A-Level Chemistry

Electrochemical Cells

Question Paper

Time available: 60 minutes
Marks available: 58 marks

1. This question is about the development of lithium cells.
The value of E^{o} for lithium suggests that a lithium cell could have a large EMF.

The table below shows some electrode potential data.

	***E*° / V**
$Li^+(aq) + e^- \rightarrow Li(s)$	–3.04
$2\ H_2O(l) + 2\ e^- \rightarrow H_2(g) + 2\ OH^-(aq)$	–0.83
$\frac{1}{2}\ I_2(s) + e^- \rightarrow I^-(aq)$	+0.54

(a) Use data in the table above to explain why an aqueous electrolyte is **not** used for a lithium cell.

_____

_____

_____

(2)

(b) In the 1970s lithium-iodine cells became a common power source for heart pacemakers. Lithium iodide is the final product of the cell reaction.

Use the data in the table above to calculate the cell EMF of a standard lithium-iodine cell.

_____

(1)

(c) An EMF value for a commercial lithium-iodine cell is 2.80 V

Suggest why this value is different from the value calculated in part (b).

_____

_____

(1)

(d) In some lithium cells, lithium perchlorate ($LiClO_4$) is used as the electrolyte.

Deduce the oxidation state of chlorine in $LiClO_4$

_____

(1)

In other lithium cells, lithium cobalt oxide electrodes **and** lithium electrodes are used.

(e) Give an equation for the reaction that occurs at the positive lithium cobalt oxide electrode.

_____

(1)

(f) Give an equation for the reaction that occurs at the negative lithium electrode.

_____

(1)

(Total 7 marks)

2. This question is about a glucose–oxygen fuel cell.

When the cell operates, the glucose ($C_6H_{12}O_6$) molecules react with water at the negative electrode to form carbon dioxide and hydrogen ions.

Oxygen gas reacts with hydrogen ions to form water at the positive electrode.

(a) Deduce the half-equation for the reaction at the negative electrode.

_____

(1)

(b) Deduce the half-equation for the reaction at the positive electrode.

_____

(1)

(c) Give the equation for the overall reaction that occurs in the Glucose–oxygen fuel cell.

_____

(1)

(d) The negative electrode is made of carbon and the positive electrode is made of platinum.

Give the conventional representation for the glucose–oxygen fuel cell.

_____

_____

(2)

(e) State what must be done to maintain the EMF of this fuel cell when in use.

_____

(1)

(Total 6 marks)

3. A representation of a hydrogen–oxygen fuel cell that operates in alkaline conditions is

$$Pt|H_2|H_2O||O_2|OH^-|Pt$$

(a) (i) Write a half-equation for the reaction that occurs at each electrode.
Use the half-equations to deduce an overall equation for the cell.

Half-equation at positive electrode _____

Half-equation at negative electrode _____

Overall equation _____

(3)

(ii) State and explain the effect, if any, of increasing the pressure of oxygen on the e.m.f of this cell.

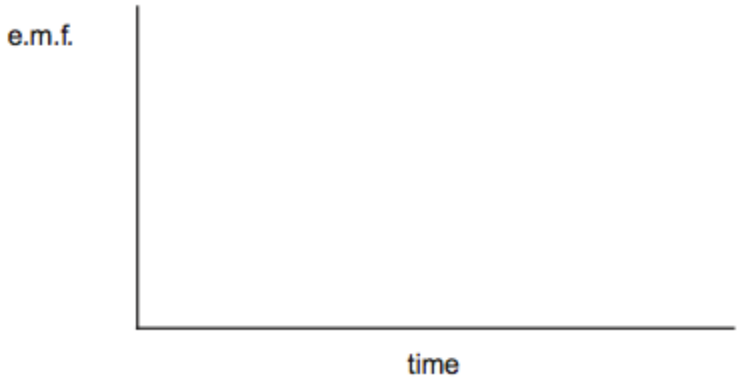
Effect on e.m.f. _____

Explanation _____

_____

(2)

(b) Complete the diagram to show how the e.m.f. of a hydrogen–oxygen fuel cell changes with time.



(1)

(c) (i) Suggest the effect, if any, on the e.m.f. of this cell if the surface area of each platinum electrode is increased.

_____

(1)

(ii) State the main environmental advantage of using a hydrogen–oxygen fuel cell to power a car.

_____

_____

(1)

(d) Suggest why the use of a hydrogen–oxygen fuel cell might not be carbon-neutral.

_____

_____

_____

_____

(1)

(Total 9 marks)

4. 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.

_____

_____

_____

_____

(2)

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

_____

_____

_____

(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.

_____

_____

_____

(1)

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

_____

_____

(1)

(Total 7 marks)

5. The table shows some electrode half-equations and the associated standard electrode potentials.

Equation number	Electrode half-equation	$E^{\ominus}$ / V
1	$Cd(OH)_2(s) + 2e^- \rightarrow Cd(s) + 2OH^-(aq)$	–0.88
2	$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$	–0.76
3	$NiO(OH)(s) + H_2O(l) + e^- \rightarrow Ni(OH)_2(s) + OH^-(aq)$	+0.52
4	$MnO_2(s) + H_2O(l) + e^- \rightarrow MnO(OH)(s) + OH^-(aq)$	+0.74
5	$O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$	+1.23

(a) In terms of electrons, state the meaning of the term *oxidising agent*.

_____

_____

(1)

(b) Deduce the identity of the weakest oxidising agent in the table.
Explain how $E^{\ominus}$ values can be used to make this deduction.

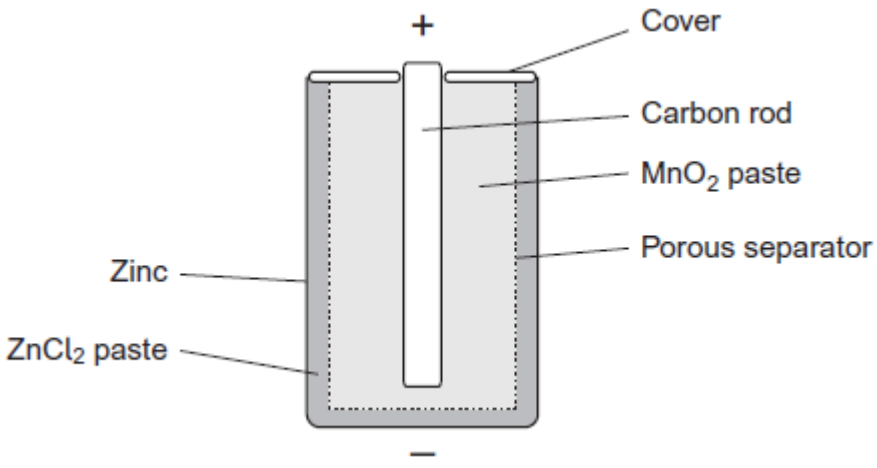
Weakest oxidising agent _____

Explanation _____

_____

(2)

(c) The diagram shows a non-rechargeable cell that can be used to power electronic devices.
The relevant half-equations for this cell are equations **2** and **4** in the table above.



(i) Calculate the e.m.f. of this cell.

_____

_____

_____

(1)

(ii) Write an equation for the overall reaction that occurs when the cell discharges.

_____

_____

_____

(1)

(iii) Deduce **one** essential property of the non-reactive porous separator labelled in the diagram.

_____

_____

(1)

(iv) Suggest the function of the carbon rod in the cell.

_____

_____

(1)

(v) The zinc electrode acts as a container for the cell and is protected from external damage. Suggest why a cell often leaks after being used for a long time.

_____

_____

(1)

(d) A rechargeable nickel–cadmium cell is an alternative to the cell shown in part (c). The relevant half-equations for this cell are equations **1** and **3** in the table above.

(i) Deduce the oxidation state of the nickel in this cell after recharging is complete. Write an equation for the overall reaction that occurs when the cell is **recharged**.

Oxidation state _____

Equation _____

_____

_____

(3)

(ii) State **one** environmental advantage of this rechargeable cell compared with the non-rechargeable cell described in part (c).

_____

_____

(1)

(e) An ethanol–oxygen fuel cell may be an alternative to a hydrogen–oxygen fuel cell. When the cell operates, all of the carbon atoms in the ethanol molecules are converted into carbon dioxide.

(i) Deduce the equation for the overall reaction that occurs in the ethanol–oxygen fuel cell.

_____

(1)

(ii) Deduce a half-equation for the reaction at the ethanol electrode.
In this half-equation, ethanol reacts with water to form carbon dioxide and hydrogen ions.

_____

(1)

(iii) The e.m.f. of an ethanol–oxygen fuel cell is 1.00 V. Use data from the table above to calculate a value for the electrode potential of the ethanol electrode.

_____

_____

(1)

(iv) Suggest why ethanol can be considered to be a carbon-neutral fuel.

_____

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_____

_____

(2)

(Total 17 marks)

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

$$Li \mid Li^+ \parallel Li^+, CoO_2 \mid LiCoO_2 \mid Pt$$

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.

$$Li^+ + CoO_2 + e^- \longrightarrow Li^+[CoO_2]^-$$

(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)

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

_____

(1)

(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)

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

_____

_____

(1)

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

$ClO_3^-(aq) + 6H^+(aq) + 6e^- \longrightarrow Cl^-(aq) + 3H_2O(l)$ $\quad E^{\ominus} = +1.45$ V

$SO_4^{2-}(aq) + 2H^+(aq) + 2e^- \longrightarrow SO_3^{2-}(aq) + H_2O(l)$ $\quad E^{\ominus} = +0.17$ V

(i) Write the conventional representation for the cell using platinum contacts.

_____

(2)

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

Overall equation _____

_____

_____

Oxidising agent _____

Reducing agent _____

(3)

(Total 12 marks)