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# UNIVERSITI SAINS MALAYSIA

Second Semester Examination  
Academic Session 2010/2011

April/May 2011

## **EBS 323/3 - Pyrometallurgy** **[Pirometalurgi]**

Duration : 3 hours  
[Masa : 3 jam]

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Please ensure that this examination paper contains NINE printed pages and ONE page of APPENDIX before you begin the examination.

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

This paper consists of SEVEN questions.

*[Kertas soalan ini mengandungi TUJUH soalan.]*

**Instruction:** Answer **FIVE** questions. If a candidate answers more than five questions only the first five questions answered in the answer script would be examined.

**[Arahan:** Jawab **LIMA** soalan. 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 shall be used.

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

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1. [a] Describe the differences between the following processes and give examples:

- (i) Oxidation roasting
- (ii) Chloridizing roasting
- (iii) Sulphating roasting
- (iv) Volatizing roasting

*Huraikan dengan jelas perbezaan proses berikut dan berikan contoh:*

- (i) *Pemanggangan pengoksidaan*
- (ii) *Pemanggangan penkloridaan*
- (iii) *Pemanggangan pengulfatan*
- (iv) *Pemanggangan meruap*

(40 marks/markah)

[b] If the blast furnace operator wants to maintain the ratio of CO/CO<sub>2</sub> to be 2.5:1, ignoring the amount of CO<sub>2</sub> added by the decomposition of CaCO<sub>3</sub>, calculate,

- (i) The weight of carbon required per ton of iron reduced.
- (ii) The volume of air required per ton of iron reduced.

Given: Atomic weights of Fe = 56, O = 16, C = 12 g/mol, and density of air = 1.168 kgm<sup>-3</sup>.

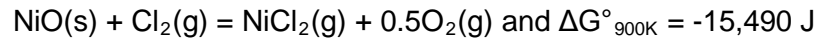
*Sekiranya pengendali relau bagas ingin mengekalkan nisbah CO/CO<sub>2</sub> menjadi 2.5:1, dengan mengabaikan amaun CO<sub>2</sub> yang ditambah oleh penguraian CaCO<sub>3</sub>, kirakan:*

- (i) *Berat karbon yang diperlukan per tan besi yang diturunkan.*
- (ii) *Isipadu udara yang diperlukan per tan besi yang diturunkan.*

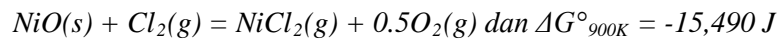
*Diberi berat atom Fe = 56, O = 16, C = 12 g/mol dan ketumpatan udara = 1.168 kgm<sup>-3</sup>.*

(60 marks/markah)

2. [a] The Chlorination of NiO is carried out at 900K and the conversion of Cl<sub>2</sub> is required to be 90% during a single pass through the reactor. Calculate the total gas pressure needed to achieved this conversion. Given the reaction equation below:



*Pengkloridaan NiO telah dijalankan pada suhu 900 K dan penukaran kepada Cl<sub>2</sub> mestilah sebanyak 90% dan ia berlaku dalam reaktor dengan sekali lalu. Kirakan tekanan gas klorin yang di perlukan untuk mencapai penukaran itu. Diberikan persamaan tindakbalas berikut:*



(60 marks/markah)

- [b] Schematically, show the process flow sheet of the HyL III process indicating the reactions involved and how it differs from MIDREX and COREX process. Label the input and output.

*Secara skematik, tunjukkan carta alir proses bagi satu unit HyL III dengan tindakbalas yang berlaku dan tunjukkan bagaimana ia berbeza dengan proses MIDREX dan COREX. Labelkan input dan outputnya.*

(40 marks/markah)

3. Write short notes on any **four** of the following:

*Berikan catatan ringkas mana-mana empat daripada 5 pernyataan berikut:*

- (a) Henry's Law and Raoult's law with its application to steel making.

*Hukum Henry dan Raoult's dan hubungannya dengan aplikasi pembuatan keluli.*

- (b) Sulphate capacity of slag and its use in steel making.

*Muatan sulfat bagi jermang dan penggunaannya bagi pembuatan keluli.*

- (c) Whitman's Two Film Theory.

*Teori dua filem Whitman.*

- (d) Basic and acidic slag with description of its structure and applications.

*Huraikan struktur dan aplikasi slag kebesan dan berasid.*

- (e) 3 ways of retarding oxidation of DRI (Direct Reduced Iron).

*Tiga cara untuk menghalang pengoksidaan DRI (Penurunan Terus Besi).*

(100 marks/markah)

4. [a] One blast furnace of working volume  $2000\text{m}^3$  produces 250 metric tonnes of hot metal per hour. The average hot metal composition is: (Fe = 93%, C = 4.2%, Si = 1.6%, Mn = 0.8%). The furnace uses hematite ore ( $\text{Fe}_2\text{O}_3 = 95\%$ ,  $\text{SiO}_2 = 3\%$ ,  $\text{Al}_2\text{O}_3 = 1\%$ ,  $\text{MnO} = 1\%$ ), flux ( $\text{CaCO}_3 = 90\%$ ,  $\text{SiO}_2 = 10\%$ ), coke (C = 94%,  $\text{SiO}_2 = 3\%$ ,  $\text{Al}_2\text{O}_3 = 3\%$ ).

Assume:

- (i) All the iron ore charged gets reduced by carbon.
- (ii) Ore, coke, and flux are moisture free.
- (iii) The final slag contains 50% CaO.
- (iv) Coke rate = 250 kg/thm (thm = ton of hot metal).
- (v) Atomic weights given: Fe = 56, Si = 28, Ca = 40, Mn = 55, C = 12, O = 16 g/mol.

Calculate:

- (i) Amount of iron ore used in tons per day.
- (ii) Basicity ( $\text{CaO}/\text{SiO}_2$ ) of the final slag.
- (iii) Percentage of the total  $\text{SiO}_2$  reduced inside the furnace.
- (iv) Productivity of the furnace (in  $\text{t}/\text{d}/\text{m}^3$ ).

Satu relau bagas dengan isipadu kerja  $2000 \text{ m}^3$  menghasilkan 250 metrik tan logam panas sejam. Komposisi purata logam panas adalah ( $\text{Fe} = 93\%$ ,  $\text{C} = 4.2\%$ ,  $\text{Si} = 1.6\%$ ,  $\text{Mn} = 0.8\%$ ). Relau ini menggunakan bijih hematite ( $\text{Fe}_2\text{O}_3 = 95\%$ ,  $\text{SiO}_2 = 3\%$ ,  $\text{Al}_2\text{O}_3 = 1\%$ ,  $\text{MnO} = 1\%$ ), fluks ( $\text{CaCO}_3 = 90\%$ ,  $\text{SiO}_2 = 10\%$ ), kok ( $\text{C} = 94\%$ ,  $\text{SiO}_2 = 3\%$ ,  $\text{Al}_2\text{O}_3 = 3\%$ ).

Andaikan:

- (i) Semua bijih besi yang dimasukkan diturunkan oleh karbon.
- (ii) Bijih, kok dan fluks adalah bebas kelembapan.
- (iii) Kandungan akhir jermang mengandungi 50%  $\text{CaO}$ .
- (iv) Kadar kok = 250 kg/thm.
- (v) Berat atom diberi:  $\text{Fe} = 56$ ,  $\text{Si} = 28$ ,  $\text{Ca} = 40$ ,  $\text{Mn} = 55$ ,  $\text{C} = 12$ ,  $\text{O} = 16 \text{ g/mol}$ .

Kirakan:

- (i) Amaun bijih besi yang digunakan dalam tan/hari.
- (ii) Kebesan ( $\text{CaO/SiO}_2$ ) jermang akhir.
- (iii) Peratusan jumlah  $\text{SiO}_2$  yang diturunkan dalam relau.
- (iv) Pengeluaran relau dalam ( $\text{t/hari/m}^3$ ).

(60 marks/markah)

- [b] Explain fractional distillation and give examples of it uses.

Huraikan penyulingan berperingkat dan berikan contoh penggunaannya.

(40 marks/markah)

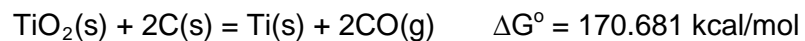
5. [a] Explained the terms below in terms of pyrometallurgy;
- (i) Slag
  - (ii) Catalyst
  - (iii) Calcinations
  - (iv) Carbothermal reduction

*Terangkan istilah berikut dalam konteks pirometalurgi;*

- (i) *Jermang*
- (ii) *Mangkin*
- (iii) *Pengkalsinan*
- (iv) *Penurunan karbotermal*

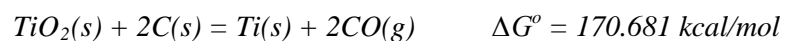
(40 marks/markah)

- [b] The carbon reduction of  $\text{TiO}_2$  at 1200 K shows the following reaction equation:



This equation shows that this reaction is thermodynamically not feasible at 1200°K. However, can it be made possible thermodynamically at that temperature by manipulating the process parameters?

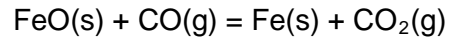
*Penurunan karbon bagi  $\text{TiO}_2$  dijalankan pada suhu 1200 K menunjukkan tindakbalas berikut:*



*Persamaan ini menunjukkan bahawa tindakbalas ini secara termodinamikanya tidak mungkin berlaku pada suhu 1200 K. Walau bagaimanapun, adakah ia boleh berlaku secara termodinamik pada suhu tersebut dengan mengubah parameter proses?*

(60 marks/markah)

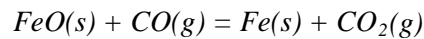
6. [a] The following equilibrium data have been determined for the reaction:



T(°C)	500	600	700	800	900
Log (K)	0.11	-0.041	-0.158	-0.246	-0.315

With reference to Figure 1 in Appendix, find  $\Delta H^\circ$ ,  $K$ , and  $\Delta G^\circ$  at 1200K by using a plot.  $\Delta H$  = Enthalpy.  $K$  = Equilibrium Constant.  $\Delta G$  = Gibbs Free Energy of Formation.

*Data keseimbangan berikut telah ditentukan bagi tindakbalas:*



T(°C)	500	600	700	800	900
Log (K)	0.11	-0.041	-0.158	-0.246	-0.315

*Dengan merujuk Rajah 1 dalam Lampiran, cari  $\Delta H^\circ$ ,  $K$ , dan  $\Delta G^\circ$  pada suhu 1200K dengan menggunakan suatu plot.  $\Delta H$  = Entalpi.  $K$  = Pemalar Keseimbangan.  $\Delta G$  = Formasi Tenaga Bebas Gibbs.*

(40 marks/markah)

- [b] Explain the process selection for vacuum degassing of molten steel.

*Terangkan proses penyahgas vakum untuk keluli lebur.*

(30 marks/markah)

- [c] Explain matte smelting of chalcopyrite ore.

*Huraikan peleburan matte bagi bijih kalkopirit.*

(30 marks/markah)



7. [a] Discuss the major reactions involved with the indirect reaction inside an iron blast furnace.

*Bincangkan tindakbalas-tindakbalas utama yang terlibat dengan tindakbalas tidak langsung dalam besi relau bagas.*

(50 marks/markah)

- [b] Explain zone refining with the aid of a phase diagram.

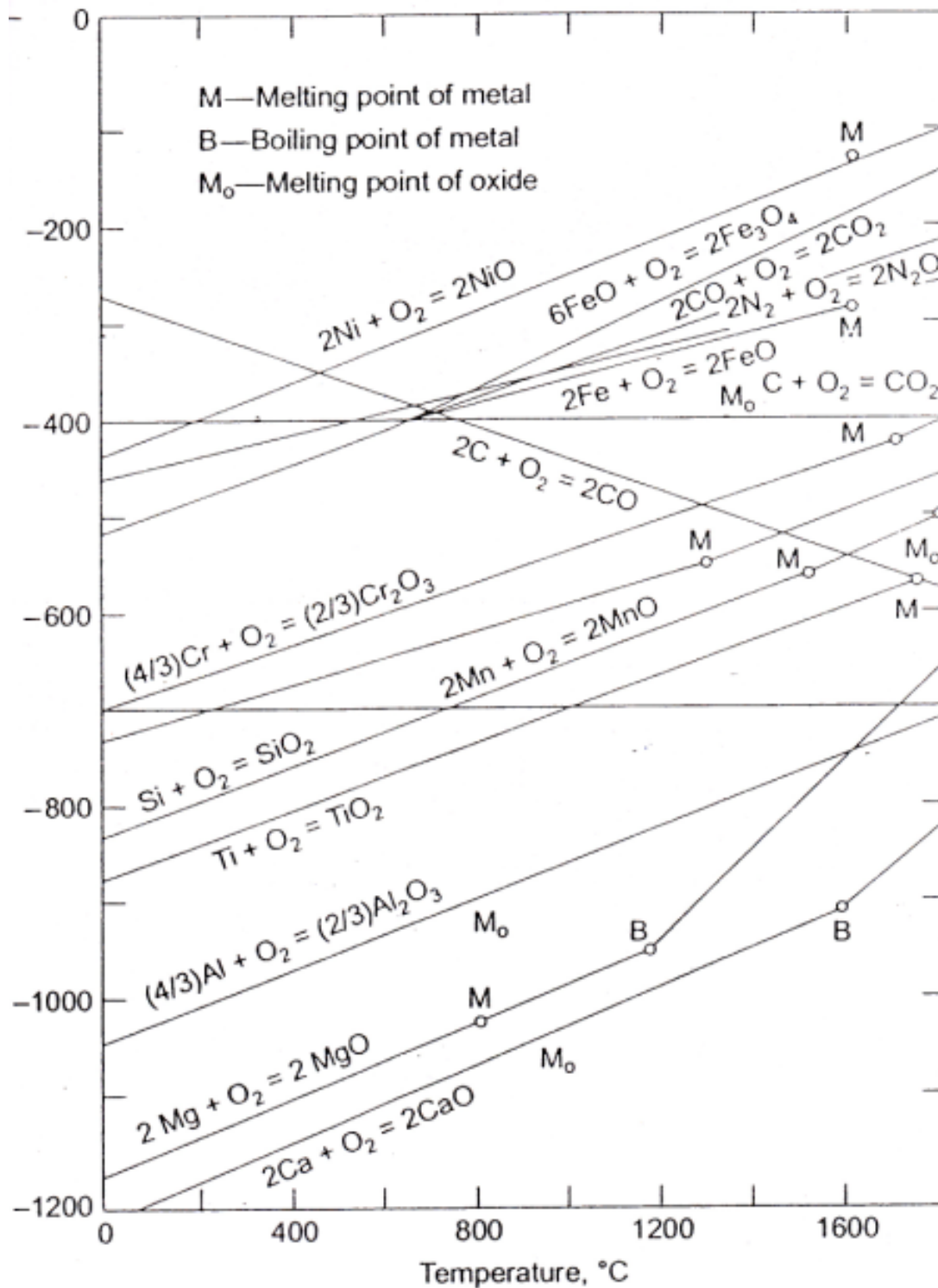
*Terangkan zon penapisan dengan bantuan satu gambarajah fasa.*

(30 marks/markah)

- [c] In the Hall-Heroult cell, list 4 factors affecting electrolysis.

*Dalam sel Hall-Heroult, senaraikan 4 faktor yang mempengaruhi elektrolisis.*

(20 marks/markah)

AppendixLampiran

**Figure 1: Standard free energy of formation of some oxides as function of temperature.**