



NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF ENGINEERING

DEPARTMENT OF CHEMICAL ENGINEERING

EXTRACTIVE METALLURGY 1B /ADVANCED MINERALS ENGINEERING IB

ECE5207/TCE 5207

Final Examination Paper

March 2025

This examination paper consists of four pages

Time Allowed: 3 hours

Total Marks: 100

Special Requirements: Periodic Table of Elements and Electrochemical Series

INSTRUCTIONS

1. Answer **ALL** questions in **SECTION A**
2. Answer **ANY THREE** questions in **SECTION B**
3. Each question carries 20 marks
4. Use of calculators is permissible

MARK ALLOCATION

QUESTION	MARKS
A1	20
A2	20
B1	20
B2	20
B3	20
B4	20
TOTAL ATTAINABLE MARK	100

Page 1 of 4

SECTION A

ANSWER ALL QUESTIONS

QUESTION A1

- a) Discuss the advantages of hydrometallurgical extraction of copper over its pyro metallurgical extraction from its ores. [5]
- b) With reference to 'multi-lift' heaps, give detail on how you would construct a heap for a low grade copper ore, your description should include the base, ore placement, aeration, solution application and pregnant solution collection. [10]
- c) Calculate the mass of Zn deposited onto an inert lead cathode in a zinc electro winning cell where the electrolytic cell is receiving a current of 25 Amps, for a duration of 10hours. [5]

QUESTION A2

- a) Bornite can be leached with oxygen in acid solution according to the following reaction:



A bornite ore contains 0.22% copper by weight and is processed at a rate of 1500tons/hr. The extent of copper leaching is 75%.

- (i) How much oxygen gas is needed in kg/hr. [3]
- (ii) How much sulphuric acid is needed in kg/hr. [3]
- b) A copper electrowinning tankhouse operates at a current density of 400A/m². Assuming that the standard electrode potential difference is 60% of the whole cell voltage. Calculate the copper electrowinning energy consumption in kWh/kg when the deposition current efficiency is 96%. Use a basis of one hour. [5]
- c) In electrowinning cells, a voltage higher than E_{cell} has to be applied i.e. more energy than what is dictated by thermodynamics has to be supplied. Discuss overpotential in terms of the following three components:
- (i) activation overpotential [3]
- (ii) ohmic polarization [3]
- (iii) concentration overpotential [3]

SECTION B

ANSWER ANY THREE QUESTIONS

QUESTION B1

a)

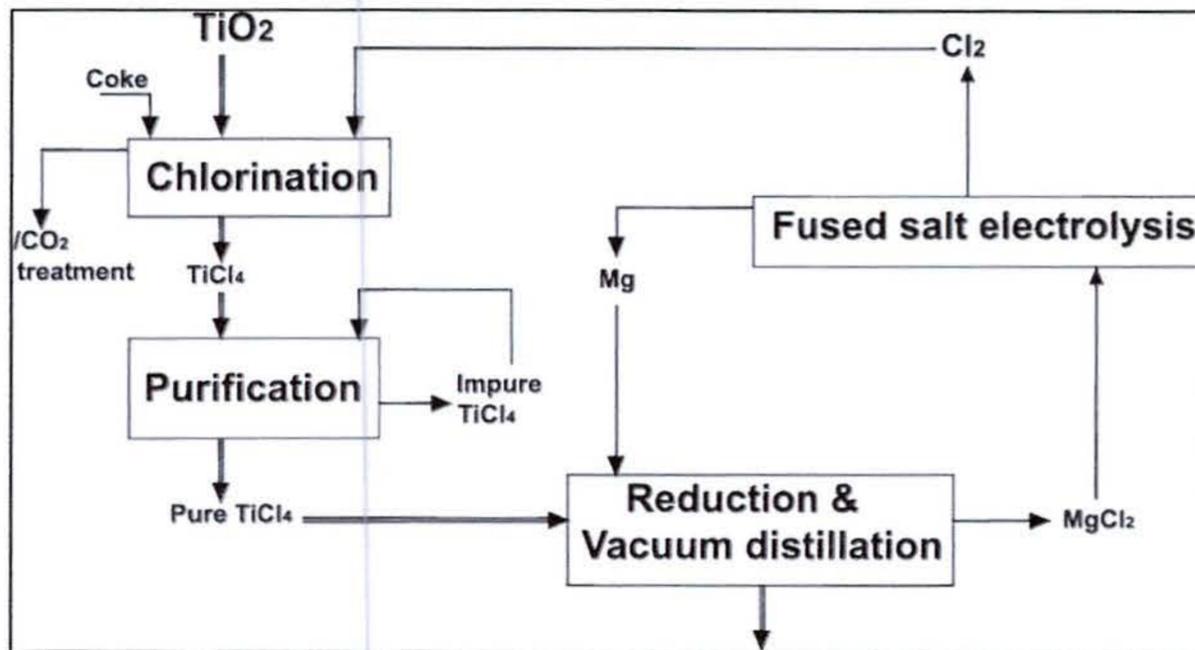


Fig. B1 Kroll process for titanium extraction

The process flowsheet for titanium extraction is shown in Fig. B1. Give a detailed description of the processes taking place in each of the units, your description should include reactants, process conditions, reactions, products etc.

- | | | |
|-------|-----------------------------------|------|
| (i) | Chlorination | [3] |
| (ii) | Purification | [1] |
| (iii) | Reduction and Vacuum distillation | [10] |
| (iv) | Fused salt electrolysis | [2] |

b) Halide metallurgy is used for the extraction and refining of metals, state **four** main reasons for employing halide metallurgy over traditional metal extraction and refining technologies. [4]

QUESTION B2

a) With the aid of a diagram, give a detailed description of the Hall-Heroult process for aluminium electrowinning. [10]

b) Identify **five** leaching process variables and give a brief explanation (including examples) of how they affect the leaching process. [10]

QUESTION B3

a) During the extraction stage of solvent extraction the metal ions are transferred from the aqueous phase to the organic phase using three basic types of solvent extractants. State the extractants and give a brief description of the mechanism of transfer of metal ions for each extractant. [6]

b) Define solvent extraction and with the aid of a well annotated diagram, describe the major steps involved in the solvent extraction of a dilute copper leach pregnant solution from heap leaching operations. Your description should include the following information: concentration of copper in each stream, strength of the aqueous solution in each stream, concentration of copper in the organic extractant, type of organic extract used, reactions etc. [14]

QUESTION B4

a) The following metals and/or their compounds play an important role in the global economy i.e. Gold, Zinc, Nickel and Uranium. With reference to **one** of the metals listed sketch a generic process flow diagram for a typical hydrometallurgical process and discuss the various unit operations associated with each step.

(i) Ore/Concentrate pre-treatment [2]

(ii) Leaching [5]

(iii) Solution purification and enrichment [5]

(iv) Metal/Compound recovery [3]

b) With reference to a specific case study, discuss the negative effects of hydrometallurgy operations on the environment. [5]

(END OF PAPER)

Standard Reduction potential at 298^o K on the hydrogen scale

Sr. No.	Electrode	Reduction Half reaction Oxidising agent → Reducing agent	E ^o (volts) At 298 K
1	F ⁻ F ₂ Pt	F ₂ + 2e ⁻ → 2F ⁻	+2.87
2	Au ⁺ Au	Au ⁺ + e ⁻ → Au	+1.68
3	Ce ⁴⁺ , Ce ³⁺ Pt	Ce ⁴⁺ + e ⁻ → Ce ³⁺	+1.61
4	Au ³⁺ Au	Au ³⁺ + 3e ⁻ → Au	+1.50
5	Cl ⁻ Cl ₂ Pt	Cl ₂ + 2e ⁻ → 2Cl ⁻	+1.36
6	Pt ²⁺ Pt	Pt ²⁺ + 2e ⁻ → Pt	+1.20
7	Br ⁻ Br ₂ Pt	Br ₂ + 2e ⁻ → 2Br ⁻	+1.08
8	Hg ₂ ²⁺ Hg	Hg ₂ ²⁺ + 2e ⁻ → Hg	+0.854
9	Ag ⁺ Ag	Ag ⁺ + e ⁻ → Ag	+0.799
10	Hg ₂ ²⁺ Hg	Hg ₂ ²⁺ + 2e ⁻ → Hg ₂	+0.790
11	Fe ³⁺ , Fe ²⁺ Pt	Fe ³⁺ + e ⁻ → Fe ²⁺	+0.771
12	I ⁻ I ₂ (s) Pt	I ₂ + 2e ⁻ → 2I ⁻	+0.535
13	Cu ²⁺ Cu	Cu ²⁺ + 2e ⁻ → Cu	+0.337
14	Pt Hg Hg ₂ Cl ₂ Cl ⁻	Hg ₂ Cl ₂ + 2e ⁻ → 2Hg + 2Cl ⁻	+0.242
15	Ag AgCl(s) Cl ⁻	AgCl + e ⁻ → Ag + Cl ⁻	+0.222
16	Cu ²⁺ Cu ⁺	Cu ²⁺ + e ⁻ → Cu ⁺	+0.153
17	Sn ⁴⁺ , Sn ²⁺ Pt	Sn ⁴⁺ + 2e ⁻ → Sn ²⁺	+0.15
18	H ⁺ H ₂ Pt	2H ⁺ + 2e ⁻ → H ₂ (g)	0.0 (Definition)
19	Pb ²⁺ Pb	Pb ²⁺ + 2e ⁻ → Pb	-0.126
20	Sn ²⁺ Sn	Sn ²⁺ + 2e ⁻ → Sn	-0.136
21	Ni ²⁺ Ni	Ni ²⁺ + 2e ⁻ → Ni	-0.257
22	Co ²⁺ Co	Co ²⁺ + 2e ⁻ → Co	-0.280
23	Cd ²⁺ Cd	Cd ²⁺ + 2e ⁻ → Cd	-0.403
24	Fe ²⁺ Fe	Fe ²⁺ + 2e ⁻ → Fe	-0.440
25	Cr ³⁺ Cr	Cr ³⁺ + 3e ⁻ → 3Cr	-0.740
25	Zn ²⁺ Zn	Zn ²⁺ + 2e ⁻ → Zn	-0.763
26	Al ³⁺ Al	Al ³⁺ + 3e ⁻ → 3Al	-1.66
27	Mg ²⁺ Mg	Mg ²⁺ + 2e ⁻ → Mg	-2.37
28	Na ⁺ Na	Na ⁺ + e ⁻ → Na	-2.714
29	Ca ²⁺ Ca	Ca ²⁺ + 2e ⁻ → Ca	-2.866
30	K ⁺ K	K ⁺ + e ⁻ → K	-2.925
31	Li ⁺ Li	Li ⁺ + e ⁻ → Li	-3.045