



SCHOOL OF ENGINEERING

MAIN EXAMINATIONS: NOVEMBER 2025

COURSE AND CODE: EXTRACTIVE METALLURGY ENCH4EM

DURATION: 2 HOURS

TOTAL MARKS: 100

INTERNAL EXAMINER/S: Dr J Pocock

INTERNAL MODERATOR: Prof A.H. Mohammadi

EXTERNAL MODERATOR: Mrs K Moodley

INSTRUCTIONS:

1. **ALL** questions should be attempted. Answer in **INK**.
2. Any programmable or non-programmable calculator may be used provided it has been cleared of any information that would subvert the purpose of the examination.
3. Calculations must be shown in sufficient detail to illustrate your understanding of the procedure.
4. **Two answer books are provided. Label them Book A and Book B. Answer Section A in Book A and Section B in Book B.**
5. This examination question paper, together with all associated diagrams, **MUST BE HANDED IN TOGETHER WITH YOUR SCRIPT.**

Student Number:

SECTION A**QUESTION 1**

Using an example from the case studies presented, describe a pyrometallurgical (or pyro-electrometallurgical) process used for the processing of an ore or concentrate of an ore. Include details of the raw materials and products, reactions, process conditions and equipment used in the process and a brief overview of any particular health and safety concerns mitigated by the process plant. Give reasons why pyrometallurgical processing is suited to the processing of the particular ore or concentrate.

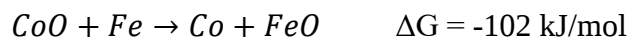
TOTAL /25/**QUESTION 2**

Using an example from the case studies presented, describe a hydrometallurgical process used for the processing of an ore or concentrate of an ore. Include details of the raw materials and products, reactions, process conditions and equipment used in the process and a brief overview of any particular health and safety concerns mitigated by the process plant. Give reasons why hydrometallurgical processing is suited to the processing of the particular ore or concentrate.

TOTAL /25/

SECTION B**QUESTION 3**

- a. Permendur (an alloy of iron and cobalt) can be manufactured by addition of amounts of cobalt oxide to molten iron in a blown furnace. Cobalt oxide in a slag is added in a 1:1 molar ratio to molten iron at 1400°C in an alloying furnace. The following reaction occurs:



The slag composition is 50% CoO, 20% CaO, 30% SiO₂ (molar basis) and the iron composition can be taken to be pure iron. What will be the final molar composition of the alloy and the composition of the discard slag? (14 marks)

- b. What are the main functions of a slag in a smelter? (3 marks)
c. What are the main properties required of a slag layer in a smelter? (5 marks)

TOTAL /22/

QUESTION 4

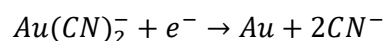
In hydrometallurgical processing, solvent extraction is often used between leaching and electrowinning.

- a. What is the purpose of solvent extraction in a hydrometallurgical processing plant? (2 marks)
b. What are the important characteristics of a chelating reagent used in the solvent extraction process? (3 marks)
c. What are the important characteristics of the organic phase used in the solvent extraction process? (3 marks)

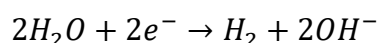
TOTAL /8/

QUESTION 5

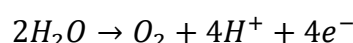
- a. In a gold electrowinning process, gold is being precipitated out onto a gold cathode, with a lead oxide anode generating oxygen by dissociation of water. The gold in solution is in the form of gold cyanate, the cathodic half cell reaction is:



To ensure that no cyanide gas is generated during the process, the pH is maintained at 11. Under these conditions, hydrogen can be generated at the cathode by dissociation of water by the following half cell reaction:



At the anode, water dissociation follows the standard anodic reaction:



For a 1 molar solution of gold cyanate at pH11, determine the overall cell voltage (included overpotential) to plate gold at a current density of 150 A/m² and determine whether there will be a problem with Hydrogen generation at the cathode. (15 marks)

Data:

Half Cell Reaction (Cathode)	E ⁰ (V)	Tafel Slope (mV)	Log i ₀
$Au(CN)_2^- + e^- \rightarrow Au + 2CN^-$	-0.63	60	1.4
$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$	-0.828	120	-1.7
Half Cell Reaction (Anode)	E ⁰ (V)	Tafel Slope (mV)	Log i ₀
$2H_2O \rightarrow O_2 + 4H^+ + 4e^-$	1.23-0.0591pH	120	-12.0

- b. What other resistances have to be taken into account when determining the voltage supplied to an electrolytic circuit? (3 marks)

TOTAL /20/