UNIVERSITI SAINS MALAYSIA

First Semester Examination
Academic Session of 2007/2008

October/November 2007

EBS 315 – Hydrometallurgy
[Hidrometalurgi]

Duration: 3 hours
[Masa: 3 jam]

Please ensure that this paper consists of TWELVE printed pages and ONE page APPENDIX before you proceed with the examination.
[Sila pastikan bahawa kertas peperiksaan ini mengandungi DUA BELAS muka surat yang bercetak dan SATU muka surat LAMPIRAN sebelum anda memulakan peperiksaan.]

This paper contains SEVEN questions.
[Kertas soalan ini mengandungi TUJUH soalan.]

Instruction: Answer **FIVE** (5) questions. If a candidate answers more than five questions, only the first five questions answered will be examined and awarded marks.
***[Arahan:** Jawab **LIMA** (5) soalan. Jika calon menjawab lebih daripada lima soalan hanya lima soalan pertama mengikut susunan dalam skrip jawapan akan diberi markah.]*

Answers 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] Discuss the common pre-treatment techniques adopted for metallic ores before their leaching to improve the efficiency of the leaching process.

Bincangkan teknik pra-rawatan yang lazim digunakan bagi bijih logam sebelum pelarutlesapan untuk mempertingkatkan kecekapan proses pelarutlesapan.

(30 marks/*markah*)

[b] During leaching of an ore body, what are the governing equations controlling the transport of a reactant across the solid-liquid interface? What are the ways to control this step towards improving the rate of leaching?

Semasa pelarutlesapan satu jasad bijih, apakah persamaan-persamaan yang mengawal pengangkutan reaktan melalui antaramuka pepejal-cecair? Apakah cara-cara untuk mengawal langkah ini untuk memperbaiki kadar pelarutlesapan?

(40 marks/*markah*)

[c] Outline the major features of agitation leaching.
Schematically illustrate the various configurations of the agitation leaching process.

Berikan ciri-ciri utama pelarut lesapan pengadukan.
Lukiskan gambarajah skema menunjukkan pelbagai konfigurasi proses pelarutlesapan pengadukan.

(30 marks/*markah*)

2. [a] With a suitable example, describe the technique of oxidative leaching of ores.

Dengan contoh yang sesuai, huraikan teknik pelarutlesapan oksidatif bagi suatu bijih.

(40 marks/*markah*)

[b] During the dissolution process in leaching, what are the fundamental steps involved that might control the overall process?

Semasa proses pelarutan dalam pelarutlesapan, apakah langkah-langkah asas yang terlibat yang mungkin mengawal keseluruhan proses?

(30 marks/*markah*)

[c] Compare the "direct" and "indirect" mechanisms of bacterial leaching.

Bandingkan mekanisme "langsung" dan "tak langsung" bagi pelarutlesapan bakteria.

(30 marks/*markah*)

3. [a] The chemistry of the Merril-Crowe process for cementation of gold on zinc can be represented by the following redox reaction:

$$Au(CN)^-_{2(aq)} + 2CN^-_{(aq)} + Zn_{(s)} + H_2O_{(l)} \rightarrow Au_{(s)} + Zn(CN)_4^{2-} + \tfrac{1}{2} H_{2(g)} + OH^-_{(aq)}$$

What is being oxidized and what is being reduced?

Write the balanced anodic and cathodic half-reactions.

Kimia bagi proses Merril-Crowe dalam pensimenan emas ke atas zink boleh diwakili oleh tindakbalas redoks berikut:

$$Au(CN)^-_{2(aq)} + 2CN^-_{(aq)} + Zn_{(s)} + H_2O_{(l)} \rightarrow Au_{(s)} + Zn(CN)_4^{2-} + \tfrac{1}{2} H_{2(g)} + OH^-_{(aq)}$$

Apakah spesi-spesi yang dioksidakan dan diturunkan?

Tuliskan tindakbalas setengah yang seimbang bagi anod dan katod.

(20 marks/*markah*)

[b] Write the basic chemical exchange reaction occurring during the sorption process of gold onto an ion exchange resin. Briefly discuss the mechanism of transport and the kinetics of the ion exchange process. What are the rate controlling steps for the overall exchange process. What are the factors affecting the selectivity of the ion exchanger?

Tuliskan tindakbalas penukaran kimia asas yang berlaku semasa proses serapan emas ke atas resin penukar ion. Bincangkan secara ringkas mekanisme pengangkutan dan kinetik proses penukaran ion. Apakah langkah-langkah kawalan kadar bagi keseluruhan proses penukaran? Apakah faktor-faktor yang mempengaruhi kememilihan penukar ion?

(40 marks/*markah*)

[c] In a dump leaching process, 12,000 ton of ore has been processed. The ore containing 0.32 % copper in the oxide form has undergone leaching process using the liquor solution from the electrolytic plant.
From the data given below, obtain the efficiency of extraction.
From the unrecovered residual copper, what is the fraction of copper that is in the tailing and what is the fraction undissolved?

Dalam suatu proses pelarutlesapan timbunan, sebanyak 12,000 tan bijih telah diproses. Bijih tersebut mengandungi 0.32 % kuprum dalam bentuk oksida, yang telah menjalani proses pelarutlesapan menggunakan larutan likor dari loji elektrolitik.
Dari data yang diberikan di bawah, dapatkan kecekapan pengekstrakan.
Dari baki kuprum yang tidak diperolehi, apakah pecahan yang tertinggal dalam hampas dan pecahan yang tidak larut?

Solution added / *Larutan ditambah*			**Solution removed / *Larutan dikeluarkan***		
Ton	**% Cu**	**Cu (T)**	**Ton**	**% Cu**	**Cu (T)**
2000	1.6	32.0	2200	2.10	46.2
2200	1.1	23.2	2500	2.00	50.6
2500	1.2	30.0	2300	1.75	40.25
2700	1.6	43.2	2400	1.45	34.8
2200	1.5	33.0	2000	1.20	24
2000	0.3	6.00	1700	0.40	6.8
300	-				
13,900	**Total/*Jumlah* Cu**	**167.4**	**13,100**	**Total/*Jumlah* Cu**	**202.05**

(40 marks/*markah*)

4. [a] Given the following reaction equations:

Diberikan persamaan-persamaan tindakbalas berikut:

(i) $Cu^{2+} + 2H_2O = HCuO_2^- + 3H^+$

(ii) $Cu^{2+} + 2H_2O = CuO_2^{2-} + 4H^+$

(iii) $HCuO_2^- = CuO_2^{2-} + H^+$

(iv) $Cu^{2+} + e^- = Cu^+$

(v) $HCuO_2^- + 3H^+ + e^- = Cu^+ + 2H_2O$

(vi) $CuO_2^{2-} + 4H^+ + e^- = Cu^+ + 2H_2O$

The Nernst equation for the water dissociation reaction by electrolysis:

Persamaan Nernst bagi penguraian air secara elektrolisis diberikan:

$$E = - 0.0591\ pH \qquad (4.1)$$

$$E = 1.23 - 0.0591\ pH \qquad (4.2)$$

On the Pourbaix diagram for water and using all the equations from (i) to (vi) above, draw a Pourbaix diagram for the Cu-H_2O system using the standard chemical potential values for the species present as given in Table 4.1.

Pada gambarajah Pourbaix bagi air dan menggunakan semua persamaan dari (i) hingga (vi) di atas, lukiskan gambarajah air bagi sistem Cu-H_2O menggunakan nilai-nilai keupayaan kimia bagi spesi-spesi yang hadir dalam Jadual 4.1.

Table 4.1: Standard chemical potentials values of species present
Jadual 4.1: Nilai-nilai keupayaan kimia piawai bagi spesi-spesi yang hadir

Solid *Pepejal*	μ_o (kJ mol^{-1})	**Solute** *Zat Pelarut*	μ_o (kJ mol^{-1})
Cu	0	Cu^+	50.2
Cu_2O	-146.2	Cu^{2+} $HCuO_2^-$	64.9 -256.7
CuO	-127.1	CuO_2^{2-} H^+	-181.8 0
Solvent / *Pelarut* H_2O	-237.0		

Assume the activities of the chemical species present in a single equation are the same.

Anggapkan keaktifan spesi–spesi kimia yang wujud dalam satu persamaan itu mempunyai keaktifan yang sama.

(50 marks/*markah*)

[b] From the Pourbaix diagram, in what condition is the dissolution of copper oxide (CuO) possible in acid and alkaline solution?

Dari gambarajah Pourbaix, dalam keadaan apakah pelarutan kuprum oksida (CuO) itu adalah mungkin dalam larutan berasid dan beralkali?

(20 marks/*markah*)

[c] Draw a summary flow sheet for the refining of gold and describe briefly the process.

Lukiskan satu ringkasan carta alir bagi penulenan emas dan huraikan secara ringkas proses ini.

(30 marks/*markah*)

5. [a] The Carbon-in-pulp method is used for the recovery of gold from dilute leach liquors. With the help of a process flow sheet, describe the process for the recovery of gold from the leach liquor.

Kaedah karbon-dalam-pulpa digunakan dalam perolehan emas dari likor pelarutlesapan cair. Dengan bantuan satu carta alir proses, huraikan proses perolehan emas dari likor pelarutlesapan.

(30 marks/*markah*)

[b] The design of the carbon adsorption system for gold leach solutions depend essentially on the capacity of a given type of carbon to adsorb and hold the gold ions. Discuss a typical curve depicting the characteristics of a given activated carbon.
How do you determine the number of ideal stages required to remove gold from the solution of a given initial concentration of gold?

Rekabentuk sistem penjerapan karbon dari larutan emas pelarutlesapan bergantung kepada muatan suatu jenis karbon untuk menjerap dan mengikat ion-ion emas. Bincangkan satu keluk yang lazim yang mempamerkan ciri-ciri suatu karbon teraktif.
Bagaimanakah anda menentukan bilangan peringkat ideal yang diperlukan untuk menyingkirkan emas dari larutan dengan kepekatan emas asal diberikan?

(40 marks/*markah*)

[c] A copper solution containing 30 kg of Cu/m^3 is being treated by scrap iron to precipitate copper at room temp (25°C). The residual solution after copper recovery contains iron to the extent of 0.5 kg/m^3. Estimate the percentage of copper recovered.

Satu larutan kuprum mengandungi sebanyak 30 kg Cu/m^3 dirawat menggunakan skrap besi untuk memendakkan kuprum pada suhu bilik (25°C). Larutan baki selepas perolehan kuprum mengandungi besi sehingga 0.5 kg/m^3. Anggarkan peratus perolehan kuprum.

Given / *Diberikan*: $E^{\circ}_{Fe/Fe^{2+}} = 0.441$ V, $E^{\circ}_{Cu/Cu^{2+}} = -0.337$ V

(30 marks/*markah*)

6. [a] On a production tonnage basis, the most widely used metal recovery technique from aqueous solution is electrolysis.
Give the four essential components for an electrolytic cell and state the two laws of electrolysis.

Pada asas pengeluaran dalam tan, teknik perolehan logam dari larutan akuas yang paling banyak digunakan adalah elektrolisis.
Berikan empat komponen utama bagi satu sel elektrolisis dan nyatakan dua hukum elektrolisis.

(20 marks/*markah*)

[b] Pregnant leach solution from a copper heap leaching operation is purified and concentrated by solvent extraction prior to the electrowinning of copper.

Larutan pelarutlesapan pregnan dari operasi pelarutlesapan himpunan ditulinkan dan dikonsentratkan melalui pengekstrakan pelarut sebelum elektrolehan kuprum.

(i) Using the simplified SX flow diagram (Figure 6.1) and the equilibrium data (Table 6.1) for this process given below, plot the McCabe-Thiele diagram for the extraction step. How many stages are involved in the extraction circuit?

Menggunakan carta alir mudah SX dan data keseimbangan yang diberikan di bawah bagi proses ini, plotkan gambarajah McCabe-Thiele bagi langkah pengesktrakan tersebut. Berapakah bilangan peringkat yang terlibat dalam litar pengekstrakan?

(50 marks/*markah*)

(ii) What is the percent copper extracted into the organic phase?

Apakah peratus kuprum yang terekstrak?

(15 marks/*markah*)

(iii) What is the percent copper stripped?

Apakah peratus kuprum yang dilucutkan?

(15 marks/*markah*)

Note: There are vital pieces of information missing from the flow diagram below.

***Nota**: Ada maklumat-maklumat penting yang tiada dalam carta alir berikut.*

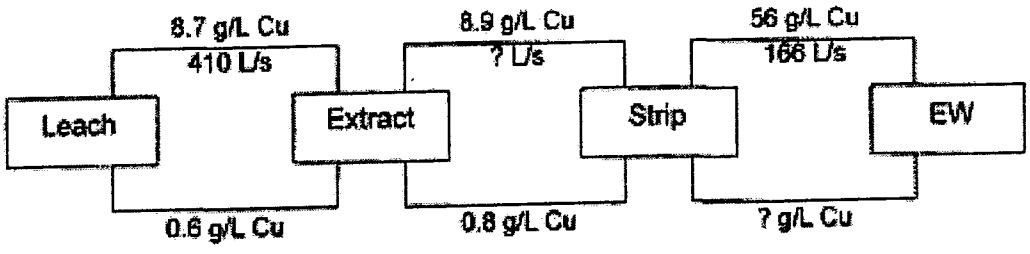

Figure 6.1: Simplified SX Process Flow Diagram

Rajah 6.1: Gambarajah carta alir mudah bagi proses pengekstrakan pelarut

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Table 6.1: Equilibrium Data for the Extraction Isotherm
Jadual 6.1: Data keseimbangan bagi Pengekstrakan Isoterma

Aqueous Copper Conc. (g/L) *Kepekatan akuas kuprum (g/L)*	Organic Copper Conc. (g/L) *Kepekatan organik kuprum (g/L)*
0.0	0.0
0.5	3.3
1.3	5.7
2.7	8.1
4.0	9.4

7. [a] 100 metric tons of a copper concentrate averaging 21 percent are to be processed in 6 months (with 25 working days per month and 8 working hours per day). The concentrate is to be leached by sulphuric acid and then the solution electrolyzed. Estimate the minimum rating (voltage and current) of the power supply unit for 12 cells in series.

Given: E^{o} (cathode) = - 0.337V , E^{o} (anode) = 1.23V and F = 96,500 C

100 tan metrik konsentrat kuprum dengan kandungan purata 21 peratus kuprum akan diproseskan dalam masa 6 bulan (dalam 25 hari waktu bekerja setiap bulan dan 8 jam waktu bekerja sehari). Konsentrat akan dilarutlesapkan menggunakan asid sulfurik dan larutan dielektrolisiskan. Anggarkan kadar minima (voltan dan arus) unit bekalan tenaga bagi 12 sel yang disusun bersiri.

Diberikan: E^{o} (katod) = - 0.337V , E^{o} (anod) = 1.23V dan F = 96,500 C

(40 marks/*markah*)

[b] Gaseous reduction of metal:

Penurunan logam dengan gas diberikan:

$$M^{z+}\ (aq) + z/2\ H_2\ (g) = M\ (s) + zH^+\ (aq) \qquad (7.1)$$

(i) At equilibrium, $E_{H2} = E_M$. What is the requirement for the reaction equation in (7.1) to be thermodynamically feasible?

Pada keseimbangan, $E_{H2} = E_M$. Apakah keperluan bagi persamaan tindakbalas dalam persamaan (7.1) untuk berlaku secara termodinamik?

(10 marks/*markah*)

(ii) Write the simplified Nernst equation for these potentials at 25°C.

Tuliskan persamaan Nernst yang telah dipermudahkan bagi kupayaan elektrod ini pada 25°C.

(10 marks/*markah*)

(iii) The following Figure 7.1 shows the plot of hydrogen and metals electrode potential at 25°C. Assuming the concentration of metal values, C_{Mz+}, is 10^{-2} molal, calculate the minimum pH required for the precipitation of Zn^{2+}, Cd^{2+} and Co^{2+} ions from aqueous solution at 25°C.

Note: Refer to Table 7.1 for values of standard electrode potentials.

Rajah 7.1 berikut menunjukkan keupayaan elektrod bagi hidrogen dan logam-logam pada 25°C. Dengan menganggapkan nilai-nilai kepekatan logam, C_{Mz+}, adalah 10^{-2} molal, kirakan pH minima yang diperlukan bagi pemendakkan ion-ion Zn^{2+}, Cd^{2+} dan Co^{2+} dari larutan akuas pada 25°C.

***Nota**: Rujuk Jadual 7.1 bagi nilai-nilai piawai keupayaan elektrod.*

(40 marks/*markah*)

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APPENDIX
LAMPIRAN

Table 7.1: Values of standard single electrode potentials (E^0) at 25°C
Jadual 7.1: Nilai-nilai piawai keupayaan elektrod (E^0) pada 25°C

Element/ion	E°, V	Element/ion	E°, V
Li/Li^+	+3.045	Co/Co^{2+}	+0.30
K/K^+	+2.925	Ni/Ni^{2+}	+0.25
Cs/Cs^+	+2.923	Mo/Mo^{3+}	+0.20
Ca/Ca^{2+}	+2.87	Sn/Sn^{2+}	+0.14
Na/Na^+	+2.713	Pb/Pb^{2+}	+0.126
Mg/Mg^{2+}	+2.37	Fe/Fe^{3+}	+0.036
Th/Th^{4+}	+1.90	$H_2/2H^+$	0.000
Be/Be^{2+}	+1.85	Sb/Sb^+	−0.1
U/U^{3+}	+1.80	Bi/Bi^{3+}	−0.2
Al/Al^{3+}	+1.66	Cu/Cu^{2+}	−0.337
Zr/Zr^{4+}	+1.53	Co/Co^{3+}	−0.40
Mn/Mn^{2+}	+1.19	Cu/Cu^+	−0.52
Cr/Cr^{2+}	+0.86	Ag/Ag^+	−0.80
Zn/Zn^{2+}	+0.763	Hg/Hg^{2+}	−0.554
Cr/Cr^{3+}	+0.74	Pt/Pt^{2+}	−0.987
Fe/Fe^{2+}	+0.44	Au/Au^{3+}	−1.50
Cd/Cd^{2+}	+0.402	Au/Au^+	−1.68

Figure 7.1: Hydrogen and metal electrode potentials at 25°C
Rajah 7.1: Keupayaan elektrod bagi hidrogen dan logam logam pada 25°C