

Extracting Metals

Mark Scheme



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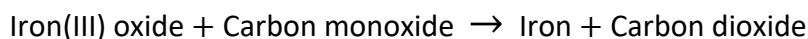
1. The vast majority of metals exist not as shiny, ready to use elements, but as compounds within the Earth's crust. Extracting these for our use is hugely important to the world's economy.

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

- a) Which of the following metals is most easily extracted from its ore?

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

Iron is extracted from iron(III) oxide in a blast furnace. The main reaction is shown in the word equation:



What type of reaction has the iron(III) oxide undergone?

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

- b) Which row in the table correctly links the metal to its main extraction method?

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

- c) Aluminium is a reactive metal extracted by the electrolysis of molten aluminium oxide.

Why is electrolysis used for aluminium instead of reduction with carbon?

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

(Total for Question 1 is 4 marks)

2. The table below shows some observations about the reactivity of metals with dilute hydrochloric acid.

a) Based on the information above. Place these metals in order of their reactivity.

Least reactive: Copper → Iron → Magnesium → Calcium: Most reactive	(2)
Marking note: Award 1 mark for each correct pair.	
	Total: 2 marks

b) A student observes that when iron is added to dilute acid, it produces bubbles slowly. When magnesium is added to the same acid, it fizzes vigorously.

Predict the observation when zinc is added to the acid and explain your reasoning.

Observation: Bubbles / fizzing produced.	(1)
Reasoning: Zinc is more reactive than iron but less reactive than magnesium.	(1)
Allow: Zinc is higher in reactivity series than iron. Reasoning must reference the reactivity relative to the other metals.	
	Total: 2 marks

c) Explain why the extraction is carried out **molten** magnesium chloride rather than **solid** magnesium chloride.

An explanation to include the following:	
Solid ionic compounds cannot conduct electricity as their ions are not free to move.	(1)
Allow: Ions are held in fixed positions / in a giant lattice.	
Molten ionic compounds contain ions which can move.	(1)
Ions which can move can carry charge.	(1)
Do not accept references to electrons moving in the solid/molten salt.	
	Total: 3 marks

d) Explain why magnesium has to be extracted by electrolysis rather than by heating its oxide with carbon.

Magnesium is more reactive than carbon.	(1)
Allow: carbon is less reactive than magnesium	
So carbon cannot displace magnesium / carbon cannot reduce the magnesium oxide.	(1)
	Total: 2 marks

e) Suggest why an inert gas is blown over the surface of the molten magnesium.

To prevent the (molten) magnesium from reacting with oxygen (in the air).	(1)
Allow: to prevent magnesium from burning.	
	Total: 1 mark

(Total for Question 2 is 10 marks)

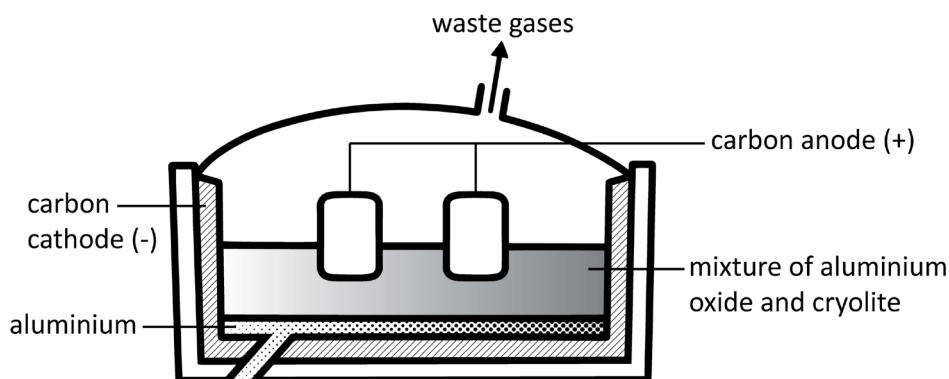
3. Aluminium is a very useful metal for the manufacture of products.

The position of aluminium in the reactivity series of metals is shown in the table below.

Magnesium	More reactive  Less reactive
Aluminium	
Zinc	
Copper	

Aluminium is extracted by the electrolysis.

The figure below shows the extraction of aluminium.



a) Identify the main aluminium ore.

Bauxite.	(1)
Total: 1 mark	

b) Why is molten cryolite added to the electrolyte?

Lowers the melting point (of the aluminium oxide / electrolyte).	(1)
So less energy is needed (to melt it) / reduces energy costs.	(1)
Allow: cheaper to run.	
Total: 2 marks	

c) Oxygen is produced at the positive electrode (anode).

Name another gas which is given off at this electrode.

Carbon dioxide / CO ₂	(1)
Total: 1 mark	

At the negative electrode (cathode), aluminium ions (Al³⁺) are reduced to form molten aluminium (Al).

Write the **balanced** half-equation for this reaction.

Al ³⁺ + 3e ⁻ → Al	(2)
Allow: 1 mark for correct species if balancing is incorrect.	
Total: 2 marks	

(Total for Question 3 is 6 marks)

4. This question is about iron.

a. Identify the main ore of iron.

<u>Haematite.</u>	Allow Magnetite.	Allow: Iron(III) oxide	(1)
			Total: 1 mark

b. Iron ore is reduced to iron in a blast furnace.

The unbalanced chemical equation for the reaction is shown below.

Balance the equation for this reaction.

$\text{Fe}_2\text{O}_3 + 3\text{CO} \rightarrow 2\text{Fe} + 3\text{CO}_2$ Award 1 mark for the 2 in front of Fe. Award 1 mark for the 3 in front of CO₂. Award 1 mark for the 1 (or leaving blank) in front of Fe₂O₃ (if other numbers are correct). Allow multiples.	(3)
Total: 3 marks	

c. Which substance, in the equation above acted as the reducing agent.

Give a reason for your answer.

Substance: carbon monoxide / CO.	(1)
Reason: It gains oxygen / It removes oxygen (from the iron oxide).	(1)
Total: 2 marks	

Iron is a transition metal. Sodium is a Group 1 metal.

d. Give **two** differences between the properties of iron and sodium.

Any two from:	
- Iron has a higher melting/boiling point (or converse). - Iron is harder / stronger (or converse). Iron is more dense (or converse). - Iron is less reactive (or converse). - Iron forms coloured compounds. - Iron forms ions with different charges / acts as a catalyst.	
Total: 2 marks	

e. Nickel is extracted from nickel oxide by reduction with carbon.

Explain why carbon can be used to extract nickel from nickel oxide.

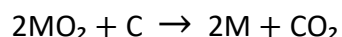
Carbon is more reactive than nickel.	(1)
So carbon can displace nickel / remove oxygen from nickel oxide.	(1)
Total: 2 marks	

(Total for Question 4 is 10 marks)

5. This question is about the extraction of metals.

An unknown metal, M, is extracted from its oxide by reduction with carbon.

The equation for the reaction is:



The sum of the relative formula masses (M_r) of the reactants ($2\text{MO}_2 + \text{C}$) is 186.

- a. Calculate the relative atomic mass (A_r) of M.

Relative atomic masses (A_r): C = 12, O = 16.

Calculate mass of reactants minus carbon: $186 - 12 = 174$	(1)
Calculate mass of one mole of MO_2 : $174 \div 2 = 87$	(1)
Calculate A_r of M: $87 - 32 = 55$	(1)
Accept an alternative method that gets the same correct answer. Allow 3 marks for correct answer with no working.	
	Total: 3 marks

- b. Identify the unknown metal **M**.

To identify M you should use:

- your answer from part (a)
- the periodic table.

Manganese / Mn	(1)
Because the relative atomic mass matches / is closest to 55.	(1)
	Total: 2 marks

The Thermite reaction is sometimes used to produce small amounts of molten iron.

The unbalanced equation for the reaction between aluminium and iron(III) oxide is:

- c. Balance the equation and use it to calculate the percentage atom economy for extracting iron (Fe) in this reaction.

$2\text{Al} + \text{Fe}_2\text{O}_3 \rightarrow 2\text{Fe} + \text{Al}_2\text{O}_3$	
Allow multiples.	
Award 1 mark for a 2 in front of Al and for a 2 in front of Fe.	(1)
Mass of desired product: $2 \times 56 = 112$	(1)
Total mass of reactants: $(2 \times 27) + (2 \times 56) + (3 \times 16) = 214$	(1)
Calculation: $(112 \div 214) \times 100 = 52.3 \%$	(1)
	Total: 4 marks

(Total for Question 5 is 9 marks)

6. Industrial chemists must choose the most suitable method to extract a metal from its ore.
This choice depends on the metal's chemical reactivity and the overall economic cost of the process.
- a. Discuss why sodium, zinc, and platinum are obtained using vastly different methods.

In your answer, you should:

- Link each metal to its approximate position in the reactivity series.
- Name and describe the extraction method used for each.
- Explain why some methods are significantly more expensive than others.

Marking guidance		
Level	Marks	Descriptor
Level 1	1 - 2	Basic statements are made regarding reactivity or extraction methods. There may be confusion between methods or vague references to cost.
Level 2	3 - 4	Relevant features are identified. The link between reactivity and extraction method is made for at least two metals, with some mention of cost differences.
Level 3	5 - 6	A detailed and coherent explanation is provided that links the position of all three metals to their extraction method and relative costs. Logical reasoning is clearly identified

Indicative content:	
Sodium: • Sodium is very high in the reactivity series (more reactive than carbon). • It cannot be displaced by carbon, so it must be extracted by electrolysis of its molten ore. • This process is significantly more expensive because large amounts of electricity (energy) are required to melt the ore and run the current. Zinc: • Zinc is in the middle of the reactivity series (less reactive than carbon). • It is extracted by reduction with carbon (heating the ore with carbon). • This method is cheaper than electrolysis because carbon is inexpensive and acts as a fuel/reducing agent. Platinum: • Platinum is very low in the reactivity series (unreactive). • It is found in its native state (as the metal element itself) in the Earth's crust. • It does not require chemical extraction; it is mined and separated mechanically. • This has the lowest energy cost for the extraction process.	
	Total: 6 marks

- b. Cars are generally made of steel.
When a car reaches the end of its useful life, the car body which is mostly steel can be recycled, reused or sent to a landfill.

Describe **three** reasons why the steel from a car's body should be recycled and not reused or sent to landfill.

Any three from:	
• Conserves finite resources / iron ore. • Uses less energy (than extracting fresh iron from ore). • Reduces waste sent to landfill. • Reduces carbon footprint / CO₂ emissions / global warming. • Car bodies cannot be reused because they are damaged / rusted / fatigued / wrong shape. • Prevents visual pollution of scrap heaps.	
	Total: 3 marks

Titanium, Ti is a strong, corrosion-resistant metal used in high-performance alloys. It is extracted from its main ore, titanium dioxide, TiO₂. A manufacturer needs to choose the best method to produce a sample of high-purity titanium.

The table below shows information about **three** possible reduction methods.

Method	Reactant	Relative cost of reactant	Products
A	Carbon	Low	Titanium solid Carbon monoxide gas Titanium carbide solid
B	Hydrogen	High	Titanium solid Water vapour
C	Copper	Low	No reaction

- c. Evaluate the three methods and justify which one the manufacturer should choose to produce high-purity titanium.

Evaluate Method C: Method C will not work because Copper is less reactive than Titanium / cannot displace Titanium.	(1)
Evaluate Method A: Method A produces Titanium Carbide / a solid impurity (so the titanium is not high purity).	(1)
Evaluate Method B: Method B produces pure Titanium (as the other product is water vapour/gas which escapes)	(1)
Justification / Conclusion: Therefore Method B should be chosen, because high purity is required (despite the higher cost)	(1)
	Total: 4 marks

(Total for Question 6 is 13 marks)

7. Traditional mining methods, such as smelting, are often used to extract copper from high-grade ores. However, for low-grade ores, newer methods like **bioleaching** and **phytomining** are being developed.

Compare and evaluate the use of bioleaching and phytomining for extracting copper from low-grade ores.

Marking guidance		
Level	Marks	Descriptor
Level 1	1 - 2	Basic statements are made about growing plants or using bacteria. There is little or no evaluation of the methods compared to traditional mining.
Level 2	3 - 4	Relevant features of both methods are described, but the evaluation/comparison is limited. OR one method is described in detail with a good evaluation, but the other method is missing or weak
Level 3	5 - 6	A detailed and coherent comparison is provided. The method for both bioleaching and phytomining is described clearly, and valid advantages/disadvantages compared to traditional mining are discussed. Logical linking of ideas is present.

Phytomining (Description) - Plants are grown on land containing low-grade copper ore. - As the plants grow, they absorb copper ions through their roots. - The plants are harvested and burnt to produce ash. - The ash is dissolved in acid to produce a solution (leachate) containing copper compounds. - Copper is finally extracted from the solution by electrolysis or displacement with scrap iron. Bioleaching (Description) Bacteria are used to feed on/break down low-grade copper ores. - The bacteria produce a leachate solution that contains copper ions. - Copper is then finally extracted from the solution using the process of electrolysis or displacement with scrap iron. Evaluation (vs. Traditional Mining) Advantage: Both methods allow copper to be extracted from low-grade ores (waste rock), which traditional mining cannot use economically. Advantage: They avoid digging large holes/quarries, causing less damage to the landscape. Advantage: They use less energy than smelting (high temperatures are not required). Disadvantage: Both processes are very slow compared to traditional smelting. Disadvantage: Phytomining is dependent on the weather/seasons for plant growth. Disadvantage: There is a risk of toxic chemicals (leachate) running off into water sources.	Total: 6 marks
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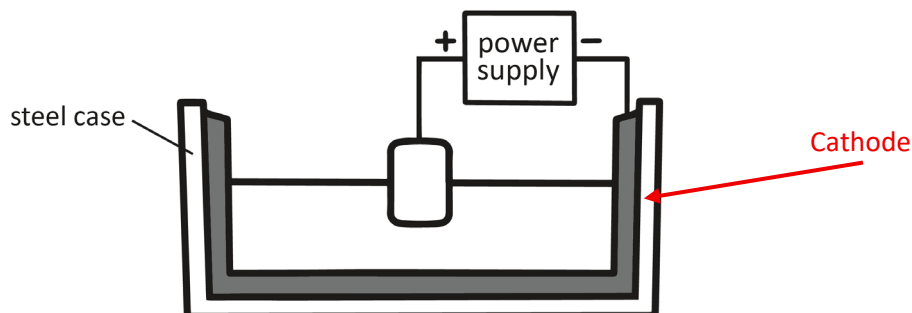
(Total for Question 7 is 6 marks)

8. Aluminium is extracted by electrolysis of its purified ore.

a. Name the main **ore** of aluminium.

Bauxite.	(1)
	Total: 1 mark

b. The figure below shows a simplified version of the apparatus used for the extraction of aluminium.



i. Label the cathode in figure above.

Label line drawn to the casing / lining of the tank.	(1)
	Total: 1 mark

ii. The electrolyte contains molten aluminium oxide.

State the product formed at **each** electrode during electrolysis.

Positive electrode: Oxygen or O ₂ .	(1)
Negative electrode: Aluminium.	(1)
	Total: 2 marks

c. State **two** physical properties that explain why aluminium is used in overhead electrical cables.

Good conductor of electricity.	(1)
Low density.	(1)
Allow: lightweight.	
	Total: 2 marks

d. Aluminium oxide has the formula Al₂O₃.

Calculate the percentage by mass of aluminium in aluminium oxide.

Find the Mr: $(2 \times 27) + (3 \times 16) = 102$	(1)
Calculate the percentage: $(54 \div 102) \times 100 = 52.9 \%$	(1)
	Total: 2 marks

(Total for Question 8 is 8 marks)