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# UNIVERSITI SAINS MALAYSIA

Second Semester Examination  
Academic Session 2010/2011

April/May 2011

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

Duration : 3 hours  
*[Masa : 3 jam]*

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

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

This paper consists of ONE question from PART A and SIX questions from PART B.

*[Kertas soalan ini mengandungi SATU soalan dari BAHAGIAN A dan ENAM soalan dari BAHAGIAN B.]*

**Instruction:** Answer question from PART A and **FOUR** questions from PART B. If candidate answers more than five questions only the first five questions answered in the answer script would be examined.

**Arahan:** *Jawab soalan dari BAHAGIAN A dan **EMPAT** 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, the English version must be used.

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

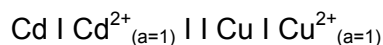
**PART A / BAHAGIAN A**

1. [a] The rate constant of a first-order reaction is  $3.5 \times 10^{-2} \text{ minute}^{-1}$ . Calculate the time taken for half the initial concentration to react.

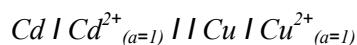
*Kadar pemalar bagi tindakbalas tertib pertama adalah  $3.5 \times 10^{-2} \text{ minit}^{-1}$ . Hitungkan masa yang diambil untuk tindakbalas kepekatan separuh daripada kepekatan awal.*



(25 marks/markah)

- [b] Calculate the standard emf of the cell below:



*Kirakan emf sel piawai bagi sel di bawah:*



Electrode	Oxidation reaction	Standard potential (volts)	Notes	
Li   Li <sup>+</sup>	Li → Li <sup>+</sup> + e <sup>-</sup>	+3.040	 reducing agents	
K   K <sup>+</sup>	K → K <sup>+</sup> + e <sup>-</sup>	+2.924		
Ca   Ca <sup>2+</sup>	Ca → Ca <sup>2+</sup> + 2e <sup>-</sup>	+2.870		
Na   Na <sup>+</sup>	Na → Na <sup>+</sup> + e <sup>-</sup>	+2.710		
Al   Al <sup>3+</sup>	Al → Al <sup>3+</sup> + 3e <sup>-</sup>	+1.660		
Zn   Zn <sup>2+</sup>	Zn → Zn <sup>2+</sup> + 2e <sup>-</sup>	+0.762		
Fe   Fe <sup>2+</sup>	Fe → Fe <sup>2+</sup> + 2e <sup>-</sup>	+0.441		
Cd   Cd <sup>2+</sup>	Cd → Cd <sup>2+</sup> + 2e <sup>-</sup>	+0.403		
Ni   Ni <sup>2+</sup>	Ni → Ni <sup>2+</sup> + 2e <sup>-</sup>	+0.236		
Sn   Sn <sup>2+</sup>	Sn → Sn <sup>2+</sup> + 2e <sup>-</sup>	+0.140		
Pb   Pb <sup>2+</sup>	Pb → Pb <sup>2+</sup> + 2e <sup>-</sup>	+0.126		
Pt   H <sub>2</sub>   H <sup>+</sup>	H <sub>2</sub> → 2H <sup>+</sup> + 2e <sup>-</sup>	0.000		
Cu   Cu <sup>2+</sup>	Cu → Cu <sup>2+</sup> + 2e <sup>-</sup>	-0.337		 oxidising agents
Ag   Ag <sup>+</sup>	Ag(s) → Ag + e <sup>-</sup>	-0.799		
Hg   Hg <sup>2+</sup>	Hg(l) → Hg <sup>2+</sup> + 2e <sup>-</sup>	-0.920		
Cl <sub>2</sub>   Cl <sup>-</sup>	2Cl <sup>-</sup> → Cl <sub>2</sub> (g) + 2e <sup>-</sup>	-1.359		

(25 marks/markah)

...3/-

- [c] One mole of a perfect gas at  $27^{\circ}\text{C}$  expands isothermally and reversibly from 10 to 1 bar against a pressure that is gradually reduced. Calculate  $q$  and  $w$  and each of the thermodynamic quantities changes of internal energy ( $\Delta U$ ), changes of enthalpy ( $\Delta H$ ), free energy ( $\Delta G$ ), Helmholtz energy ( $\Delta A$ ), and entropy ( $\Delta S$ ). Since the process is carried out isothermally and reversibly.

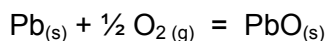
*Pada suhu  $27^{\circ}\text{C}$ , satu mol gas unggul berkembang secara isoterma dan berbalik dari 10 ke 1 bar menentang tekanan yang dikurangkan secara perlahan. Hitungkan perubahan haba,  $q$  dan kerja,  $w$  serta setiap kuantiti termodinamik seperti perubahan tenaga dalam ( $\Delta U$ ), perubahan entalpi ( $\Delta H$ ), tenaga beban ( $\Delta G$ ), tenaga Helmholtz ( $\Delta A$ ), dan entropi ( $\Delta S$ ). Anggap prosesnya berlaku secara isoterma dan berbalik.*

(50 marks/markah)

**PART B / BAHAGIAN B**

2. [a] Calculate the standard heat formation of PbO from Pb and O<sub>2</sub> at 227°C from the following data:

*Hitungkan haba pembentukan piawai bagi PbO daripada Pb dan O<sub>2</sub> pada suhu 227°C dengan menggunakan data berikut:*



$$\Delta H_{298}^{\circ} = -219.24 \text{ kJ mol}^{-1}$$

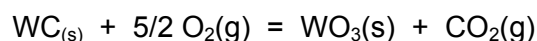
$$C_{p, \text{PbO}(s)} = 44.35 + 16.74 \times 10^{-3} T \text{ JK}^{-1} \text{ mol}^{-1}$$

$$C_{p, \text{Pb}(s)} = 23.56 + 9.75 \times 10^{-3} T \text{ J K}^{-1} \text{ mol}^{-1}$$

$$C_{p, \text{O}_2(g)} = 22.96 + 4.184 \times 10^{-3} T - 1.67 \times 10^{-5} T^2 \text{ J K}^{-1} \text{ mol}^{-1}$$

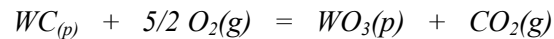
(50 marks/markah)

- [b] The heat of combustion ( $\Delta H$ ) of tungsten carbide at 300°K is - 1195.13 kJ/mole WC, and the reaction is:



Calculate the heat for the same reaction if it takes place in a constant-volume bomb calorimeter at 300°K. Assume that the gases behave ideally and that corrections to standard states are negligible for solid species.

*Haba pembakaran ( $\Delta H$ ) tungsten karbida pada 300°K ialah - 1195.13 kcal/mol WC, dan tindakbalasnya adalah seperti:*



*Hitungkan haba bagi tindakbalas yang serupa jika dilakukan dalam kalorimeter bom dengan isipadu tetap pada suhu 300 K. Anggaplah gas bersifat unggul dengan pembetulan isipadu dianggap tersangat kecil bagi pepejal.*

(50 marks/markah)

3. [a] Calculate the energy required and the cost of heating a copper slab of mass one metric ton (1000 kg) from 300 K to 1000 K, the copper will be heated by passing it through a furnace that uses electricity as its source of energy. The cost of electrical energy is assumed to be 20 cents per kilowatt-hour. Assume that there are no extraneous heat losses from the furnace; that is, all the electrical energy entering the furnace is used to heat the copper. Given  $C_p$  for copper is  $22.64 + 6.28 \times 10^{-3} T \text{ J K}^{-1} \text{ mole}^{-1}$ . Atomic weight of copper is 63.54 g/mole. Given 1 kWh =  $3.600 \times 10^6 \text{ J}$ .

*Hitungkan tenaga yang diperlukan dan kos pembakaran dari suhu 300 K sehingga 1000 K bagi plat logam kuprum seberat satu ton matrik (1000kg). Kuprum dibakar dengan menggunakan relau yang menggunakan kuasa elektrik. Kos tenaga elektrik bagi per unit kilowat-jam sebanyak 20sen. Anggapkan tidak ada kehilangan tenaga haba, bermaksud semua tenaga elektrik yang memasuki relau dianggap memanaskan kuprum sepenuhnya. Diberi  $C_p$  kuprum =  $22.64 + 6.28 \times 10^{-3} T \text{ J K}^{-1} \text{ mol}^{-1}$ . Berat atom kuprum 63.54 g/mol. Diberi 1 kWh =  $3.600 \times 10^6 \text{ J}$ .*

(50 marks/markah)

- [b] Zinc melts at 420°C and its standard entropy at 25°C is 41.63 J K<sup>-1</sup> mole<sup>-1</sup>. Calculate the standard entropy of zinc at 800°C.

Given:

Heat of fusion of Zn at the melting point,

$$\Delta H_f = 7.28 \text{ k J/mole}$$

$$C_{p \text{ Zn(s)}} = 22.38 + 10.04 \times 10^{-3} T \text{ J K}^{-1} \text{ mole}^{-1}$$

$$C_{p \text{ Zn(l)}} = 31.38 \text{ J K}^{-1} \text{ mole}^{-1}$$

*Logam Zink melebur pada suhu 420°C dan entropi piawainya pada 25°C ialah 41.63 J K<sup>-1</sup> mol<sup>-1</sup>. Hitungkan entropi piawai bagi Zink pada 800°C.*

*Diberi:*

*Haba lakuran zink pada takat leburnya*

$$\Delta H_f = 7.28 \text{ k J/mol}$$

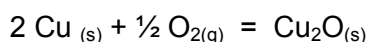
$$C_{p \text{ Zn(s)}} = 22.38 + 10.04 \times 10^{-3} T \text{ J K}^{-1} \text{ mol}^{-1}$$

$$C_{p \text{ Zn(l)}} = 31.38 \text{ J K}^{-1} \text{ mol}^{-1}$$

(50 marks/markah)

4. [a] What is the Gibbs–Helmholtz Equation? Using Gibbs-Helmholtz equation, calculate the standard enthalpy and entropy changes at 25°C for the reaction:

*Apakah persamaan Gibbs–Helmholtz? Dengan menggunakan persamaan tersebut, hitungkan perubahan entalpi dan entropi piawai pada 25°C bagi tindakbalas:*



Given / Diberi:

$$\Delta G^\circ = -169,452 - 16.40T \log T + 123.43T \text{ J}$$

(60 marks/markah)

- [b] Using the above equation, calculate the equilibrium pressure of oxygen which allows cuprous oxide, (Cu<sub>2</sub>O) and metallic copper to exist at temperature above 1000°C. Calculate the oxygen pressure when only metallic copper exist?

*Dengan menggunakan persamaan dan data di atas, hitungkan tekanan keseimbangan bagi gas oksigen bagi membolehkan logam kuprum dan kuprum oksida (Cu<sub>2</sub>O) wujud bersama pada suhu 1000°C. Hitungkan tekanan oksigen yang hanya membenarkan logam kuprum sahaja wujud?*

(40 marks/markah)

5. [a] In a second-order reaction, where the initial concentration of the reactants is the same, half of the reactants are consumed in 60 minutes. If the specific reaction rate is  $5.2 \times 10^{-3} \text{ mol}^{-1}\text{Lminutes}^{-1}$ , what is the initial concentration of the reactants?

*Dalam sesuatu tindakbalas tertib kedua, di mana kepekatan bahan tindakbalas adalah sama, separuh daripada bahan tindakbalas telah bertindakbalas dalam 60 minit. Jika kadar tindakbalas spesifik adalah  $5.2 \times 10^{-3} \text{ mol}^{-1}\text{Lminit}^{-1}$ , apakah kepekatan awal bahan tindakbalas?*

(50 marks/markah)

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

*Kadar tindakbalas spesifik bagi sesuatu tindakbalas kimia pada suhu 273 K dan 303 K di dapati masing-masing adalah  $2.45 \times 10^{-5}$  dan  $162 \times 10^{-5}$ . Kirakan tenaga pengaktifan bagi tindakbalas ini.*

(50 marks/markah)



6. [a] Calculate the emf of a Daniell cell at 25°C, when the concentration of ZnSO<sub>4</sub> and CuSO<sub>4</sub> are 0.001 M and 0.1 M respectively. The standard potential of the cell is 1.1 V.

*Kirakan emf sel Daniell pada 25°C, apabila kepekatan of ZnSO<sub>4</sub> dan CuSO<sub>4</sub> masing-masing adalah 0.001 M dan 0.1 M. Keupayaan piawai sel ini didapati 1.1 V.*

(50 marks/markah)

- [b] Reproduce a sketch of galvanic cell and explain the function of the galvanic cell in brief.

*Lakarkan sel galvanik dan terangkan fungsinya secara ringkas.*

(50 marks/markah)

7. [a] Name four factors that affect reaction rate.

*Namakan empat faktor yang mempengaruhi kadar tindakbalas.*

(20 marks/markah)

- [b] Name four examples of commercial cells (batteries) and justify the metals used in each of them.

*Berikan empat contoh sel komersial (bateri) dan tunjukkan logam-logam yang digunakan dalam setiap satu.*

(40 marks/markah)

- [c] Write down Nernst's equation and calculate the reduction potential for the reduction of O<sub>2</sub> at pH = 7 given a partial pressure of O<sub>2</sub>. [pO<sub>2</sub>] = 0.20 bar and E° = 1.229 V at pH = 7.

*Tuliskan persamaan Nernst dan hitungkan keupayaan bagi penurunan O<sub>2</sub> pada pH = 7. Diberikan tekanan separa O<sub>2</sub> [pO<sub>2</sub>] = 0.20 bar dan E° = 1.229 V pada pH = 7.*

(40 marks/markah)