Q1. Fuel cells are an increasingly important energy source for vehicles. Standard electrode potentials are used in understanding some familiar chemical reactions including those in fuel cells.

The following table contains some standard electrode potential data.

Electrode half-equation	$E^\ominus$ **/ V**
$F_2 + 2e^- \longrightarrow 2F^-$	+2.87
$Cl_2 + 2e^- \longrightarrow 2Cl^-$	+1.36
$O_2 + 4H^+ + 4e^- \longrightarrow 2H_2O$	+1.23
$Br_2 + 2e^- \longrightarrow 2Br^-$	+1.07
$I_2 + 2e^- \longrightarrow 2I^-$	+0.54
$O_2 + 2H_2O + 4e^- \longrightarrow 4OH^-$	+0.40
$SO_4^{2-} + 4H^+ + 2e^- \longrightarrow SO_2 + 2H_2O$	+0.17
$2H^+ + 2e^- \longrightarrow H_2$	0.00
$4H_2O + 4e^- \longrightarrow 4OH^- + 2H_2$	−0.83

(a) A salt bridge was used in a cell to measure electrode potential.

Explain the function of the salt bridge.

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(2)

(b) Use data from the table above to deduce the halide ion that is the weakest reducing agent.

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(1)

(c) Use data from the table to justify why sulfate ions should **not** be capable of oxidising bromide ions.

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(1)

(d) Use data from the table to calculate a value for the EMF of a hydrogen–oxygen fuel cell operating under alkaline conditions.

EMF = ... V

(1)

(e) There are two ways to use hydrogen as a fuel for cars. One way is in a fuel cell to power an electric motor, the other is as a fuel in an internal combustion engine.

Suggest the major advantage of using the fuel cell.

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(1)
(Total 6 marks)

Q2. An experiment was carried out to measure the e.m.f. of this cell.

$$Al(s) \mid Al^{3+}(aq) \parallel H^{+}(aq) \mid H_2(g) \mid Pt(s)$$

(a) The aluminium used as the electrode is rubbed with sandpaper prior to use.

Suggest the reason for this.

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(1)

(b) Draw a labelled diagram of a suitable apparatus for the right-hand electrode in this cell. You do **not** need to include the salt bridge or the external electrical circuit.

(2)

(c) A simple salt bridge can be prepared by dipping a piece of filter paper into potassium carbonate solution. Explain why such a salt bridge would **not** be suitable for use in this cell.

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(2)
(Total 5 marks)

Q3. The table below shows some standard electrode potential data.

	$E^\ominus$ / V
$ZnO(s) + H_2O(l) + 2e^- \longrightarrow Zn(s) + 2OH^-(aq)$	–1.25
$Fe^{2+}(aq) + 2e^- \longrightarrow Fe(s)$	–0.44

$O_2(g) + 2H_2O(l) + 4e^- \longrightarrow 4OH^-(aq)$	+0.40
$2HOCl(aq) + 2H^+(aq) + 2e^- \longrightarrow Cl_2(g) + 2H_2O(l)$	+1.64

(a) Give the conventional representation of the cell that is used to measure the standard electrode potential of iron as shown in the table.

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(2)

(b) With reference to electrons, give the meaning of the term **reducing agent**.

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(1)

(c) Identify the weakest reducing agent from the species in the table.

Explain how you deduced your answer.

Species..

Explanation...

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(2)

(d) When HOCl acts as an oxidising agent, one of the atoms in the molecule is reduced.

(i) Place a tick (✓) next to the atom that is reduced.

Atom that is reduced	**Tick (✓)**
H	
O	
Cl	

(1)

(ii) Explain your answer to part (i) in terms of the change in the oxidation state of this atom.

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.... **(1)**

(e) Using the information given in the table, deduce an equation for the redox reaction that would occur when hydroxide ions are added to HOCl

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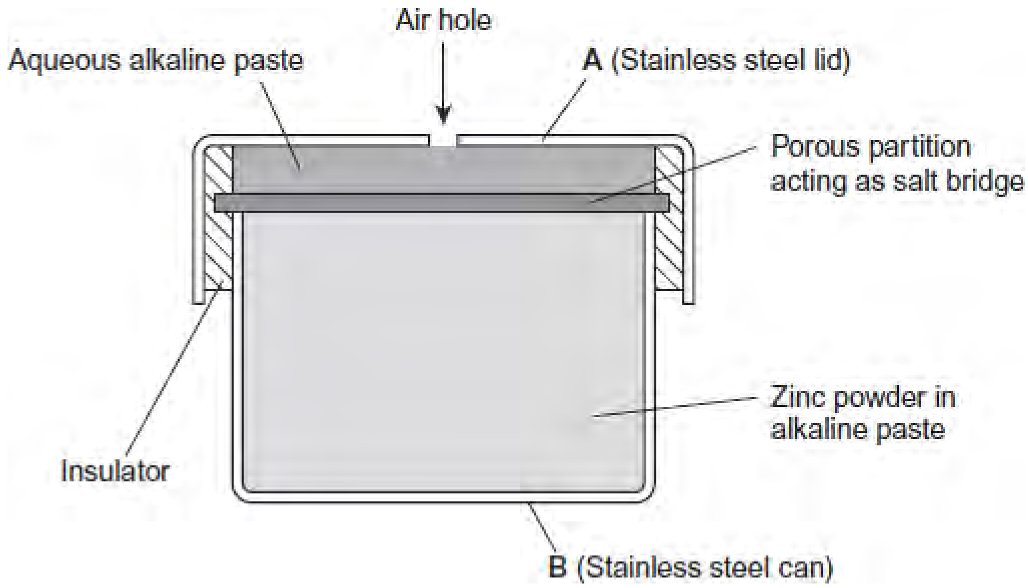
.... **(2)**

(f) The table is repeated to help you answer this question.

	$E^\ominus$ / V
$ZnO(s) + H_2O(l) + 2e^- \longrightarrow Zn(s) + 2OH^-(aq)$	–1.25
$Fe^{2+}(aq) + 2e^- \longrightarrow Fe(s)$	–0.44
$O_2(g) + 2H_2O(l) + 4e^- \longrightarrow 4OH^-(aq)$	+0.40
$2HOCl(aq) + 2H^+(aq) + 2e^- \longrightarrow Cl_2(g) + 2H_2O(l)$	+1.64

The half-equations from the table that involve zinc and oxygen are simplified versions of those that occur in hearing aid cells.

A simplified diagram of a hearing aid cell is shown in the following figure.



(i) Use data from the table to calculate the e.m.f. of this cell.

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Answer = ...

(1)

(ii) Use half-equations from the table to construct an overall equation for the cell reaction.

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(1)

(iii) Identify which of **A** or **B**, in the figure, is the positive electrode. Give a reason for your answer.

Positive electrode ....

Reason ....

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(2)

(iv) Suggest **one** reason, other than cost, why this type of cell is **not** recharged.

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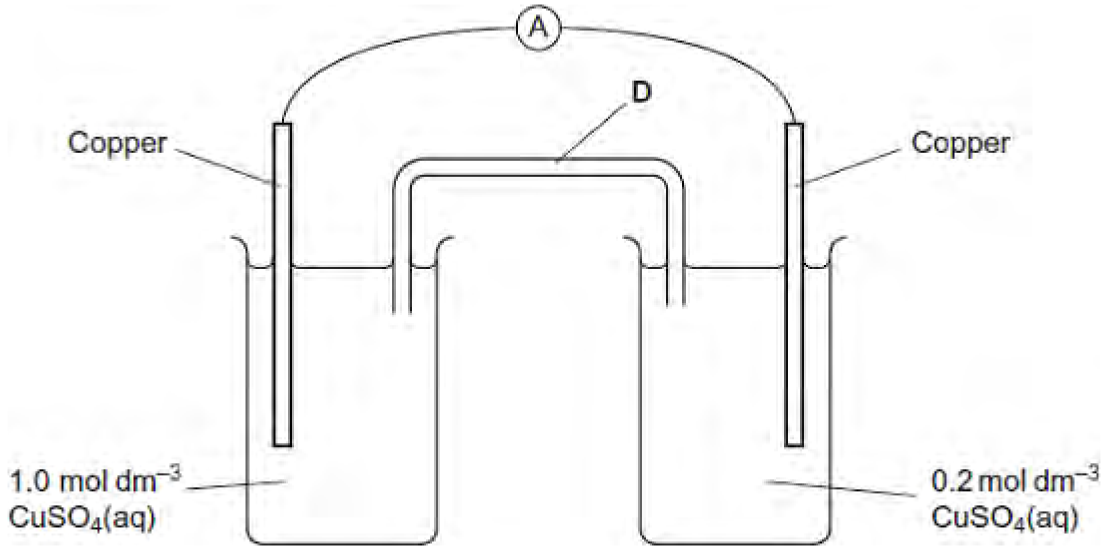
(1)
(Total 14 marks)

Q4. An electrochemical cell is shown in the diagram. In this cell, the amount of copper in the electrodes is much greater than the amount of copper ions in the copper sulfate solutions.



(a) Explain how the salt bridge **D** provides an electrical connection between the two electrodes.

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(1)

(b) Suggest why potassium chloride would **not** be a suitable salt for the salt bridge in this cell.

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(1)

(c) In the external circuit of this cell, the electrons flow through the ammeter from right to left.

Suggest why the electrons move in this direction.

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(2)

(d) Explain why the current in the external circuit of this cell falls to zero after the cell has operated for some time.

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(1)

(e) The simplified electrode reactions in a rechargeable lithium cell are

Electrode **A** $Li^+ + MnO_2 + e^- \longrightarrow LiMnO_2$ $E = -0.15$ V

Electrode **B** $Li^+ + e^- \longrightarrow Li$

Electrode **B** is the negative electrode.

(i) The e.m.f. of this cell is 2.90 V.

Use this information to calculate a value for the electrode potential of electrode **B**.

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(1)

(ii) Write an equation for the overall reaction that occurs when this lithium cell is being **recharged**.

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(2)

(iii) Suggest why the recharging of a lithium cell may lead to release of carbon dioxide into the atmosphere.

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(1)
(Total 9 marks)

Q5. Hydrogen–oxygen fuel cells are used to provide electrical energy for electric motors in vehicles.

(a) In a hydrogen–oxygen fuel cell, a current is generated that can be used to drive an electric motor.

(i) Deduce half-equations for the electrode reactions in a hydrogen–oxygen fuel cell.

Half-equation 1 ....

Half-equation 2 ....

(2)

(ii) Use these half-equations to explain how an electric current can be generated.

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(2)

(b) Explain why a fuel cell does **not** need to be recharged.

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(1)

(c) To provide energy for a vehicle, hydrogen can be used either in a fuel cell or in an internal combustion engine.

Suggest the main advantage of using hydrogen in a fuel cell rather than in an internal combustion engine.

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(1)

(d) Identify **one** major hazard associated with the use of a hydrogen–oxygen fuel cell in a vehicle.

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(1)
(Total 7 marks)

Q6. Copper, in the form of nanoparticles of copper(II) hexacyanoferrate(II), has recently been investigated as an efficient method of storing electrical energy in a rechargeable cell.

(a) Solar cells generate an electric current from sunlight. These cells are often used to provide electrical energy for illuminated road signs.

Explain why rechargeable cells are connected to these solar cells.

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(2)

(b) Suggest **one** reason why many waste disposal centres contain a separate section for cells and batteries.

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(1)
(Total 3 marks)