
UNIVERSITI SAINS MALAYSIA

Second Semester Examination
Academic Session 2007/2008

April 2008

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 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 contains SEVEN questions.

[Kertas soalan ini mengandungi TUJUH soalan.]

Instructions: Answer **FIVE** questions. If a candidate answers more than five questions only the first five questions in the answer sheet will be graded.

[Arahan: Jawab **LIMA** soalan. Jika calon menjawab lebih daripada lima soalan hanya lima soalan pertama mengikut susunan dalam skrip jawapan akan diberi markah.]

Answer to any question must start on a new page.

[Mulakan jawapan anda untuk setiap 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.]

1. [a] Calculate the amount of enthalpy needed to heat 1 kg of BaTiO₃ from 300K to 1800K.

$$\text{Given: } C_p = 121.46 + 8.54 \times 10^{-3} T - 19.16 \times 10^{-5} T^2 \text{ Jmol}^{-1}\text{K}^{-1}$$

$$\text{MW of BaTiO}_3 = 233.31 \text{ g/mol}$$

Kira jumlah entalpi yang diperlukan untuk memanaskan 1 kg BaTiO₃ dari 300K kepada 1800K.

$$\text{Diberi: } C_p = 121.46 + 8.54 \times 10^{-3} T - 19.16 \times 10^{-5} T^2 \text{ Jmol}^{-1}\text{K}^{-1}$$

$$\text{Berat Molekul BaTiO}_3 = 233.31 \text{ g/mol}$$

(6 marks/markah)

- [b] Calculate the heat of reaction of chlorination of zirconium oxide at 25°C and 777°C, according to the following reaction.

Kirakan haba tindakbalas bagi pengklorinan zirkonium oksida pada 25°C dan 777°C, merujuk kepada tindakbalas berikut:



Given:

Diberi:

$$\text{ZrCl}_4 : \Delta H_{298}^{\circ} = -981.98 \text{ kJ/mol}$$

$$C_p = 133.55 - 12.18 \times 10^{-5} T^2 \text{ J/K/mol}$$

$$\text{CO}_2 : \Delta H_{298}^{\circ} = -393.50 \text{ kJ/mol}$$

$$C_p = 44.14 + 9.04 \times 10^{-3} T - 8.58 \times 10^{-5} T^2 \text{ J/K/mol}$$

$$\text{ZrO}_2 : \Delta H_{298}^{\circ} = -1.085.75 \text{ kJ/mol}$$

$$C_p = 69.62 + 7.53 \times 10^{-3} T - 14.06 \times 10^{-5} T^2 \text{ J/K/mol}$$

$$\text{Cl}_2 : C_p = 36.90 - 0.25 \times 10^{-3} T - 2.85 \times 10^{-5} T^2 \text{ J/K/mol}$$

$$\text{C} : C_p = 17.15 + 4.27 \times 10^{-3} T - 8.79 \times 10^{-5} T^2 \text{ J/K/mol}$$

(14 marks/markah)

...3/-

2. [a] Two pieces of a metal of same size at temperatures T_1 and T_2 are brought together and allowed to cool to a constant temperature. Show that the entropy change due to this cooling process is:

Dua blok logam yang sama dengan saiz yang sama pada suhu yang berbeza, T_1 dan T_2 . Blok-blok ini didekatkan dan dibiarkan mencapai suhu yang sama. Tunjukkan bahawa perubahan entropi diberikan oleh:

$$\Delta S = C_p \ln \frac{(T_1 + T_2)^2}{4T_1 T_2}$$

(10 marks/markah)

- [b] A 40 kg steel casting at a temperature of 450°C was quenched in 150 kg oil at 25°C . Assume that there is no heat loss to the surroundings, calculate the change in entropy in (i) the casting, (ii) the oil bath, (iii) the entire system (casting + oil).

Given:

Steel cast : $C_p = 0.5 \text{ kJ/kg K}$

Oil $C_p = 2.5 \text{ kJ/kg K}$

Comment on the value for the entire system.

Keluli tuangan dengan jisim sebanyak 40 kg dan suhu 450°C dilindap kejut di dalam 150 kg minyak pada suhu 25°C . Dengan andaian tiada kehilangan haba kepada persekitaran, kira perubahan entropi dalam (i) tuangan, (ii) kubang minyak, (iii) keseluruhan sistem (tuangan + minyak).

Diberi:

Keluli tuang : $C_p = 0.5 \text{ kJ/kg K}$

Minyak $C_p = 2.5 \text{ kJ/kg K}$

Berikan komen pada nilai untuk keseluruhan sistem.

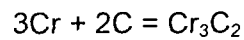
(10 marks/markah)

3. [a] 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.

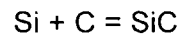
Kromium dan karbon hadir dalam keluli tahan karat membentuk kromium karbida pada 600°C. Tunjukkan melalui pengiraan termodinamik mana satukah antara logam-logam Si, Ti dan V yang perlu dialoikan kepada keluli tahan karat bagi menghalang pembentukan kromium karbida.

Given:

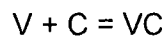
Diberi:



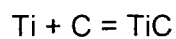
$$\Delta G^\circ = -87,027 - 16.74 T \text{ J}$$



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



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

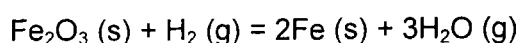


$$\Delta G^\circ = -188,280 + 11.71 T \text{ J}$$

(8 marks/markah)

- [b] Iron oxide is reduced to iron by hydrogen gas according to the following reaction. Using the given information, determine whether this reduction is spontaneous.

Besi oksida mengalami penurunan oleh gas hidrogen seperti ditunjukkan oleh tindakbalas berikut pada 25°C dan tekanan 1 atm (101, 325 N/m²). Adakah proses ini berlaku secara spontan?



Given:

Diberi:

$$\Delta H_{298}^{\circ}(\text{H}_2\text{O}) = -241,789 \text{ J/mol}$$

$$\Delta H_{298}^{\circ}, <\text{Fe}_2\text{O}_3> = -196,500 \text{ J/mol}$$

$$\Delta S_{298}^{\circ}(\text{H}_2\text{O}) = 188.7 \text{ J/K/mol}$$

$$\Delta S_{298}^{\circ}, <\text{Fe}> = 27.15 \text{ J/K/mol}$$

$$\Delta S_{298}^{\circ}(\text{H}_2) = 130.58 \text{ J/K/mol}$$

$$\Delta S_{298}^{\circ}, <\text{Fe}_2\text{O}_3> = 89.95 \text{ J/K/mol}$$

(12 marks/markah)

4. [a] Derived the Gibbs – Helmholtz equation

Terbitkan persamaan Gibbs – Helmholtz

$$\left[\frac{\partial \left(\frac{\Delta G}{T} \right)}{\partial T} \right]_P = -\frac{\Delta H}{T^2}$$

(10 marks/markah)

- [b] What is the minimum temperature at which CaCO_3 will begin to decompose into CaO and CO_2 in air at 1 atm. Assume the partial pressure of CO_2 in air is 3.5×10^{-4} atm. The $\Delta G^\circ(T)$ for the decomposition reaction is $168,400T$ J/mole CaO .

Apakah suhu minima bagi bermulanya penguraian CaCO_3 kepada CaO dan CO_2 dalam udara pada 1 atm. Andaikan tekanan separa CO_2 dalam udara ialah 3.5×10^{-4} atm. $\Delta G^\circ(T)$ bagi tindakbalas penguraian ialah $168,400T$ J/mol CaO .

(10 marks/markah)

5. [a] Consider the Maxwell equation

Pertimbangkan tindakbalas Maxwell

$$\left(\frac{\partial P}{\partial T}\right)_V = \left(\frac{\partial S}{\partial V}\right)_T$$

For a liquid in equilibrium with vapour in an enclosed space, $\Delta V = V_{\text{vapour}} - V_{\text{liquid}} \approx V_{\text{vapour}}$. Using this derive a relationship showing the change in $\ln P$ with temperature, T .

Bagi cecair berada dalam keseimbangan dengan wap di dalam ruangan tertutup, $\Delta V = V_{\text{wap}} - V_{\text{cecair}} \approx V_{\text{wap}}$. Dengan menggunakan maklumat tersebut, terbitkan hubungan menunjukkan perubahan $\ln P$ dengan suhu, T .

(10 marks/markah)

- [b] For a sample of liquid brass at 1100°C , with 30 atomic% Zn, apply the Clausius-Clapeyron equation, and find the vapour pressure of copper and zinc over the alloy. Assume that the alloy is ideal. The boiling points are 2595°C and 905°C for copper and zinc respectively, and the heats of vaporization are 305.6 kJ/mol and 115.9 kJ/mol for copper and zinc respectively.

Bagi loyang cair pada 1100°C , dengan 30 %atom Zn, gunakan persamaan Clausius-Clapeyron dan dapatkan tekanan wap bagi kuprum dan zink terhadap aloi. Andaikan bahawa aloi adalah ideal. Takat didih adalah 2595°C dan 905°C bagi kuprum dan zink, dan haba pengewapan ialah 305.6 kJ/mol dan 115.9 kJ/mol bagi kuprum dan zink.

(10 marks/markah)

6. [a] Show that the time required for the reaction of any given fraction of the material initially present is independent of the initial concentration for a first order reaction, but it varies with the initial concentration for a second order reaction.

Tunjukkan bahawa masa yang diperlukan untuk tindakbalas bagi sebarang juzuk bahan yang hadir pada permulaan tidak bergantung pada kepekatan awal bagi tindakbalas tertib pertama, tetapi berubah dengan kepekatan awal bagi tindakbalas tertib kedua.

(10 marks/markah)

- [b] The specific rate constant of a reaction at 400°C is double to that at 300°C . Calculate the activation energy at the reaction.

Pemalar kadar spesifik bagi tindakbalas pada 400°C adalah dua kali ganda daripada pemalar kadar spesifik bagi tindakbalas pada 300°C . Kirakan tenaga pengaktifan tindakbalas tersebut.

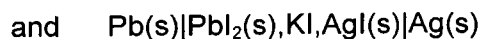
(10 marks/markah)

7. [a] Calculate the potential, at 25°C of a cell consisting of a SCE attached to the negative terminal of the voltmeter and a silver wire electrode attached to the positive terminal. The silver wire electrode is dipping in a solution of $1.29 \times 10^{-3} \text{M Ag}^+$. Standard potential for $\text{Ag}^+ + e = \text{Ag}$ is 0.799V on hydrogen scale. SCE has potential 0.244V on hydrogen scale.

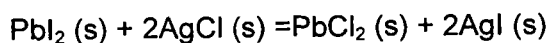
Kirakan keupayaan pada 25°C bagi sel yang mengandungi SCE yang disambung kepada terminal negatif pada meter volt dan elektrod wayar perak yang disambung pada terminal positif. Elektrod wayar perak direndam di dalam larutan $1.29 \times 10^{-3} \text{M Ag}^+$. Keupayaan piawai bagi $\text{Ag}^+ + e = \text{Ag}$ ialah 0.799V pada skala hidrogen. SCE mempunyai keupayaan 0.244V dalam skala hidrogen.

(5 marks/markah)

- [b] The e.m.f of the reversible cells



at 25°C are -4902 and 0.2111 V respectively. The temperature coefficients of e.m.f of the above cells are -186×10^{-6} and -127×10^{-6} V/deg respectively. Calculate the values of ΔG° and ΔH° for the reaction



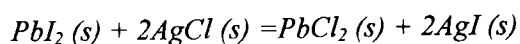
If the standard enthalpies of PbI_2 , AgCl , and PbCl_2 at 25°C are -175.3 kJ/mol, -126.8 kJ/mole, -359.0 kJ/mole respectively, calculate the standard enthalpy of AgI at 25°C.

e.m.f. bagi sel-sel berbalik



dan $Pb(s)|PbI_2(s),KI,AgI(s)|Ag(s)$

pada 25°C masing-masing adalah -4902 dan 0.2111V. Pekali suhu e.m.f bagi sel-sel tersebut masing-masing adalah -186×10^{-6} and -127×10^{-6} V/deg. Kirakan nilai ΔG° dan ΔH° bagi tindakbalas



Jika entalpi piawai bagi PbI_2 , $AgCl$, dan $PbCl_2$ pada 25°C masing-masing adalah -175.3 kJ/mol, -126.8 kJ/mol, -359.0 kJ/mol, kirakan entalpi piawai bagi AgI pada 25°C.

(15 marks/markah)