Second Semester Examination
2017/2018 Academic Session

May/June 2018

EBB 160/3 – Physical Chemistry of Engineering Materials
[Kimia Fizikal Bahan Kejuruteraan]

Duration : 3 hours
[Masa : 3 jam]

Please ensure that this examination paper contains THIRTEEN(13) printed pages before you begin the examination.
[Sila pastikan bahawa kertas peperiksaan ini mengandungi TIGA BELAS(13) muka surat yang bercetak sebelum anda memulakan peperiksaan ini.]

This paper consists of SEVEN(7) questions. THREE(3) questions in PART A and FOUR(4) questions in PART B.
[Kertas soalan ini mengandungi TUJUH(7) soalan. TIGA(3) soalan di BAHAGIAN A dan EMPAT(4) soalan di BAHAGIAN B.]

Instruction: Answer **FIVE(5)** questions. PART A is **COMPULSORY**. Answer **TWO (2)** questions from PART B. If a candidate answers more than five questions only the first five questions answered in the answer script would be examined.
*[**Arahan**: Jawab **LIMA(5)** soalan. BAHAGIAN A **WAJIB** dijawab. Jawab **DUA(2)** soalan dari BAHAGIAN B. Jika calon menjawab lebih daripada lima soalan hanya lima soalan pertama mengikut susunan dalam skrip jawapan akan diberi markah.]*

The answers to all questions must start on a new page.
[Mulakan jawapan anda untuk semua soalan pada muka surat yang baru.]

You may answer a question either in Bahasa Malaysia or in English.
[Anda dibenarkan menjawab soalan sama ada dalam Bahasa Malaysia atau Bahasa Inggeris.]

In the event of any discrepancies in the examination questions, the English version shall be used.
[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah digunapakai.]

PART A/ *BAHAGIAN A*

1. [a] The first law of thermodynamics is the application of the conservation of energy principle to heat and thermodynamic processes. Describe the internal energy change and work performed when a battery is recharged.

Hukum pertama termodinamik adalah aplikasi prinsip pemuliharaan tenaga untuk haba dan proses termodinamik. Terangkan perubahan tenaga dalaman dan kerja yang dilakukan apabila bateri dicas semula.

(20 marks/*markah*)

[b] One mole of an ideal gas at 298 K is expanded reversibly and isothermally from 1.0 L to 10 L. Determine the amount of work done by the system in Joules. Calculate the work done by the same system (in Joules) if the gas expanded irreversibly from 1.0 L to 10 L against a constant external pressure of 1.0 atm. Compare and briefly explain the difference in magnitude between reversible and irreversible works of the system.

Satu mol gas unggul pada 298 K dikembangkan secara berbalik dan isoterma dari 1.0 L hingga 10 L. Tentukan jumlah kerja yang dilakukan oleh sistem dalam Joule. Kirakan kerja yg dilakukan oleh sistem yang sama (dalam Joule) jika gas dikembangkan secara tidak berbalik dari 1.0 L hingga 10 L terhadap tekanan luar tetap iaitu 1.0 atm. Banding dan terangkan secara ringkas perbezaan magnitud antara kerja berbalik dan tidak berbalik untuk sistem tersebut.

(50 marks/*markah*)

[c] Calculate the standard entropy of solid copper at 1073 ^{0}C from the following data:

Kira entropi piawai untuk kuprum pepejal pada 1073 ^{0}C berdasarkan data berikut:

$S^o_{300,Cu}$ = 33.47 J/K/mol

$C_{p,Cu}$ = 22.63 + 6.27 x 10^{-3} T J/K/mol

(30 marks/*markah*)

2. [a] Define the molar conductivity (λ) of an electrolyte and specify the units.

Takrifkan kekonduksian molar (λ) suatu elektrolit dan nyatakan unitnya.

(10 marks/*markah*)

[b] Compare the characteristic of molar conductivity of weak electrolyte and strong electrolyte.

Bandingkan ciri kekonduksian molar elektrolit lemah dan elektrolit kuat.

(20 marks/*markah*)

[c] Explain Kohlrausch Law.

Jelaskan Kohlrausch Law.

(10 marks/*markah*)

[d] The resistances of a series of aqueous NaCl solutions, formed by successive dilution of a sample, were measured in a cell constant (the constant C in the relation $\kappa = C/R$ equal to 0.2063 cm^{-1}). The following values were given:

Rintangan bagi satu siri larutan NaCl akuas yang terbentuk daripada pencairan berturut-turut bagi suatu sampel, diukur dengan pemalar sel (pemalar C dimana hubungan $\kappa = C/R$ sama dengan 0.2063 cm^{-1}). Nilai berikut diberikan:

Table 1: Concentration and resistance of the NaCl solution in a cell constant
Jadual 1: Kepekatan dan rintangan larutan NaCl dalam sel pemalar

c/mol dm^{-3}	0.00050	0.0010	0.0050	0.010	0.020	0.050
R/Ω	3314	1669	342.1	174.1	89.08	37.14

(i) Verify that the molar conductivity follows the Kohlrausch Law.

Sahkan bahawa kekonduksian molar mengikut Hukum Kohlrausch.

(20 marks/*markah*)

(ii) Find the limiting molar conductivity.

Cari kekonduksian molar terhad.

(20 marks/*markah*)

(iii) Determine the coefficient K.

Tentukan pekali K.

(20 marks/*markah*)

3. [a] Name 5 factors that have an effect on reaction rates.

Namakan 5 faktor yang memberi kesan kepada kadar tindak balas.

(25 marks/*markah*)

[b] What are the differences in a homogeneous reaction and a heterogeneous reaction? Give an example for each of them.

Apakah perbezaan dalam tindakbalas homogen dan heterogen? Berikan satu contoh untuk setiap satunya.

(20 marks/*markah*)

[c] 75 % of the first-order reaction was completed in 32 minutes. Estimate the time taken for 50 % of the reaction to be completed.

75 % tindakbalas tertib pertama dilengkapkan dalam 32 minit. Jangkakan masa yang diambil untuk lengkapkan 50 % tindakbalas.

(55 marks/*markah*)

PART B/ *BAHAGIAN B*

4. [a] Using an appropriate diagram, briefly explain the difference between the work done by a system during a multi-stage irreversible and reversible expansion.

Menggunakan rajah yang bersesuaian, terangkan secara ringkas perbezaan antara kerja yang dilakukan oleh suatu sistem semasa pengembangan berbilang bagi peringkat berbalik dan tidak berbalik.

(30 marks/*markah*)

[b] Calculate the standard entropy change of the following reaction at 727 °C.

Kira perubahan entropi piawai bagi tindak balas berikut pada suhu 727 °C.

$$2Al + {}^{3}/_{2}\, O_2 = Al_2O_3$$

$$\Delta S^{o}_{298} = -313.26 \text{ J/K/mol}$$

Given / *Diberi*:

Melting point of aluminium / *Takat lebur aluminium* = 659 °C

Heat of fusion of aluminium at the melting point / *Haba pelakuran aluminium pada takat lebur* = 10,460 J/mol

$C_{pAl_2O_3}$ = 105.19 J/K/mol

C_{p,O_2} = 31.67 J/K/mol

$C_{pAl(solid)}$ = 28.28 J/K/mol

$C_{pAl(liquid)}$ = 29.29 J/K/mol

(40 marks/*markah*)

[c] Calculate the equilibrium constant for the following reaction at 750 °C.

Kira pemalar keseimbangan untuk tindak balas berikut pada suhu 750 °C.

$$NiO + H_2 = Ni + H_2O$$

Given / *Diberi*:

$$Ni + \frac{1}{2}O_2 = NiO \; ; \quad \Delta G^o = -244{,}555 + 98.53\,T \;\; \text{J}$$

$$H_2 + \frac{1}{2}O_2 = H_2O \; ; \quad \Delta G^o = -246{,}438 + 54.81\,T \;\; \text{J}$$

(30 marks/*markah*)

5. [a] Briefly explain the importance of Gibbs-Helmholtz equation.

Terangkan secara ringkas kepentingan persamaan Gibbs-Helmholtz.

(20 marks/*markah*)

[b] One mole of supercooled liquid copper crystallizes to solid copper spontaneously at a constant temperature of 1000 K. Calculate the heat released during this process. The following thermodynamics informations are given about copper:

Satu mol cecair dingin lampau kuprum menghablur kepada pepejal kuprum secara spontan pada suhu tetap 1000 K. Kirakan haba yang dibebaskan semasa proses tersebut. Maklumat termodinamik mengenai kuprum adalah seperti berikut:

The melting point of copper (at 1 atm) / *Takat lebur kuprum (pada 1 atm)* = 1356 K

The latent heat of fusion at 1356 K / *Haba pendam pelakuran pada 1356 K* = 13 kJ/mol

The heat capacity of solid copper at 1 atm / *Kapasiti haba kuprum pepejal pada 1 atm* = $22.6 - 6.3 \times 10^{-3}$ T J mol^{-1} K^{-1}

The heat capacity of the super-ccoled copper melt / *Kapasiti haba cecair dingin lampau kuprum* = 31.4 J mol^{-1} K^{-1}

(50 marks/*markah*)

[c] Chromium and carbon in stainless steel form chromium carbide at 600 °C. Show by thermodynamic calculation which of the metals among Si, Ti, and V should be alloyed to stainless steel so as to prevent the formation of chromium carbide.

Kromium dan karbon hadir dalam keluli tahan karat membentuk kromium karbida pada 600 ^{0}C. Tunjukkan melalui pengiraan termodinamik yang mana satukah antara logam-logam Si, Ti dan V yang perlu dialoikan kepada keluli tahan karat bagi menghalang pembentukan kromium karbida.

Given / *Diberi*:

$3Cr + 2C = Cr_3C_2$

$\Delta G^o = -87{,}027 - 16.74\ T\ J$

$Si + C = SiC$

$\Delta G^o = -53{,}430 - 6.95\ T\ J$

$V + C = VC$

$\Delta G^o = -83{,}680 - 6.69\ T\ J$

$Ti + C = TiC$

$\Delta G^o = -188{,}280 + 11.71\ T\ J$

(30 marks/*markah*)

6. [a] Explain how the size of an ion in group 1 affect hydration radii.

Terangkan bagaimana saiz ion dalam kumpulan 1 menjejaskan jejari penghidratan.

(20 marks/*markah*)

[b] Define why do ionic compound conduct electricity only when molten or in aqueous solution.

Nyatakan mengapa sebatian // onic mengalirkan elektrik hanya semasa melebur atau dalam larutan akuas.

(20 marks/*markah*)

[c] For a cell, with the following reaction Ag + HgCl = AgCl + Hg, at 25 ^{0}C, have d.g.e 0.0455 V and the temperature coefficient of 3:38 x10^{-4} V/ K. Evaluate ΔG_o, ΔS_o, ΔH_o for the reaction

Suatu sel, dengan tindak balas berikut Ag + HgCl = AgCl + Hg, pada 25 ^{0}C, mempunyai d.g.e 0.0455 V dan pekali suhu 3:38 x10^{-4} V/ K. Nilaikan ΔG_o, ΔS_o, ΔH_o bagi tindak balas tersebut.

(30 marks/*markah*)

[d] Determine whether the following reaction would proceed spontaneously as written at 298 K: Refer to Table 1 for further details.

Tentukan sama ada tindak balas berikut akan berterusan secara spontan seperti yang ditulis pada 298 K: Rujuk pada Jadual 1 untuk maklumat lanjut.

$Co(s)+Fe^{2+}(aq) \rightarrow Co^{2+}(aq)+Fe(s)$

$Co(s)+Fe^{2+}(ak) \rightarrow Co^{2+}(ak)+Fe(s)$

Given that:
$[Co^{2+}]=0.15$ M and $[Fe^{2+}]=0.68$ M

Di beri:
$[Co^{2+}]=0.15$ M and $[Fe^{2+}]=0.68$ M

(30 marks/*markah*)

Table 1: Standard Reduction Potential at 25°C

Jadual 1: Potensi Penurunan Standard pada 25°C

Half-Reaction	$E°$(V)
$F_2(g) + 2e^- \longrightarrow 2F^-(aq)$	+2.87
$O_3(g) + 2H^+(aq) + 2e^- \longrightarrow O_2(g) + H_2O$	+2.07
$Co^{3+}(aq) + e^- \longrightarrow Co^{2+}(aq)$	+1.82
$H_2O_2(aq) + 2H^+(aq) + 2e^- \longrightarrow 2H_2O$	+1.77
$PbO_2(s) + 4H^+(aq) + SO_4^{2-}(aq) + 2e^- \longrightarrow PbSO_4(s) + 2H_2O$	+1.70
$Ce^{4+}(aq) + e^- \longrightarrow Ce^{3+}(aq)$	+1.61
$MnO_4^-(aq) + 8H^+(aq) + 5e^- \longrightarrow Mn^{2+}(aq) + 4H_2O$	+1.51
$Au^{3+}(aq) + 3e^- \longrightarrow Au(s)$	+1.50
$Cl_2(g) + 2e^- \longrightarrow 2Cl^-(aq)$	+1.36
$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \longrightarrow 2Cr^{3+}(aq) + 7H_2O$	+1.33
$MnO_2(s) + 4H^+(aq) + 2e^- \longrightarrow Mn^{2+}(aq) + 2H_2O$	+1.23
$O_2(g) + 4H^+(aq) + 4e^- \longrightarrow 2H_2O$	+1.23
$Br_2(l) + 2e^- \longrightarrow 2Br^-(aq)$	+1.07
$NO_3^-(aq) + 4H^+(aq) + 3e^- \longrightarrow NO(g) + 2H_2O$	+0.96
$2Hg^{2+}(aq) + 2e^- \longrightarrow Hg_2^{2+}(aq)$	+0.92
$Hg_2^{2+}(aq) + 2e^- \longrightarrow 2Hg(l)$	+0.85
$Ag^+(aq) + e^- \longrightarrow Ag(s)$	+0.80
$Fe^{3+}(aq) + e^- \longrightarrow Fe^{2+}(aq)$	+0.77
$O_2(g) + 2H^+(aq) + 2e^- \longrightarrow H_2O_2(aq)$	+0.68
$MnO_4^-(aq) + 2H_2O + 3e^- \longrightarrow MnO_2(s) + 4OH^-(aq)$	+0.59
$I_2(s) + 2e^- \longrightarrow 2I^-(aq)$	+0.53
$O_2(g) + 2H_2O + 4e^- \longrightarrow 4OH^-(aq)$	+0.40
$Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$	+0.34
$AgCl(s) + e^- \longrightarrow Ag(s) + Cl^-(aq)$	+0.22
$SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \longrightarrow SO_2(g) + 2H_2O$	+0.20
$Cu^{2+}(aq) + e^- \longrightarrow Cu^+(aq)$	+0.15
$Sn^{4+}(aq) + 2e^- \longrightarrow Sn^{2+}(aq)$	+0.13
$2H^+(aq) + 2e^- \longrightarrow H_2(g)$	0.00
$Pb^{2+}(aq) + 2e^- \longrightarrow Pb(s)$	−0.13
$Sn^{2+}(aq) + 2e^- \longrightarrow Sn(s)$	−0.14
$Ni^{2+}(aq) + 2e^- \longrightarrow Ni(s)$	−0.25
$Co^{2+}(aq) + 2e^- \longrightarrow Co(s)$	−0.28
$PbSO_4(s) + 2e^- \longrightarrow Pb(s) + SO_4^{2-}(aq)$	−0.31
$Cd^{2+}(aq) + 2e^- \longrightarrow Cd(s)$	−0.40
$Fe^{2+}(aq) + 2e^- \longrightarrow Fe(s)$	−0.44
$Cr^{3+}(aq) + 3e^- \longrightarrow Cr(s)$	−0.74
$Zn^{2+}(aq) + 2e^- \longrightarrow Zn(s)$	−0.76
$2H_2O + 2e^- \longrightarrow H_2(g) + 2OH^-(aq)$	−0.83
$Mn^{2+}(aq) + 2e^- \longrightarrow Mn(s)$	−1.18
$Al^{3+}(aq) + 3e^- \longrightarrow Al(s)$	−1.66
$Be^{2+}(aq) + 2e^- \longrightarrow Be(s)$	−1.85
$Mg^{2+}(aq) + 2e^- \longrightarrow Mg(s)$	−2.37
$Na^+(aq) + e^- \longrightarrow Na(s)$	−2.71
$Ca^{2+}(aq) + 2e^- \longrightarrow Ca(s)$	−2.87
$Sr^{2+}(aq) + 2e^- \longrightarrow Sr(s)$	−2.89
$Ba^{2+}(aq) + 2e^- \longrightarrow Ba(s)$	−2.90
$K^+(aq) + e^- \longrightarrow K(s)$	−2.93
$Li^+(aq) + e^- \longrightarrow Li(s)$	−3.05

Increasing strength as oxidizing agent ↑

Increasing strength as reducing agent ↓

*For all half-reactions the concentration is 1 *M* for dissolved species and the pressure is 1 atm for gases. These are the standard state values.

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7. [a] Define activation energy.

Takrifkan tenaga pengaktifan.

(30 marks/*markah*)

[b] The specific reaction rates of a chemical reaction at 273 K and 303 K are respectively 2.45×10^{-5} and 162×10^{-5}. Calculate the activation energy of the reaction.

Kadar tindakbalas spesifik bagi suatu tindakbalas kimia pada 273 K dan 303 K didapati 2.45×10^{-5} *and* 162×10^{-5} *masing-masing. Kira jumlah tenaga pengaktifan dalam tindakbalas ini.*

(45 marks/*markah*)

[c] For the reaction: $2H_2O_2$ (aq) → $2H_2O$ (l) + O_2 (g), the initial concentration of the reactant is 0.5 M and its concentration after 5 minutes is 0.3 M. Calculate the rate of H_2O_2 decomposition.

Bagi tindakbalas berikut: $2H_2O_2$ *(aq)* → $2H_2O$ *(l)* + O_2 *(g), kepekatan asal bahan tindakbalas adalah 0.5 M dan kepekatan akhirnya adalah 0.3 M selepas 5 minit. Kirakan kadar dekomposisi* H_2O_2.

(25 marks/*markah*)

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