

Chemical Cells and Fuel Cells

Mark Scheme



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1. Chemical cells and fuel cells are devices that harness chemical reactions to directly produce electrical energy. Circle the letter of the correct answer for each of the following questions.

- a. A simple chemical cell is made by placing a zinc electrode and a copper electrode into a solution of an electrolyte. Zinc is more reactive than copper.

Which statement is correct?

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

- b. In a hydrogen-oxygen fuel cell, hydrogen and oxygen are supplied to the electrodes.

What is the only waste product formed in this type of fuel cell?

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

- c. Fuel cells and rechargeable batteries can both be used to power electric vehicles.

What is a major advantage of a hydrogen fuel cell compared to a rechargeable battery?

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

- d. Which row about a hydrogen–oxygen fuel cell is correct?

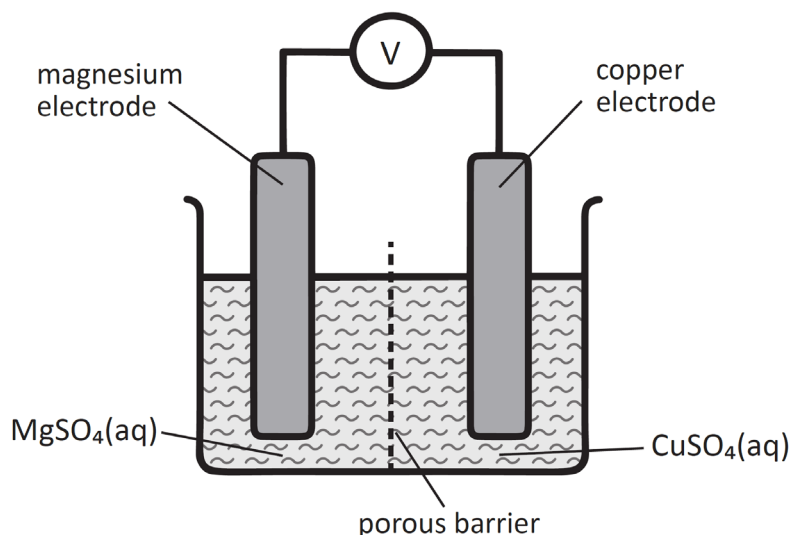
D – is the only correct answer.	1 mark
	Total: 1 mark

- e. What is the primary function of the electrolyte in a simple chemical cell?

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

(Total for Question 1 is 5 marks)

2. The figure below shows a chemical cell.



- a. State which electrode, magnesium or copper, is the negative terminal.
Give a reason for your answer.

Electrode: Magnesium / Mg.	1 mark
Reason: Magnesium is more reactive (than copper).	1 mark
Allow it loses electrons more easily. Do not accept: it is a better conductor.	
	Total: 2 marks

- b. What would be observed on the voltmeter? Explain the observation.

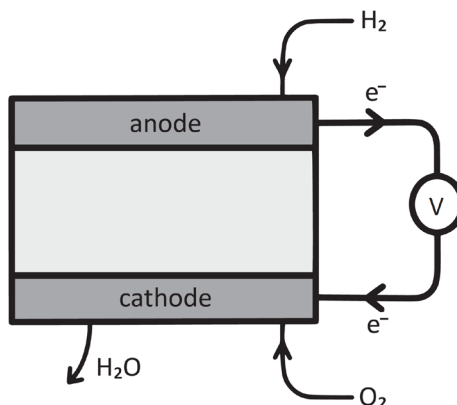
Observation: A voltage reading / A potential difference / Deflection on the needle.	1 mark
Allow "a current flows" or "bulb lights up" (if bulb was present, but voltmeter implies reading)	
Explanation: There is a difference in reactivity between the two metals (causing electrons to flow).	1 mark
Allow magnesium transfers electrons to copper.	
	Total: 2 marks

- c. State the function of the porous barrier.

Accept any one of the following:	
To complete the circuit.	1 mark
To allow ions to pass through (from one half-cell to the other).	1 mark
Allow to balance the charge.	1 mark
	Total: 1 mark

(Total for Question 2 is 5 marks)

3. A fuel cell generates electricity from a chemical reaction between a fuel and oxygen. The figure below shows a fuel cell that uses hydrogen, which is the most common fuel. Other fuels, such as methane and methanol, can also be used.



- a. Methane (CH_4) can also be used as a fuel in this type of cell. Name the product, other than water, that is formed.

Carbon dioxide / CO_2	1 mark
Reject carbon monoxide. Reject water.	
	Total: 1 mark

- b. Write a balanced chemical equation for the overall reaction that occurs in the hydrogen fuel cell shown.

$2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$	2 marks
Allow multiples.	
Award 1 mark for the correct chemical formulae.	1 mark
Award 1 mark for the correct balancing.	1 mark
	Total: 2 marks

- c. State whether oxidation or reduction happens at the anode. Explain your answer using information from the diagram.

Statement: oxidation	
Explanation: hydrogen loses electrons.	
Both points are needed for the mark.	
	Total: 1 mark

- d. Write the half-equation for the reaction occurring at the anode.

$\text{H}_2 \rightarrow 2\text{H}^+ + 2\text{e}^-$	2 marks
Allow multiples.	
Award 1 mark for the correct chemical formulae.	1 mark
Award 1 mark for the correct balancing.	1 mark
	Total: 2 marks

e. What chemical process happens at the cathode?

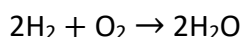
Reduction	1 mark
	Total: 1 mark

f. Describe **two advantages** and **one disadvantage** of using a hydrogen fuel cell to power a car compared to using a petrol engine.

A description to include any two of the following advantages:	
• Produces only water / no pollutants / no CO₂ • Highly efficient • Silent operation. • Does not need recharging (if fuel supplied).	2 marks
And any one of the following disadvantages:	
• Hydrogen is difficult/expensive to store (high pressure needed). • Hydrogen is flammable / explosive. • Lack of infrastructure (filling stations). • Hydrogen often made from fossil fuels (methane).	1 mark
	Total: 3 marks

(Total for Question 3 is 10 marks)

4. A space mission needs a reliable source of electrical energy.
Engineers are considering either hydrogen-oxygen fuel cells or traditional chemical cells (batteries).
The overall reaction in the fuel cell is:

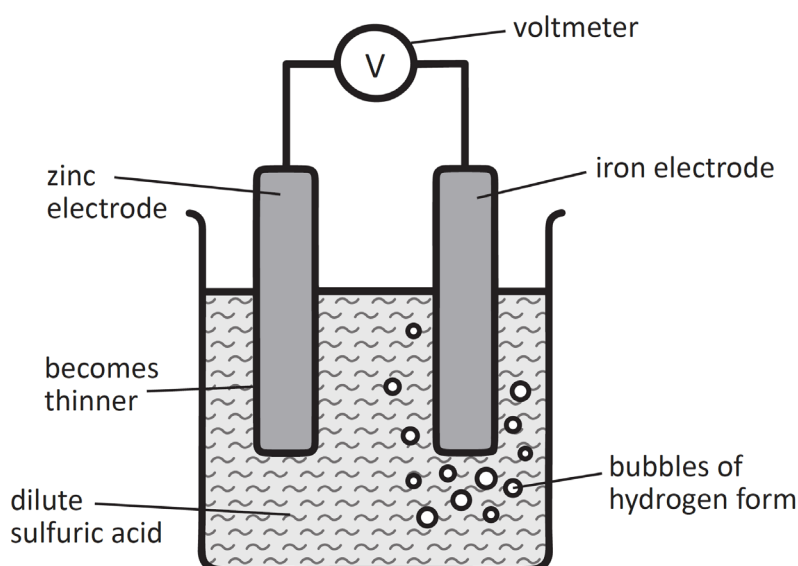


a. Compare the use of hydrogen-oxygen fuel cells with chemical cells for this purpose.
You should include both the benefits and drawbacks of using fuel cells in your answer.

Marking guidance		
Level	Marks	Descriptor
Level 1	1 - 2	Relevant points are made about fuel cells or chemical cells, but they are isolated statements rather than a linked comparison.
Level 2	3 - 4	An attempt to compare is made. Some benefits and drawbacks are given, but the answer may lack detail or fail to link fully to the context of a space mission.
Level 3	5 - 6	A detailed and coherent comparison is provided. The student considers both benefits and drawbacks of both types of cells and links them to the specific context (space mission / water production).

Indicative content:	
Fuel cells (benefits): - Produce water, which is useful for drinking on a space mission. - Do not need to be electrically recharged; they run continuously as long as fuel is supplied. - Maintain a constant voltage output (do not get weaker over time). - Compact and lightweight relative to the energy produced. Fuel cells (drawbacks): - Hydrogen and oxygen must be stored on board (requires heavy tanks / high pressure). - Hydrogen is highly flammable / explosive risk. Chemical cells / batteries (benefits): - Simple technology / reliable. - Store energy ready for immediate use. Chemical cells / batteries (drawbacks): - Finite lifespan; they run out and need replacing or recharging. - Voltage drops as the reactants are used up. - Disposal of used batteries is difficult in space. - Heavy if a large amount of energy is needed. Conclusion: Fuel cells are generally preferred for spacecraft because the water produced is a vital resource for astronauts, reducing the launch weight of water supplies.	
	Total: 6 marks

b. The figure below shows a simple cell.



i. State what type of cell is shown in the figure above.

Simple cell or battery.	1 mark
	Total: 1 mark

- ii. Identify the positive electrode and the negative electrode in this cell.
Explain your answer using observations from the figure of the cell and your knowledge of reactivity.

Positive: Iron / Fe.	1 mark
Negative: Zinc / Zn.	1 mark
Explanation:	
- Zinc is more reactive than Iron. - Zinc oxidises / loses electrons (and pushes them to the iron).	2 marks
	Total: 4 marks

- c. Write half-equations for the reactions occurring at each electrode.

Zn Electrode: $\text{Zn} \rightarrow \text{Zn}^{2+} + 2\text{e}^-$	Fe Electrode: $2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2$	2 marks
Allow multiples.		
Award 1 mark for the correct chemical formulae.		1 mark
Award 1 mark for the correct balancing.		1 mark
		Total: 2 marks

- d. Explain why the voltmeter shows a reading and describe the direction of electron flow in the external circuit.

The voltmeter shows a reading because there is <u>a difference in reactivity between the two metals</u> .	1 mark
Electrons flow from the zinc.	1 mark
to the Iron.	1 mark
	Total: 3 marks

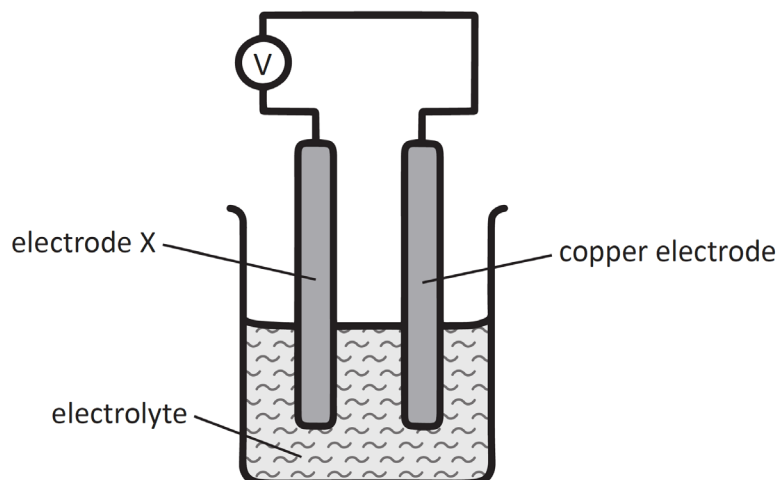
- e. If the iron electrode was replaced with a copper electrode, predict how the voltage reading would change, if at all.

Justify your answer in terms of the reactivity series.

Prediction: The voltage would increase.	1 mark
Justification:	
Copper is less reactive than iron.	1 mark
Therefore there is a greater difference in reactivity (between zinc and copper compared to zinc and iron).	1 mark
	Total: 3 marks

(Total for Question 4 is 19 marks)

5. The figure below shows a chemical cell.



The electrolyte is a solution that completes the electrical circuit inside the cell.

- a. State what type of compound must be present in the electrolyte to complete the circuit?

ionic compound / salt (solution).	1 mark
Allow acid/ base or alkali.	
	Total: 1 mark

To produce a voltage, electrode X must have a different reactivity to copper. The student knows that the greater the difference in reactivity between the two metals, the larger the voltage produced. The reactivity series is shown below.

Metal	
Magnesium	(most reactive) ↓ (least reactive)
Zinc	
Iron	
Copper	
Gold	

- b. Using the reactivity series, predict which metals (magnesium, zinc, or gold) would produce the largest voltage when used as electrode X.

Explain your choice.

Metals: Magnesium.	1 mark
Explanation: largest difference in reactivity (between the two metals).	1 mark
	Total: 2 marks

- c. Oxidation occurs at the zinc electrode.

Write the half-equation for the reaction taking place at the zinc electrode. Include state symbols.

$\text{Zn(s)} \rightarrow \text{Zn}^{2+}(\text{aq}) + 2\text{e}^{-}$	2 marks
Allow multiples.	
Award 1 mark for the correct half-equation.	1 mark
Award 1 mark for correct state symbols.	1 mark
	Total: 2 marks

- d. Zinc is more reactive than copper.

State which electrode (zinc or copper) will be the negative terminal. Give a reason for your answer.

Electrode: Zinc.	1 mark
Reason: It is more reactive (than copper) so it loses electrons / oxidises.	1 mark
	Total: 2 marks

- e. Describe **one** change you would expect to see to the zinc electrode if the cell were left running for 24 hours.

A description to include one of the following:	
• Voltage drops to zero. • The zinc electrode becomes smaller / disappears.	
	Total: 1 mark

- f. Hydrogen-oxygen fuel cells can be used as a source of electrical energy on spacecraft.

Suggest **one** advantage of using fuel cells rather than chemical cells in spacecraft.

The water produced can be used for drinking (potable water).	1 mark
Allow: it is lightweight / compact. Allow: no toxic fumes in enclosed spacecraft.	
	Total: 1 mark

(Total for Question 5 is 9 marks)