Second Semester Examination
2023/2024 Academic Session

July/August 2024

EBS323/3 – Pyrometallurgy
(Pirometalurgi)

Duration : 3 hours
(Masa : 3 jam)

Please check that this examination paper consists of TEN (10) pages of printed material including APPENDIX before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi SEPULUH (10) muka surat yang bercetak termasuk LAMPIRAN sebelum anda memulakan peperiksaan ini].

Instruction: Answer **FIVE (5)** questions. Part A is **COMPULSORY**. Answer **TWO (2)** questions from PART B. All questions carry the same marks.

*[**Arahan**: Jawab **LIMA (5)** soalan. Bahagian A **WAJIB** dijawab. Jawab **DUA (2)** soalan dari BAHAGIAN B. Semua Soalan membawa jumlah markah yang sama].*

In the event of any discrepancies, the English version shall be used.

[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah digunapakai].

PART A / *BAHAGIAN A*

(1). (a). The initial weight of iron ore pellet is 2.5 g. The pellet is reduced by hydrogen gas at 950°C for 60 minutes. After reduction, weight of pellet is decreased to 1.0 g. Calculate the degree of reduction.

Berat asal bijih besi ialah 2.5 g. Bijih besi diturunkan oleh gas hydrogen pada suhu 950°C untuk 60 minit. Selepas penurunan, berat bijih besi ialah 1.0 g. Kirakan tahap penurunan.

(10 marks/*markah*)

(b). Discuss the major reactions involved with the indirect/direct reactions inside an iron blast furnace.

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

(10 marks/*markah*)

(2). (a). Describe the process of calcination and its significance in the extraction of metals from ores. Provide examples of ores that undergo calcination and explain the changes that occur during this thermal treatment.

Terangkan proses pengkalsinan dan kepentingannya dalam pengekstrakan logam daripada bijih. Berikan contoh bijih yang mengalami pengkalsinan dan terangkan perubahan yang berlaku semasa rawatan haba ini.

(5 marks/*markah*)

(b). Differentiate between roasting and smelting processes, providing examples of ores that undergo roasting. Additionally, discuss the types of roasting methods commonly used in the metallurgical industry and their respective applications.

Bezakan antara proses pemanggangan dan peleburan, berikan contoh bijih yang mengalami pemanggangan. Selain itu, bincangkan jenis kaedah pemanggangan yang biasa digunakan dalam industri metalurgi dan aplikasi masing-masing.

(5 marks/*markah*)

(c). A copper ore has the following proximate analysis wt. %: Cu_2S: 20%, FeS_2:56%, and SiO_2:24%. It is smelted in a reverberatory furnace using pure limestone as a flux. The slag has 36% FeO and 21% CaO.

Bijih tembaga mempunyai analisis proksimat seperti berikut, berat %: Cu_2S: 20%, Fe_S2:56%, and SiO_2:24%. Ia dilebur dalam relau pantulan menggunakan batu kapur tulen sebagai fluks. Jermang mempunyai 36% FeO dan 21% CaO.

(i). With the aid of diagram explain the operation of reverberatory furnace in a smelting process.

Dengan bantuan gambar rajah terangkan operasi relau pantulan dalam proses peleburan.

(4 marks/*markah*)

(ii). Calculate (per 1000g of ore) weight of limestone, slag, and matte.

Kira (setiap 1000g bijih) berat batu kapur, jermang dan "matte".

(6 marks/*markah*)

(3). (a). (i). Explain why copper sulfide ores cannot be smelted directly with carbon to yield metallic products. Provide specific chemical reactions to support your answer.

Terangkan mengapa bijih kuprum sulfida tidak boleh dilebur secara langsung dengan karbon untuk menghasilkan produk logam. Berikan tindak balas kimia tertentu untuk menyokong jawapan anda.

(5 marks/*markah*)

(ii). Discuss the matte smelting process for copper recovery from their sulfide ores. Include the formation of matte, the role of the converting stage, and the final products obtained.

Bincangkan proses peleburan "matte" untuk pemulihan kuprum daripada bijih sulfidanya. Termasuk pembentukan "matte", peranan peringkat penukaran, dan produk akhir yang diperoleh.

(5 marks/*markah*)

(b). Compare and contrast the chemical processes involved in the removal of iron from ilmenite and rutile ores in the production of pure titanium dioxide for the paint industry. Discuss the key factors influencing the choice between the chloride and sulfate routes for iron removal.

Bandingkan dan bezakan proses kimia yang terlibat dalam penyingkiran besi daripada ilmenit dan bijih rutil dalam penghasilan titanium dioksida tulen untuk industri cat. Bincangkan faktor utama yang mempengaruhi pilihan antara laluan klorida dan sulfat untuk penyingkiran besi.

(5 marks/*markah*)

(c). Draw a schematic diagram of the reduction of titanium sponge by Kroll Process and briefly explain the process. What are the main advantages of the Kroll process?

Lukiskan satu gambarajah skema penurunan span titanium oleh proses Kroll dan terangkan proses tersebut secara ringkas. Apakah kebaikan utama menggunakan proses Kroll ini?

(3 marks/*markah*)

(d). Briefly state the difference between Kroll and Hunter process in terms reactions, limitation, and economic perspectives.

Nyatakan secara ringkas perbezaan antara proses Kroll dan Hunter dari segi reaksi, had dan perspektif ekonomi.

(2 marks/*markah*)

PART B / *BAHAGIAN B*

(4). Prepare answer in brief the following (any four (4) out of the total five (5) questions). Only the best four (4) answers will be considered. Explain your answer.

Pilih dan sediakan jawapan secara ringkas mana-mana empat (4) daripada lima (5) soalan berikut. Hanya empat (4) jawapan terbaik akan dikira. Terangkan jawapan anda.

(i). Acidic slag

Jermang asid

(5 marks/*markah*)

(ii). Henry's Law and Raoult's law

Hukum Henry dan Raoult's

(5 marks/*markah*)

(iii). Decarburization in steelmaking.
Penyahkarbonan di dalam pembuatan besi.

(5 marks/*markah*)

(iv). The principle of inclusion modification in steel with Al treatment.

Prinsip yang diambil kira dalam pengubahsuaian keluli dengan rawatan Al.

(5 marks/*markah*)

(v). Fusion zone in blast furnace

Zon asimilasi di dalam relau bagas

(5 marks/*markah*)

(5). (a). In the context of pyrometallurgy, define the term "refining" and list **SIX (6)** examples of techniques used to refine metals.

*Dalam konteks pirometalurgi, takrifkan istilah "penulenan" dan senaraikan **ENAM (6)** contoh teknik-teknik yang digunakan untuk penulenan logam.*

(4 marks/*markah*)

(b). In metal purification, the starting material for the refiner is the crude metal produced in bulk. Discuss the steps involved in the purification process for this following method.

Dalam penulenan logam, bahan permulaan untuk penapisan ialah logam mentah yang dihasilkan secara pukal. Bincangkan langkah-langkah yang terlibat dalam proses penulenan untuk kaedah berikut.

(i). Fire refining
Penulenan api

(ii). Iodide process
Proses Iodida

(8 marks/*markah*)

(c). Explain the Imperial Smelting Process (ISP) liquation unit, include a sketch showing how it works, and discuss how it differs from conventional smelting techniques in terms of effectiveness and environmental effect.

Terangkan unit likuasi di dalam Proses Peleburan Imperial (PPI), sertakan lakaran yang menunjukkan cara ianya berfungsi, dan bincangkan bagaimana ianya berbeza daripada teknik peleburan konvensional dari segi keberkesanan dan kesannya ke atas alam sekitar.

(8 marks/*markah*)

(6). (a). Describe the following process with the aid of diagram:
Jelaskan proses-proses berikut dengan bantuan gambar rajah;

(i). Hall-Heroult process
Proses "Hall-Heroult"

(ii). Hoopes process
Process "Hoopes"

(6 marks/*markah*)

(b). Discuss **TWO (2)** possible environmental issues for the Hoopes process.

*Bincangkan **DUA (2)** kemungkinan isu alam sekitar untuk proses "Hoopes".*

(4 marks/*markah*)

(c). Magnesium is the sixth most abundant element in the earth's crust. There are two principal magnesium extraction processes: silicothermic process (Pidgeon) and electrolytic process (Dow).

Magnesium adalah unsur ke-enam paling banyak dalam kerak bumi. Terdapat dua proses pengekstrakan magnesium utama: proses silikotermik (Pidgeon) dan proses elektrolitik (Dow).

(i). Discuss the three main steps involved in the Pidgeon process for extracting magnesium, and how does each step contribute to the overall extraction of magnesium?

Bincangkan tiga langkah utama yang terlibat dalam proses Pidgeon untuk mengekstrak magnesium, dan bagaimana setiap langkah menyumbang kepada pengekstrakan keseluruhan magnesium?

(4 marks/*markah*)

(ii). Discuss the similarities and differences between the silicothermic process (Pidgeon process) and the electrolytic process (Dow process). Provide illustrations to aid your explanation.

Bincangkan persamaan dan perbezaan antara proses silikotermik (proses Pidgeon) dan proses elektrolitik (proses Dow). Sediakan ilustrasi untuk membantu penjelasan anda.

(4 marks/*markah*)

(iii). Discus the advantages of the Pidgeon process compared to the Dow process.

Bincangkan kelebihan proses Pidgeon berbanding dengan proses Dow

(2 marks/*markah*)

APPENDIX 1: Periodic Table/ *LAMPIRAN 1: Jadual Berkala* #

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Periodic Table of the Elements

1 IA												13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1 **H** 1.0079	2 IIA															1 **H** 1.0079	2 **He** 4.0026
3 **Li** 6.941	4 **Be** 9.012											5 **B** 10.81	6 **C** 12.011	7 **N** 14.007	8 **O** 15.999	9 **F** 18.998	10 **Ne** 20.179
11 **Na** 22.990	12 **Mg** 24.305	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 ←	9 VIIIB	10 →	11 IB	12 IIB	13 **Al** 26.982	14 **Si** 28.086	15 **P** 30.974	16 **S** 32.06	17 **Cl** 35.453	18 **Ar** 39.948
19 **K** 39.098	20 **Ca** 40.08	21 **Sc** 44.956	22 **Ti** 47.90	23 **V** 50.941	24 **Cr** 51.996	25 **Mn** 54.938	26 **Fe** 55.847	27 **Co** 58.933	28 **Ni** 58.70	29 **Cu** 63.546	30 **Zn** 65.38	31 **Ga** 69.72	32 **Ge** 72.59	33 **As** 74.922	34 **Se** 78.96	35 **Br** 79.904	36 **Kr** 83.80
37 **Rb** 85.468	38 **Sr** 87.62	39 **Y** 88.906	40 **Zr** 91.22	41 **Nb** 92.906	42 **Mo** 95.94	43 **Tc** [97.91]	44 **Ru** 101.07	45 **Rh** 102.905	46 **Pd** 106.4	47 **Ag** 107.868	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.69	51 **Sb** 121.75	52 **Te** 127.60	53 **I** 126.904	54 **Xe** 131.30
55 **Cs** 132.905	56 **Ba** 137.33	57-71 **La**	72 **Hf** 178.49	73 **Ta** 180.948	74 **W** 183.85	75 **Re** 186.21	76 **Os** 190.2	77 **Ir** 192.22	78 **Pt** 195.05	79 **Au** 196.966	80 **Hg** 200.59	81 **Tl** 204.37	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** [209]	85 **At** [210]	86 **Rn** [222]
87 **Fr** [223.02]	88 **Ra** [226.03]	89-103 **Ac**	104 **Rf** [265.12]	105 **Db** [268.13]	106 **Sg** [271.13]	107 **Bh** [270]	108 **Hs** [277.15]	109 **Mt** [276.15]	110 **Ds** [281.16]	111 **Rg** [280.16]	112 **Cn** [285.17]	113 **Nh** [284.18]	114 **Fl** [289.19]	115 **Mc** [288.19]	116 **Lv** [293]	117 **Ts** [294]	118 **Og** [294]

	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
Lanthanides	**La** 138.905	**Ce** 140.12	**Pr** 140.907	**Nd** 144.24	**Pm** [145]	**Sm** 150.4	**Eu** 151.96	**Gd** 157.25	**Tb** 158.925	**Dy** 162.50	**Ho** 164.930	**Er** 167.26	**Tm** 168.934	**Yb** 173.04	**Lu** 174.967
	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
Actinides	**Ac** [277.03]	**Th** 232.038	**Pa** 231.035	**U** 238.029	**Np** [237.05]	**Pu** [244.06]	**Am** [243.06]	**Cm** [247.07]	**Bk** [247.07]	**Cf** [251.08]	**Es** [252.08]	**Fm** [257.10]	**Md** [258.10]	**No** [259.10]	**Lr** [262.11]

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