setiap proses adalah spontan. Suhu persekitaran adalah 298 K.

(15 marks/ *markah*)

2. A sample consisting of 1 mol of ideal gas ($C_{v,m} = \frac{3}{2}R$) is taken through the cycle shown in Figure 1.

Suatu sampel mengandungi 1 mol gas unggul ($C_{v,m} = \frac{3}{2}R$) melalui satu kitaran seperti yang ditunjukkan dalam Gambar rajah 1.

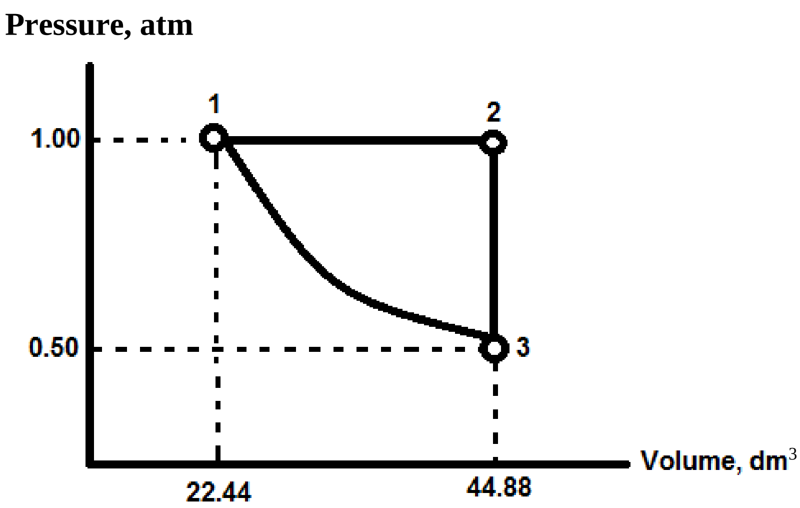

Figure 1/ *Gambar rajah 1*

(a) Determine the temperature at the points 1, 2 and 3

Tentukan suhu pada titik 1, 2 dan 3

(6 marks/*markah*)

(b) Calculate work (w), heat (q), internal energy (ΔU) and enthalpy (ΔH) for each step and for the overall cycle.

Kirakan kerja (w), haba (q), tenaga dalaman (ΔU) dan entalpi (ΔH) untuk setiap langkah dan keseluruhan kitaran.

(14 marks/*markah*)

3. (a) A battery consists of a powdered Zn/gel anode and a C/MnO_2 cathode. At the anode, Zn is oxidized to Zn^{2+} which reacts with the OH^- ion present in the paste to form $Zn(OH)_2$(s). Suppose if we use Fe metal instead of Zn metal, and that the Fe was oxidized to Fe^{2+} at the anode, what effect would this have on the cell potential (E) or electromotive force (emf) of the battery? Explain your answer briefly.

Sebuah bateri terdiri daripada serbuk anod Zn/gel dan katod C/MnO_2. Pada bahagian anod, Zn akan dioksidakan kepada Zn^{2+} yang bertindak balas dengan ion OH^- yang hadir dalam pes untuk membentuk $Zn(OH)_2$(s). Sekiranya kita menggantikan logam Zn dengan logam Fe, dan Fe akan dioksidakan kepada Fe^{2+} pada bahagian anod, apakah kesan yang akan berlaku terhadap keupayaan sel (E) atau daya elektromotif (emf) bateri tersebut? Terangkan jawapan anda secara ringkas.

(5 marks/*markah*)

(b) By finding appropriate half-cell reactions, calculate the equilibrium constant (K_{eq}) at 298.15 K for the following reactions:

Dengan menggunakan tindak balas separa sel yang sesuai, kirakan pemalar keseimbangan (K_{eq}) pada 298.15 K untuk tindak balas berikut:

(i) $2Cd(OH)_2 \rightarrow 2Cd + O_2 + 2H_2O$

(ii) $2MnO_4^{2-} + 2H_2O \rightarrow 2MnO_2 + 4OH^- + O_2$

(8 marks/*markah*)

(c) A voltaic cell is constructed to affect the reaction,

Suatu sel voltaik dibina untuk menjanakan tindak balas berikut

$$2Cr^{2+}(aq) + Pb^{2+}(aq) \rightarrow 2Cr^{3+}(aq) + Pb(s)$$

If the $[Cr^{3+}]$ = 0.0300 M, $[Pb^{2+}]$ = 0.150 M and the $[Cr^{2+}]$ = 0.250 M, calculate cell potential (E) at 25 °C.

Sekiranya $[Cr^{3+}]$ = 0.0300 M, $[Pb^{2+}]$ = 0.150 M dan $[Cr^{2+}]$ = 0.250 M, kirakan keupayaan sel (E) pada 25 °C.

(7 marks/*markah*)

4. (a) A mixture of 2.50×10^{-3} g of O_2, 3.51×10^{-3} mol of N_2, and 4.67×10^{20} molecules of CO are placed into a vessel of volume 3.50 L at 5.20 ºC.
Suatu campuran yang mengandungi 2.50×10^{-3} g O_2, 3.51×10^{-3} mol N_2, dan 4.67×10^{20} molekul CO ditempatkan ke dalam satu bekas berisipadu 3.50 L pada 5.20 ºC.

(i) Calculate the total pressure in the vessel.
Kirakan jumlah tekanan di dalam bekas.

(ii) Calculate the mole fractions and partial pressures of each gas.
Kirakan pecahan mol dan tekanan separa setiap gas.

(10 marks/*markah*)

(b) A sealed flask with a capacity of 1.00 dm^3 contains 5.00 g of ethane. The flask is so weak that it will burst if the pressure exceeds 1.00×10^6 Pa. At what temperature will the pressure of the gas exceed the bursting temperature?
Suatu kelalang tertutup dengan kapasiti 1.00 dm^3 mengandungi 5.00 g etana. Kelalang tersebut sangat lemah dan akan meletus sekiranya tekanan adalah melebihi 1.00×10^6 Pa. Pada suhu berapakah tekanan gas ini akan melebihi suhu letusan?

(5 marks/*markah*)

(c) Electrical current is passed through a resistor immersed in a liquid in an adiabatic container. The temperature of the liquid is raised by 1 ºC. The system consists solely of the liquid. Does heat or work flow across the boundary between the system and surroundings? Justify your answer.
Arus elektrik telah dialirkan melalui suatu perintang terendam di dalam suatu cecair di dalam bekas adiabatik. Suhu cecair tersebut meningkat sebanyak 1 ºC. Sistem tersebut hanya terdiri daripada cecair. Adakah haba atau kerja mengalir merentasi sempadan antara sistem dan sekitaran? Jelaskan jawapan anda.

(5 marks/*markah*)

5. (a) Consider the cell $\mathrm{Hg}(l)|\mathrm{Hg_2SO_4}(s)|\mathrm{FeSO_4}(aq, a = 0.01000)|\mathrm{Fe}(s)$.

Pertimbangkan sel $\mathrm{Hg}(l)|\mathrm{Hg_2SO_4}(s)|\mathrm{FeSO_4}(aq, a = 0.01000)|\mathrm{Fe}(s)$.

(i) Write the cell reaction.

Tuliskan tindak balas sel.

(ii) Calculate the cell potential (E), the equilibrium constant for the cell reaction (K) , and $\Delta G°_{reaction}$ at 25 °C.

Kirakan keupayaan sel (E), keseimbangan tetap untuk tindak balas sel (K) dan $\Delta G°_{tindak\ balas}$ *pada 25 °C.*

(10 marks/*markah*)

(b) At the transition temperature of 95.4 °C, the enthalpy of transition from rhombic to monoclinic sulfur is 0.38 kJ mol^{-1}.

(i) Calculate the entropy of transition under these conditions.

(ii) At its melting point, 119 °C, the enthalpy of fusion of monoclinic sulfur is 1.23 kJ mol^{-1}. Calculate the entropy of fusion.

(iii) The values given in parts (i) and (ii) are for 1 mol of sulphur. However, in crystalline and liquid sulphur, the molecule is present as S_8. Convert the values of the enthalpy and entropy of fusion in parts (i) and (ii) to those appropriate for S_8.

Pada suhu peralihan 95.4 °C, entalpi peralihan dari sulfur rombik kepada monoklinik adalah 0.38 kJ mol^{-1}.

(i) Kirakan entropi peralihan di bawah keadaan ini.

(ii) Pada takat leburnya, 119 °C, entalpi pelakuran sulfur monoklinik ialah 1.23 kJ mol^{-1}*. Kirakan entropi pelakuran.*

(iii) *Nilai yg diberi di dalam bahagian (i) dan (ii) adalah untuk 1 mol sulfur. Walaubagaimanapun, di dalam sulfur hablur dan cecair, molekulnya hadir sebagai* S_8*. Tukarkan nilai entalpi dan entropi pelakuran di bahagian (i) dan (ii)untuk disesuaikan dengan* S_8*.*

(10 marks/*markah*)

6. (a) A refrigerator operating at 30 °C is employed to maintain a cold storage tank at -10 °C. What is the minimum amount of work required to withdraw 4.184 kJ from that particular tank.

Sebuah peti sejuk beroperasi pada 30 °C digunakan untuk mengekalkan tangki penyimpanan sejuk pada -10 °C. Apakah jumlah minima kerja yang diperlukan untuk mengeluarkan 4.184 kJ daripada tangki tersebut.

(8 marks/*markah*)

(b) Consider the equilibrium $C_2H_6(g) \rightleftharpoons C_2H_4(g) + H_2(g)$. At 1000 K and a constant total pressure of 1 bar, $C_2H_6(g)$ is introduced into a reaction vessel. At equilibrium, the composition of the mixture in mole percent is $H_2(g)$: 26%, $C_2H_4(g)$: 26%, and $C_2H_6(g)$: 48%.

(a) Calculate K_p at 1000 K.

(b) If $\Delta H°_{reaction}$ = 137.0 kJ mol^{-1}, calculate the value of K_p at 298.15 K.

(c) Calculate $\Delta G°_{reaction}$ for this reaction at 298.15 K.

Pertimbangkan keseimbangan $C_2H_6(g) \rightleftharpoons C_2H_4(g) + H_2(g)$. Pada 1000 K dan tekanan tetap keseluruhan, 1 bar, $C_2H_6(g)$ telah dialirkan ke dalam bekas tindak balas. Pada keseimbangan, komposisi campuran adalah $H_2(g)$: 26%, $C_2H_4(g)$: 26%, and $C_2H_6(g)$:48%.

(a) Kirakan K_p pada 1000 K

(b) Jika $\Delta H°_{tindakbalas}$ = 137.0 kJ mol^{-1}, kirakan nilai K_p pada 298.15 K

(c) Kirakan $\Delta G°_{tindakbalas}$ untuk tindakbalas ini pada 298.15 K.

(12 marks/*markah*)

Gas Constant, R in various units

R = 8.314 J $K^{-1}mol^{-1}$

R = 8.314 Pa m^3 $K^{-1}mol^{-1}$

R = 8.314 x 10^{-2} L bar K^{-1} mol^{-1}

R = 0.082 L atm K^{-1} mol^{-1}

R = 82.057 cm^3 atm K^{-1} mol^{-1}

R = 8.314 cm^3 MPa K^{-1} mol^{-1}

Unit of Pressure and Conversion Factors

Unit of Pressure	Symbol	Numerical Value
Pascal	Pa	1 Nm^{-2} = 1 $kgm^{-1}s^{-2}$
Atmosphere	atm	1 atm = 101325 Pa
Bar	Bar	1 bar = 10^5 Pa
Torr or mm Hg	Torr	1 Torr = 101325/760 = 133.32 Pa

Types of Work

Types of Work	Variables	Equation for Work	Conventional Units
Volume Expansion	Pressure (P), Volume (V)	$w = -\int P_{external} dV$	Pam3 = J
Stretching	Tension (γ), length (l)	$w = -\int \gamma dl$	Nm = J

$Cd(OH)_2 + 2e^- \rightarrow Cd + 2\ OH^-$	$E^{\circ} = -0.809V$
$4OH^- \rightarrow O_2 + 2H_2O + 4e^-$	$E^{\circ} = -0.401V$
$MnO_4^{2-} + 2H_2O + 2e^- \rightarrow MnO_2 + 4OH^-$	$E^{\circ} = +0.60V$
$4OH^- \rightarrow O_2 + 2H_2O + 4e^-$	$E^{\circ} = -0.401V$
$2Hg + SO_4^{2-} \rightarrow Hg_2SO_4 + 2e^-\ (1)$	$E^{o} = -0.6125\ V$
$Fe^{2+} + 2e^- \rightarrow Fe\ (2)$	$E^{o} = -0.447\ V$
$2Cr^{2+}(aq) \rightarrow 2Cr^{3+}(aq) + 2e-$	$E^{o} = +0.408\ V$
$Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$	$E^{o} = -0.125\ V$
$Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$	$E^{o} = 0.7618\ V$
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	$E^{o} = 0.337\ V$
$NiOOH + H_2O + e^- \rightarrow Ni(OH)_2 + OH^-$	$E^{\circ} = +0.52V$
$4OH^- \rightarrow O_2 + 2H_2O + 4e^-$	$E^{\circ} = -0.401V$
$NO_3^- + 4H^+ + 3e^- \rightarrow NO + 2H_2O$	$E^{\circ} = +0.957\ V$
$2\ H_2O \rightarrow O_2 + 4H^+ + 4\ e^-$	$E^{\circ} = -1.229\ V$
$2Hg + SO_4^{2-} \rightarrow Hg_2SO_4 + 2e^-\ (1)$	$E^{o} = -0.6125\ V$
$Fe^{2+} + 2e^- \rightarrow Fe\ (2)$	$E^{o} = -0.447\ V$

IUPAC Periodic Table of the Elements

Key: atomic number / **Symbol** / name / standard atomic weight

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** hydrogen [1.007, 1.009]																	2 **He** helium 4.003
3 **Li** lithium [6.938, 6.997]	4 **Be** beryllium 9.012											5 **B** boron [10.80, 10.83]	6 **C** carbon [12.00, 12.02]	7 **N** nitrogen [14.00, 14.01]	8 **O** oxygen [15.99, 16.00]	9 **F** fluorine 19.00	10 **Ne** neon 20.18
11 **Na** sodium 22.99	12 **Mg** magnesium [24.30, 24.31]											13 **Al** aluminium 26.98	14 **Si** silicon [28.08, 28.09]	15 **P** phosphorus 30.97	16 **S** sulfur [32.05, 32.08]	17 **Cl** chlorine [35.44, 35.46]	18 **Ar** argon 39.95
19 **K** potassium 39.10	20 **Ca** calcium 40.08	21 **Sc** scandium 44.96	22 **Ti** titanium 47.87	23 **V** vanadium 50.94	24 **Cr** chromium 52.00	25 **Mn** manganese 54.94	26 **Fe** iron 55.85	27 **Co** cobalt 58.93	28 **Ni** nickel 58.69	29 **Cu** copper 63.55	30 **Zn** zinc 65.38(2)	31 **Ga** gallium 69.72	32 **Ge** germanium 72.63	33 **As** arsenic 74.92	34 **Se** selenium 78.97	35 **Br** bromine [79.90, 79.91]	36 **Kr** krypton 83.80
37 **Rb** rubidium 85.47	38 **Sr** strontium 87.62	39 **Y** yttrium 88.91	40 **Zr** zirconium 91.22	41 **Nb** niobium 92.91	42 **Mo** molybdenum 95.95	43 **Tc** technetium	44 **Ru** ruthenium 101.1	45 **Rh** rhodium 102.9	46 **Pd** palladium 106.4	47 **Ag** silver 107.9	48 **Cd** cadmium 112.4	49 **In** indium 114.8	50 **Sn** tin 118.7	51 **Sb** antimony 121.8	52 **Te** tellurium 127.6	53 **I** iodine 126.9	54 **Xe** xenon 131.3
55 **Cs** caesium 132.9	56 **Ba** barium 137.3	57-71 lanthanoids	72 **Hf** hafnium 178.5	73 **Ta** tantalum 180.9	74 **W** tungsten 183.8	75 **Re** rhenium 186.2	76 **Os** osmium 190.2	77 **Ir** iridium 192.2	78 **Pt** platinum 195.1	79 **Au** gold 197.0	80 **Hg** mercury 200.6	81 **Tl** thallium [204.3, 204.4]	82 **Pb** lead 207.2	83 **Bi** bismuth 209.0	84 **Po** polonium	85 **At** astatine	86 **Rn** radon
87 **Fr** francium	88 **Ra** radium	89-103 actinoids	104 **Rf** rutherfordium	105 **Db** dubnium	106 **Sg** seaborgium	107 **Bh** bohrium	108 **Hs** hassium	109 **Mt** meitnerium	110 **Ds** darmstadtium	111 **Rg** roentgenium	112 **Cn** copernicium	113 **Uut** ununtrium	114 **Fl** flerovium	115 **Uup** ununpentium	116 **Lv** livermorium	117 **Uus** ununseptium	118 **Uuo** ununoctium

57 **La** lanthanum 138.9	58 **Ce** cerium 140.1	59 **Pr** praseodymium 140.9	60 **Nd** neodymium 144.2	61 **Pm** promethium	62 **Sm** samarium 150.4	63 **Eu** europium 152.0	64 **Gd** gadolinium 157.3	65 **Tb** terbium 158.9	66 **Dy** dysprosium 162.5	67 **Ho** holmium 164.9	68 **Er** erbium 167.3	69 **Tm** thulium 168.9	70 **Yb** ytterbium 173.0	71 **Lu** lutetium 175.0
89 **Ac** actinium	90 **Th** thorium 232.0	91 **Pa** protactinium 231.0	92 **U** uranium 238.0	93 **Np** neptunium	94 **Pu** plutonium	95 **Am** americium	96 **Cm** curium	97 **Bk** berkelium	98 **Cf** californium	99 **Es** einsteinium	100 **Fm** fermium	101 **Md** mendelevium	102 **No** nobelium	103 **Lr** lawrencium

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