

- 7 The electrons transferred in redox reactions can be used by electrochemical cells to provide energy.

Some electrode half-equations and their standard electrode potentials are shown in the table below.

Half-equation	$E^\ominus / \text{V}$
$\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 14\text{H}^+(\text{aq}) + 6\text{e}^- \rightarrow 2\text{Cr}^{3+}(\text{aq}) + 7\text{H}_2\text{O}(\text{l})$	+1.33
$\text{Fe}^{3+}(\text{aq}) + \text{e}^- \rightarrow \text{Fe}^{2+}(\text{aq})$	+0.77
$2\text{H}^+(\text{aq}) + 2\text{e}^- \rightarrow \text{H}_2(\text{g})$	0.00
$\text{Fe}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Fe}(\text{s})$	-0.44
$\text{Li}^+(\text{aq}) + \text{e}^- \rightarrow \text{Li}(\text{s})$	-3.04

- 7 (a) Describe a standard hydrogen electrode.

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(4 marks)



- 7 (b)** A conventional representation of a lithium cell is given below.  
This cell has an e.m.f. of +2.91 V



Write a half-equation for the reaction that occurs at the positive electrode of this cell.

Calculate the standard electrode potential of this positive electrode.

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(2 marks)

- 7 (c)** Suggest what reactions occur, if any, when hydrogen gas is bubbled into a solution containing a mixture of iron(II) and iron(III) ions. Explain your answer.

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(2 marks)

**Question 7 continues on the next page**

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Calculate the percentage of iron(II) ions that had been oxidised by the air.

(Extra space) ..... (6 marks)

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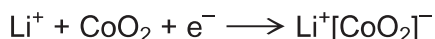


- 5 (a) Lithium ion cells are used to power cameras and mobile phones. A simplified representation of a cell is shown below.



The reagents in the cell are absorbed onto powdered graphite that acts as a support medium. The support medium allows the ions to react in the absence of a solvent such as water.

The half-equation for the reaction at the positive electrode can be represented as follows.



- 5 (a) (i) Identify the element that undergoes a change in oxidation state at the positive electrode and deduce these oxidation states of the element.

Element .....

Oxidation state 1 .....

Oxidation state 2 .....

(3 marks)

- 5 (a) (ii) Write a half-equation for the reaction at the negative electrode during operation of the lithium ion cell.

.....  
(1 mark)

- 5 (a) (iii) Suggest two properties of platinum that make it suitable for use as an external electrical contact in the cell.

Property 1 .....

Property 2 .....

(2 marks)

- 5 (a) (iv) Suggest **one** reason why water is **not** used as a solvent in this cell.

.....

.....

(1 mark)



- 5 (b)** The half-equations for two electrodes used to make an electrochemical cell are shown below.



- 5 (b) (i)** Write the conventional representation for the cell using platinum contacts.

.....  
(2 marks)

- 5 (b) (ii)** Write an overall equation for the cell reaction and identify the oxidising and reducing agents.

Overall equation .....

.....  
.....

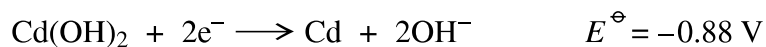
Oxidising agent .....

Reducing agent .....  
(3 marks)

Turn over for the next question



- 2 Nickel–cadmium cells are used to power electrical equipment such as drills and shavers. The electrode reactions are shown below.



- 2 (a) Calculate the e.m.f. of a nickel–cadmium cell.

.....  
(1 mark)

- 2 (b) Deduce an overall equation for the reaction that occurs in the cell when it is used.

.....  
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.....  
(2 marks)

- 2 (c) Identify the oxidising agent in the overall cell reaction and give the oxidation state of the metal in this oxidising agent.

Oxidising agent .....

Oxidation state .....  
(2 marks)

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**Turn over for the next question**

**Turn over ►**



- 3 Hydrogen–oxygen fuel cells can operate in acidic or in alkaline conditions but commercial cells use porous platinum electrodes in contact with concentrated aqueous potassium hydroxide. The table below shows some standard electrode potentials measured in acidic and in alkaline conditions.

Half-equation	$E^{\ominus}/\text{V}$
$\text{O}_2(\text{g}) + 4\text{H}^+(\text{aq}) + 4\text{e}^- \longrightarrow 2\text{H}_2\text{O}(\text{l})$	+1.23
$\text{O}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) + 4\text{e}^- \longrightarrow 4\text{OH}^-(\text{aq})$	+0.40
$2\text{H}^+(\text{aq}) + 2\text{e}^- \longrightarrow \text{H}_2(\text{g})$	0.00
$2\text{H}_2\text{O}(\text{l}) + 2\text{e}^- \longrightarrow 2\text{OH}^-(\text{aq}) + \text{H}_2(\text{g})$	−0.83

- 3 (a) State why the electrode potential for the standard hydrogen electrode is equal to 0.00 V.

.....  
(1 mark)

- 3 (b) Use data from the table to calculate the e.m.f. of a hydrogen–oxygen fuel cell operating in alkaline conditions.

.....  
(1 mark)

- 3 (c) Write the conventional representation for an alkaline hydrogen–oxygen fuel cell.

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(2 marks)

- 3 (d) Use the appropriate half-equations to construct an overall equation for the reaction that occurs when an alkaline hydrogen–oxygen fuel cell operates. Show your working.

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.....  
.....  
.....  
(2 marks)



- 3 (e) Give **one** reason, other than cost, why the platinum electrodes are made by coating a porous ceramic material with platinum rather than by using platinum rods.

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.....  
(1 mark)

- 3 (f) Suggest why the e.m.f. of a hydrogen–oxygen fuel cell, operating in acidic conditions, is exactly the same as that of an alkaline fuel cell.

.....  
(1 mark)

- 3 (g) Other than its lack of pollution, state briefly the main advantage of a fuel cell over a re-chargeable cell such as the nickel–cadmium cell when used to provide power for an electric motor that propels a vehicle.

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(1 mark)

- 3 (h) Hydrogen–oxygen fuel cells are sometimes regarded as a source of energy that is carbon neutral. Give **one** reason why this may **not** be true.

.....  
(1 mark)

10
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**Turn over for the next question**

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