

Alternative methods of metal extraction

Mark Scheme



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1. As the Earth's supply of high-grade copper ores begins to run out, scientists and miners are using new methods to extract metals from low-grade ores and waste rock.

Circle the letter of the correct answer for each of the following questions.

- a) Aluminium is extracted from bauxite by electrolysis.

Which statement is correct?

C – is the only correct answer.	1 mark
	Total: 1 mark

- b) Which row correctly describes the process of phytomining?

B – is the only correct answer.	1 mark
	Total: 1 mark

- c) In bioleaching, bacteria feed on low-grade metal ores.

What is the name of the acidic solution produced by this process?

A – is the only correct answer.	1 mark
	Total: 1 mark

- d) Why are methods such as phytomining and bioleaching becoming more important?

C – is the only correct answer.	1 mark
	Total: 1 mark

(Total for Question 1 is 4 marks)

2. Copper is a valuable metal. Traditionally, it is extracted from high-grade ores by mining and smelting. However, scientists are now using phytomining to extract copper from low-grade ores. The figure below shows a crop of wheat being used in phytomining.



- a) Describe the **process** of phytomining.

A description to include:	
The plants are grown on land containing copper / metal (ores).	1 mark
Allow: low-grade ore.	
The plants absorb copper (compounds) through their roots.	1 mark
The plants are harvested and burnt.	1 mark
The ash contains copper (compounds) which is <u>electrolysed</u> .	1 mark
Allow: copper is extracted from the ash. Allow: electrolysis is done to collect the copper/ metal.	
	Total: 4 marks

The process in part (a) produces a solution of copper sulfate.

- b) Scrap iron is often added to this solution to extract the pure copper.

- i. Explain why iron is used for this process.

Copper is less reactive than iron.	1 mark
Allow: iron is more reactive than copper.	
	Total: 1 mark

- ii. Write a word equation for the reaction between scrap iron and copper sulfate.

iron + copper sulfate → iron sulfate + copper	1 mark
Do not accept the symbol equation.	
	Total: 1 mark

(Total for Question 2 is 6 marks)

3. Copper is traditionally extracted from high-grade ores by mining and smelting. However, as high-grade ores are running out, bioleaching is increasingly used to extract copper from low-grade ores.

a) Explain how bacteria are used in the bioleaching process to extract copper.

An explanation to include:	
Bacteria feed on low-grade ores.	1 mark
The bacteria produce a solution of copper ions.	1 mark
called a leachate.	1 mark
	Total: 3 marks

To obtain pure copper metal from the solution produced in part (a), scrap iron is added.

b) Write a balanced symbol equation for the reaction between iron and copper(II) sulfate. Include state symbols in your answer.

$\text{Fe(s)} + \text{CuSO}_4\text{(aq)} \rightarrow \text{FeSO}_4\text{(aq)} + \text{Cu(s)}$	
Award 1 mark for the correct formulae of reactants.	1 mark
Award 1 mark for the correct formula of iron sulfate.	1 mark
Award 1 mark for the correct state symbols and balancing.	1 mark
	Total: 3 marks

c) Calculate the percentage atom economy for producing copper in this reaction. Give your answer to 2 significant figures.

Relative atomic masses (Ar: O = 16, S = 32, Fe = 56, Cu = 63.5)

Mr of Fe = 56 and Mr of CuSO ₄ = 159.5	1 mark
Ar of Cu = 63.5	1 mark
$(63.5 \div 215.5) \times 100 = 29 \%$	1 mark
	Total: 3 marks

d) In industrial chemistry, it is desirable to have a high atom economy. Give **two** reasons why.

Accept any two of the following:	
- Less waste produced. - More sustainable / uses fewer resources. - More economic / Cheaper (if waste product is useful). - Less pollution / hazardous waste.	
	Total: 2 marks

(Total for Question 3 is 11 marks)

4. As high-grade copper ores run out, scientists have developed methods to extract copper from low-grade ores, such as phytomining and bioleaching.
- a) Describe how phytomining and bioleaching are used to extract copper, and evaluate the advantages and disadvantages of these methods compared to traditional mining.

Marking guidance		
Level	Marks	Descriptor
Level 1	1 - 2	Simple statements are made about the methods (e.g., "plants grow on copper" or "bacteria are used"). There is little or no evaluation.
Level 2	3 - 4	Both methods are described, though some details may be missing. Some evaluation is attempted, but the comparison to traditional mining may be implied rather than explicit.
Level 3	5 - 6	A detailed description of both methods is given. The answer includes a clear evaluation of advantages and disadvantages compared to traditional mining. The answer is coherent and logically structured.

Indicative content:	
Phytomining process - Plants are grown on land containing low-grade copper ores. - The plants absorb copper ions through their roots and concentrate them in their tissue. - The plants are harvested and burnt. - The resulting ash contains soluble copper compounds. - Copper is extracted from the ash by dissolving it in acid (to make a solution) and using electrolysis or displacement (with scrap iron). Bioleaching process - Bacteria are mixed with low-grade copper ores. - The bacteria carry out chemical reactions that break down the ore. - This produces a solution containing copper ions, known as a leachate. - Copper is extracted from the leachate by displacement using scrap iron or by electrolysis. Evaluation (comparison with traditional mining) Advantage: Allows copper to be extracted from low-grade ores (which are not economical to mine traditionally). Advantage: Avoids large-scale mining (digging/quarrying), which reduces damage to the landscape and visual pollution. Advantage: Phytomining can be considered carbon neutral as plants absorb CO₂ while growing. Disadvantage: Both processes are very slow compared to traditional mining. Disadvantage: Phytomining depends on weather conditions for plant growth. Disadvantage: Bioleaching can produce toxic substances (like sulfuric acid) which may damage the environment if not contained.	
	Total: 6 marks

- b) A mining company uses phytomining to extract copper from a large area of waste land.
Based on the amount of copper compounds in the soil, the company calculates that the theoretical yield of copper should be 500 kg.

After burning the plants and processing the ash using electrolysis, the actual mass of copper obtained was 385 kg.

Calculate the percentage yield of copper for this process.

$(385 \div 500) \times 100$	1 mark
$= 77.0 \%$	1 mark
	Total: 2 marks

- c) Suggest **one** reason why the percentage yield in part (b) was less than 100%.

A suggestion to include any one from:	
• Reaction may not be complete. • Some product lost during separation / purification. • Side reactions may have occurred. • Loss of product when transferring between containers.	
	Total: 1 mark

(Total for Question 4 is 9 marks)