UNIVERSITI SAINS MALAYSIA

Second Semester Examination
2012/2013 Academic Session

June 2013

EBS 323/3 – Pyrometallurgy
[Pirometalurgi]

Duration : 3 hours
[Masa : 3 jam]

Please ensure that this examination paper contains THIRTEEN printed pages before you begin the examination.
[Sila pastikan bahawa kertas peperiksaan ini mengandungi TIGA BELAS muka surat 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 digunapakai.]

...2/-

1. [a] With a neat sketch, discuss the working principles of a DH degasser. What are the major consideration of its use in a steel making process?

Dengan bantuan lakaran, bincangkan prinsip kerja DH penyahgas. Apakah pertimbangan utama kegunaan prinsip ini dalam proses pembuatan keluli?

(60 marks/*markah*)

[b] Describe the important kinetic considerations and the possible ways to improve the overall process kinetics during the operation of industrial degassing and decarburization units?

Terangkan kepentingan keseimbangan kinetik dan cara yang dapat meningkatkan keseluruhan proses kinetik sepanjang operasi industri penyahgas dan unit penyahkarbonan?

(40 marks/*markah*)

2. [a] A blast furnace of working volume 2000 m^3 produces 100 tonnes of hot metal per hour. The average hot metal composition is: (Fe = 95%, C = 2.0%, Si = 2.0%, Mn = 0.5%). The furnace uses hematite ore (Fe_2O_3 = 90%, SiO_2 = 7%, Al_2O_3 = 2%, MnO = 1%), flux ($CaCO_3$ = 95%, SiO_2 = 5%), coke (C = 90%, SiO_2 = 8%, Al_2O_3 = 2%).

Assume:

(i) All the iron ore charged gets reduced by carbon.

(ii) Ore, coke, and flux are moisture free.

(iii) The final slag contains 60% CaO

(iv) Coke rate = 600 kg/per tonne of hot metal.

(v) Atomic weights given : Fe = 56, Si = 28, Ca = 40, Mn = 55, C = 12, O = 16 g/mol.

Satu relau bagas dengan isipadu kerja 2000 m^3 menghasilkan 100 tan logam panas per jam. Komposisi purata logam panas adalah (Fe = 95%, C = 2.0%, Si = 2.0%, Mn = 0.5%). Relau ini menggunakan bijih hematite (Fe_2O_3 = 90%, SiO_2 = 7%, Al_2O_3 = 2%, MnO = 1%), flux ($CaCO_3$ = 95%, SiO_2 = 5%), arang (C = 90%, SiO_2 = 8%, Al_2O_3 = 2%).

Anggapkan:

(i) Semua bijih besi yang dimasukkan diturunkan oleh karbon.

(ii) Bijih, arang batu dan flux adalah bebas kelembapan.

(iii) Kandungan akhir jermang mengandungi 60% CaO.

(iv) Kadar arang batu = 600kg/per tan logam panas.

(v) Berat atom diberi: Fe = 56, Si = 28, Ca = 40, Mn = 55, C = 12, O = 16 g/mol.

Calculate:

Kirakan:

(i) Amount of iron ore used in tonnes per day

Amaun bijih besi yang digunakan dalam tan/hari

(15 marks/*markah*)

(ii) Basicity (CaO/SiO_2) of the final slag.

Sifat bes (CaO/SiO_2) jermang akhir.

(15 marks/*markah*)

(iii) Percentage of the total SiO_2 reduced inside the furnace.

Peratus jumlah SiO_2 diturunkan dalam relau

(15 marks/*markah*)

(iv) Productivity of the furnace ($t/d/m^3$).

Pengeluaran relau ($t/d/m^3$)

(15 marks/*markah*)

[b] Discuss the major roles of Boudouard reaction towards the heat demand and reduction behavior in a blast furnace?

Bincangkan peranan utama tindakbalas Boudouard terhadap haba dan penurunan dalam relau bagas?

(20 marks/*markah*)

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

Bincangkan tindakbalas utama yang terlibat dengan tindakbalas tak langsung dalam relau bagas besi.

(20 marks/*markah*)

3. [a] Develop a comparison among the top blown, bottom blown, and combined blown processes in steel making in terms of kinetics, gas content in product, Fe content in slag, and metallic yield.

Perkembangkan bandingan di antara tiupan atas, tiupan tengah dan gabungan tiupan dalam pembuatan keluli dari segi kinetik, kandungan gas dalam hasil pengeluaran, kandungan Fe dalam jermang dan peratus logam yang dihasilkan.

(30 marks/*markah*)

[b] Explain the major chemical reactions involved in the sulphur transfer during iron and steel making, what are the necessary process conditions to be applied to produce low sulphur hot metal and steel.

Terangkan tindakbalas kimia utama yang terlibat dalam pemindahan sulfur semasa pembuatan besi dan keluli, apakah keadaan proses yang perlu diaplikasikan untuk menghasilkan logam panas dan keluli rendah sulfur.

(30 marks/*markah*)

[c] The following equilibrium data have been determined for the reaction:

Persamaan berikut adalah ditentukan bagi tindakbalas:

$$NiO(s) + CO(g) = Ni(s) + CO_2(g)$$

T(^{o}C)	663	716	754	793	852
k x 10^{-3}	4.535	3.323	2.554	2.037	1.577

(i) Find k, and ΔG° at 1100 K.

Cari k dan ΔG° *pada suhu 1100 K dengan menggunakan plot.*

(20 marks/*markah*)

(ii) Would an atmosphere containing 20% CO_2, 5% CO, and 75% N_2 oxidize nickel at 1100 K?

Bolehkah atmosfera yang mengandungi 20% CO_2*, 5% CO, dan 75%* N_2 *mengoksidakan nikel pada suhu 1000K?*

(20 marks/*markah*)

4. [a] Pyrometallurgical processes are typically grouped into four categories. List, define and give one example for each of the category.

Proses-proses pirometalurgi biasanya digolongkan dalam empat kategori. Senaraikan, berikan definisi dan berikan satu contoh bagi setiap kategori tersebut.

(20 marks/*markah*)

[b] With the aid of a flowchart, illustrate and explain the typical pyrometallurgical process steps in the extraction of zinc (Zn) from its ore. Include the reaction equations where possible. Give two advantages and two disadvantages of this pyrometallurgical route, compared to the more popular electrolytic method.

Dengan bantuan sebuah carta alir, lukiskan dan terangkan langkah-langkah tipikal proses pirometalurgi bagi pengekstrakan zink (Zn) daripada bijihnya. Sertakan persamaan-persamaan tindakbalas di mana mungkin. Berikan dua kelebihan dan dua kelemahan kaedah pirometalurgi ini, berbanding kaedah elektrolitik yang lebih popular.

(30 marks/*markah*)

[c] Theoretically, zinc (Zn) residue in lead (Pb) can be removed by passing chlorine gas at 390°C (663 K). Assuming that Zn (atomic weight 65.38) is the only impurity in Pb (atomic weight 207.20), the literature suggests that the reaction can be represented by equation (I), with a standard free energy change of -15,090 cal at 390°C.

Secara teori, baki sisa zink (Zn) dalam timah hitam (Pb) boleh disingkirkan dengan mengalirkan gas klorin pada suhu 390°C (663 K). Dengan mengandaikan bahawa Zn (berat atom 65.38) ialah satu-satunya bendasing dalam Pb (berat atom 207.20), kajian persuratan telah mencadangkan bahawa tindakbalas tersebut dapat diwakili oleh persamaan (I), dengan perubahan tenaga bebas piawai bernilai -15,090 cal pada 390°C.

$$[Zn]_{Pb\text{-}Zn} + (PbCl_2)_{slag} = [Pb]_{Pb\text{-}Zn} + (ZnCl_2)_{slag} \qquad (I)$$

The final product of zinc chloride slag has $ZnCl_2$ mole fraction of 0.983, while the activity of Zn in Pb at the same temperature can be represented by equation (II).

Produk akhir yang merupakan jermang zink klorida mempunyai pecahan mol $ZnCl_2$ sebanyak 0.983, sementara aktiviti Zn dalam Pb pada suhu yang sama boleh diwakili oleh persamaan (II).

$$a_{Zn} = 29x_{Zn} \qquad (II)$$

If the $PbCl_2$-$ZnCl_2$ system behaves ideally, deduce whether 1 wt% removal of Zn is possible under these circumstances.

Jika sistem $PbCl_2$-$ZnCl_2$ bersifat unggul, berikan kesimpulan sama ada penyingkiran 1% berat Zn adalah mungkin di bawah keadaan ini.

(50 marks/*markah*)

5. [a] Indicate the most unusual metallurgical property of nickel (Ni), which is exploited as the basis of vapometallurgical refining of the metal. Provide the conditions and chemical equations that explain this special property.

Berikan sifat metalurgi yang paling luarbiasa bagi nikel (Ni), yang diekspoitasi sebagai asas penulenan secara metalurgi wasap bagi logam tersebut. Sertakan keadaan-keadaan dan persamaan kimia yang menerangkan sifat istimewa tersebut.

(10 marks/*markah*)

[b] <Ni> + ½(O_2) = <NiO> (III)

Equation (III) has a value of ΔG° at 25°C (298 K) of 50.7 kcal. Calculate the ΔG° at 327 °C if given:

ΔH°_{298} for <NiO> = 57.5 kcal/mole

C_p for <Ni> = $6.03 + (10.44 \times 10^{-6} T^2) - (2.50 \times 10^{-3} T)$ cal/deg/mole

C_p for (O_2) = $7.16 + (1.00 \times 10^{-3} T) - (0.40 \times 10^{5} T^{-2})$ cal/deg/mole

C_p for (NiO) = 12.91 cal/deg/mole

<Ni> + ½(O_2) = <NiO> (III)

Persamaan (III) mempunyai ΔG° pada 25 °C (298 K) bernilai 50.7 kcal. Kirakan ΔG° pada 327°C jika diberikan:

ΔH°_{298} for <NiO> = 57.5 kcal/mol

C_p for <Ni> = $6.03 + (10.44 \times 10^{-6} T^2) - (2.50 \times 10^{-3} T)$ cal/darjah/mol

C_p for (O_2) = $7.16 + (1.00 \times 10^{-3} T) - (0.40 \times 10^{5} T^2)$ cal/darjah/mol

C_p for (NiO) = 12.91 cal/darjah/mol

(60 marks/*markah*)

...9/-

[c] In pyrometallurgical processing of Ni ore, describe two environmental issues/concerns and two health issues/concerns. Explain how these isu/concerns can be minimized.

Dalam pemprosesan pirometalurgi bijih Ni, terangkan dua isu/kebimbangan alam sekitar dan dua isu/kebimbangan kesihatan. Terangkan bagimana setiap isu/kebimbangan tersebut dapat diminimakan.

(30 marks/*markah*)

6. [a] You are a Mineral Resources engineer working in a lead producing industrial unit. You are just promoted to be in charge of the sintering process, which is done in a sintering apparatus (SLS/Dwight-Lloyd). Everyday, the Chemical Engineer in charge of sampling the sintered product sends you a data sheet with only the weight of the product after sintering. The weekly data is shown in Table 1 and Table 2 as follows:

Anda adalah seorang jurutera Sumber Mineral, bekerja di sebuah unit industri yang menghasilkan timah hitam. Anda baru sahaja dinaikkan pangkat dan bertanggungjawab ke atas proses pensinteran, yang dijalankan di dalam sebuah alat (SLS/Dwight-Lloyd). Setiap hari, jurutera Kimia yang bertanggungjawab untuk pensampelan produk tersinter menghantar helaian data yang mengandugi hanya berat produk selepas pensinteran. Data mingguan ialah seperti dalam Jadual 1 dan Jadual 2 berikut:

Table 1 - Daily weight of sintered feed

Jadual 1 - Berat harian suapan yang telah disinter

Day *Hari*	**Weight of sintered product, kg (per ton of feed)** *Berat produk tersinter, kg (per tan suapan)*
Monday / *Isnin*	835.3
Tuesday / *Selasa*	834.1
Wednesday / *Rabu*	840.3
Thursday / *Khamis*	880.5
Friday / *Jumaat*	839.6
Saturday / *Sabtu*	834.6
Sunday / *Ahad*	880.7

Table 2 - The feed characteristics where the ore being fed is a combination of four items, each with various components

Jadual 2 - Ciri-ciri suapan, yang mana bijih yang disuap ialah kombinasi empat bahan, setiap satunya mempunyai komponen yang berbeza

Weekly ore feed *Suapan bijih mingguan*	**Ore components** *Komponen bijih*		
Lead ore (100 parts) *Bijih timah hitam (100 bahagian)*	PbS (60.0 %)	FeS_2 (4.0 %)	SiO_2 (36.0 %)
Silver ore (10 parts) *Bijih perak (10 bahagian)*	PbS (4.5 %)	AgS_2 (0.5 %)	SiO_2 (95 %)
Spathic iron ore (20 parts) *Bijih besi spatik (20 bahagian)*	$FeCO_3$ (100.0 %)	-	-
Limestone (25 parts) *Batu kapur (25 bahagian)*	$CaCO_3$ (100.0 %)	-	-

A clear fluctuation of the sintered product weight is observed in Table 1. The Operations Manager has seen the data and is unhappy. He has given you the task to evaluate the process.

It is also known that the feed is moistened with water, which is estimated at 10 % of the feed weight. The various assumptions include:

- All $FeCO_3$ decomposed
- Half of $CaCO_3$ decomposed
- Heating eliminates four-fifths of the sulphur in the feed
- Dry gas analysis after sintering yielded 6.0 % SO_2
- Ignition uses 10 kg of oil (85 % C and 15 % H) per ton feed
- Half of the gas from combustion gas remains after sintering

...11/-

Perbezaan nyata bagi berat produk tersinter dapat diperhatikan dalam Jadual 1. Pengurus Operasi telahpun melihat dan tidak berpuashati dengan data tersebut. Beliau telah mengamanahkan tugas kepada anda untuk membuat penilaian terhadap proses ini.

Diketahui bahawa suapan telah dilembabkan dengan air, iaitu dianggarkan berjumlah sebanyak 10% dari berat suapan. Lain-lain andaian termasuklah:

- *Semua $FeCO_3$ telah terurai*
- *Separuh dari $CaCO_3$ telah terurai*
- *Pemanasan menyingkirkan empat per lima dari sulfur dalam suapan*
- *Analisis gas kering selepas pensinteran memberikan 6.0% SO_2*
- *Pembakaran menggunakan 10 kg minyak (85% C dan 15% H) bagi setiap tan suapan*
- *Separuh dari gas yang terhasil dari pembakaran kekal selepas pensinteran*

(i) Create a feed balance sheet of the sintering process.

Hasilkan satu helaian imbangan suapan bagi proses pensinteran ini.

(80 marks/*markah*)

(ii) Give your conclusion and recommendation on the data presented in Table 1.

Berikan kesimpulan anda dan apa syor anda terhadap data yang diberikan dalam Jadual 1.

(20 marks/*markah*)

7. [a] Aluminum (Al) known to be the most abundant metal on the earth's crust. Name the ore that makes almost of the metallic Al. Explain in brief why it is very difficult to extract Al from its ore, and list two of its unique chemical features.

Aluminium (Al) diketahui sebagai logam yang paling banyak ditemui di bahagian kerak bumi. Namakan bijih yang menghasilkan hampir keseluruhan dari jumlah logam Al. Terangkan secara ringkas mengapa sangat sukar untuk mengekstrak Al dari bijihnya, dan senaraikan dua ciri-ciri kimianya yang unik.

(30 marks/*markah*)

[b] Explain the aims of Bayer process. With an aid of a flow chart, list the various steps in the Bayer process and describe the steps briefly. Start with the type of feed and end with the product of the process. State the chemical equations where necessary.

Terangkan tujuan-tujuan proses Bayer. Dengan bantuan carta alir, senaraikan langkah-langkah dalam proses Bayer dan terangkan dengan ringkas setiap langkah-langkah tersebut. Mulakan dengan jenis suapan dan akhiri dengan produk proses tersebut. Tuliskan persamaan kimia di mana perlu.

(30 marks/*markah*)

[c] Explain the process that takes place after the Bayer process. With the aid of a figure, list the various components of the reactor for this process (process X) and describe the operation steps briefly. State the chemical reactions where necessary.

Terangkan proses yang berlaku selepas proses Bayer. Dengan bantuan gambarajah, senaraikan komponen-komponen reaktor bagi proses ini (proses X) dan terangkan secara ringkas langkah-langkah operasinya. Tuliskan tindakbalas kimia di mana perlu.

(30 marks/*markah*)

[d] Is there any further processing that can be done after process X? If there is so, name the process and explain why it needs to be done.

Adakah lagi sebarang proses yang boleh dilakukan selepas proses X? Jika ada, namakan proses tersebut dan terangkan mengapa proses itu perlu dijalankan.

(10 marks/*markah*)

- oooOooo -