

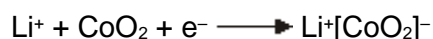
**Q16.**

- (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.



- (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 _____

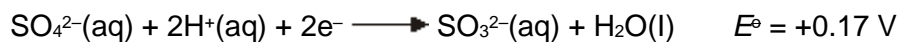
(2)

- (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.



- (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)

Q17.

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/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



- (a) Describe a standard hydrogen electrode.

(4)

- (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.

(2)

- (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.

(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)

(Total 5 marks)

Q19.

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° / V
$\text{O}_2(\text{g}) + 4\text{H}^+(\text{aq}) + 4\text{e}^- \rightarrow 2\text{H}_2\text{O}(\text{l})$	+1.23
$\text{O}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) + 4\text{e}^- \rightarrow 4\text{OH}^-(\text{aq})$	+0.40
$2\text{H}^+(\text{aq}) + 2\text{e}^- \rightarrow \text{H}_2(\text{g})$	0.00
$2\text{H}_2\text{O}(\text{l}) + 2\text{e}^- \rightarrow 2\text{OH}^-(\text{aq}) + \text{H}_2(\text{g})$	-0.83

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

(1)

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

(1)

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

(2)

- (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.

(2)



- (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.

(1)

- (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)

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

(1)

- (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)

(Total 10 marks)

Q20.

Use the standard electrode potential data in the table below to answer the questions which follow.

			E^\ominus / V
$\text{Ce}^{4+}(\text{aq}) + \text{e}^-$		$\text{Ce}^{3+}(\text{aq})$	+1.70
$\text{MnO}_4^-(\text{aq}) + 8\text{H}^+(\text{aq}) + 5\text{e}^-$		$\text{Mn}^{2+}(\text{aq}) + 4\text{H}_2\text{O}(\text{l})$	+1.51
$\text{Cl}_2(\text{g}) + 2\text{e}^-$		$2\text{Cl}^-(\text{aq})$	+1.36
$\text{VO}_2^+(\text{aq}) + 2\text{H}^+(\text{aq}) + \text{e}^-$		$\text{VO}^{2+}(\text{aq}) + \text{H}_2\text{O}(\text{l})$	+1.00
$\text{Fe}^{3+}(\text{aq}) + \text{e}^-$		$\text{Fe}^{2+}(\text{aq})$	+0.77
$\text{SO}_4^{2-}(\text{aq}) + 4\text{H}^+(\text{aq}) + 2\text{e}^-$		$\text{H}_2\text{SO}_3(\text{aq}) + \text{H}_2\text{O}(\text{l})$	+0.17

- (a) Name the standard reference electrode against which all other electrode potentials are measured.

(1)



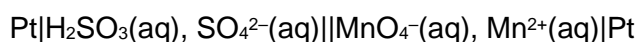
(b) When the standard electrode potential for $\text{Fe}^{3+}(\text{aq}) / \text{Fe}^{2+}(\text{aq})$ is measured, a platinum electrode is required.

(i) What is the function of the platinum electrode?

(ii) What are the standard conditions which apply to $\text{Fe}^{3+}(\text{aq})/\text{Fe}^{2+}(\text{aq})$ when measuring this potential?

(3)

(c) The cell represented below was set up under standard conditions.



Calculate the e.m.f. of this cell and write an equation for the spontaneous cell reaction.

Cell e.m.f. _____

Equation _____

(3)

(d) (i) Which one of the species given in the table is the strongest oxidising agent?

(ii) Which of the species in the table could convert $\text{Fe}^{2+}(\text{aq})$ into $\text{Fe}^{3+}(\text{aq})$ but could not convert $\text{Mn}^{2+}(\text{aq})$ into $\text{MnO}_4^-(\text{aq})$?

(3)

(e) Use data from the table of standard electrode potentials to deduce the cell which would have a standard e.m.f. of 0.93 V. Represent this cell using the convention shown in part (c).

(2)

(Total 12 marks)



Mark Scheme

Q16.

- (a) (i) Co/Cobalt
If Co or Cobalt not given CE = 0
ignore case in symbol for Co 1
- (+) 4 1
- (+) 3
Allow 4 and 3 in either order 1
- (ii) $\text{Li} \rightarrow \text{Li}^+ + \text{e}^-$
Ignore state symbols
Allow e without -ve sign
Do not allow equilibrium sign 1
- (iii) Platinum is a conductor 1
- (Platinum is) unreactive/inert
Ignore mention of surface area or catalyst
Allow 2 marks if two properties given on one answer line
Apply list principle to contradictions/wrong answers
Do not allow platinum resists corrosion 1
- (iv) Li reacts with water/forms lithium hydroxide
Allow water breaks down (or is electrolysed) on re-charge 1
- (b) (i) $\text{Pt} | \text{SO}_3^{2-} (\text{aq}), \text{SO}_4^{2-} (\text{aq}) || \text{ClO}_3^- (\text{aq}), \text{Cl}^- (\text{aq}) | \text{Pt}$
State symbols as ', ' not necessary
Allow | in place of ', ' NOT ', ' in place of |
Ignore H⁺ and H₂O
Deduct one mark for each mistake (e.g. Pt missed twice counts as two mistakes)
Allow reverse order for whole cell
Pt | Cl⁻, ClO₃⁻ || SO₄²⁻, SO₃²⁻ | Pt 2
- (ii) $\text{ClO}_3^- + 3\text{SO}_3^{2-} \rightarrow \text{Cl}^- + 3\text{SO}_4^{2-}$ 1
- Oxidising agent ClO_3^- 1
- Reducing agent SO_3^{2-}



1

[12]

Q17.

(a) Hydrogen/H₂ gas/bubbles

1

1.0 mol dm⁻³ HCl/H⁺

1

At 298K and 100kPa

*Allow 1 bar instead of 100 kPa**Do not allow 1 atm*

1

Pt (electrode)

1

(b) Li⁺ + MnO₂ + e⁻ → LiMnO₂*Ignore state symbols*

1

-0.13(V)

1

(c) Fe³⁺ ions reduced to Fe²⁺*Can score from equation/scheme*

1

Because $E(\text{Fe}^{3+}/\text{Fe}^{2+}) > E(\text{H}^+/\text{H}_2)/E(\text{hydrogen})$ *Allow emf/ E_{cell} +ve/0.77V**Allow Fe³⁺ better oxidising agent than H⁺**Allow H₂ better reducing agent than Fe²⁺**Only award this explanation mark if previous mark given*

1

(d) Moles Cr₂O₇²⁻ = 23.7 × 0.01/1000 = 2.37 × 10⁻⁴

1

1 mol Cr₂O₇²⁻ reacts with 6 mol Fe²⁺ so moles
Fe²⁺ in 25 cm³ = 6 × 2.37 × 10⁻⁴ = 1.422 × 10⁻³

1

*M1 × 6*Moles Fe²⁺ in 250 cm³ = 1.422 × 10⁻²*M2 × 10 or M4/10*

1

Original moles Fe²⁺ = 10.00/277.9 = 0.0360*Independent mark*

1

Moles Fe²⁺ oxidised = 0.0360 – 0.0142 = 0.0218*M4 – M3*

1



$$\% \text{ oxidised} = (0.0218 \times 100)/0.0360 = 60.5\%$$

(M5 × 100)/M4

Allow 60 to 61

Note Max 3 if mol ratio for M2 wrong

eg 1:5 gives 67.1%

1:1 gives 93.4%

Note also, 39.5% (39-40) scores M1, M2, M3 and M4 (4 marks)

1

[14]

Q18.

(a) 1.4 V

Allow + or –

1

(b) $2\text{NiO}(\text{OH}) + 2\text{H}_2\text{O} + \text{Cd} \rightarrow 2\text{Ni}(\text{OH})_2 + \text{Cd}(\text{OH})_2$

Mark for species, Deduct a mark for additional species (eg OH⁻) but allow balance mark

1

Balanced

If equation is reversed CE=0

1

(c) NiO(OH) or Ni(III) or nickel

1

+3

Allow conseq on wrong species

1

[5]

Q19.

(a) By definition

allow 'set to this value'

1

(b) 1.23 V

Allow + or –

1

(c) $\text{Pt}|\text{H}_2(\text{g})|\text{OH}^-(\text{aq}),\text{H}_2\text{O}(\text{l})||\text{O}_2(\text{g})|\text{H}_2\text{O}(\text{l}),\text{OH}^-(\text{aq})|\text{Pt}$

H₂O not essential, allow reverse order

Correct but with Pt missing

1

Includes Pt with correct representation

1

(d) Uses $\text{O}_2 + 2\text{H}_2\text{O} + 4\text{e}^- \rightarrow 4\text{OH}^-$

And (2x) $2\text{OH}^- + \text{H}_2 \rightarrow 2\text{H}_2\text{O} + 2\text{e}^-$



- 1
- $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$ 1
- (e) Increases the surface area (so reaction faster) 1
- (f) Overall reaction is the same ($2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$)
Or shows e.m.f. is the same 1
- (g) Hydrogen and oxygen supplied continuously
- OR**
- Can be operated without stopping to recharge
Or can be refuelled quickly
Allow any one mark 1
- (h) Hydrogen may need to be made using an energy source that is not 'carbon neutral' 1

[10]

Q20.

- (a) (Standard) hydrogen (electrode) **(1)** 1
- (b) (i) To allow transfer of electrons / provide a reaction surface **(1)**
- (ii) 298 K **(1)**
Both $\text{F}^{3+}(\text{aq})$ and $\text{Fe}^{2+}(\text{aq})$ have a concentration of
 1 mol dm^{-3} **(1)** (QoL)
OR $[\text{H}^+] = 1 \text{ mol dm}^{-3}$
NOT zero current or 100 kPa 3
- (c) +1.34 V **(1)**
 $2 \text{MnO}_4^- + 5 \text{H}_2\text{SO}_3 \rightarrow 2 \text{Mn}^{2+} + 5 \text{SO}_4^{2-} + 3 \text{H}_2\text{O} + 4 \text{H}^+$
Correct species / order **(1)**
Balanced and cancelled **(1)**
Allow one for $2 \text{MnO}_4^- + 5 \text{H}_2\text{SO}_3 \rightarrow 2 \text{Mn}^{2+} + 5 \text{SO}_4^{2-}$ 3
- (d) (i) $\text{Ce}^{4+}(\text{aq})$ **(1)**
- (ii) $\text{VO}_2^+(\text{aq})$ **(1)**; Cl_2 **(1)**
Penalise additional answers to zero 3
- (e) Pt | $\text{Fe}^{2+}(\text{aq}), \text{Fe}^{3+}(\text{aq})$ || $\text{Ce}^{4+}(\text{aq}), \text{Ce}^{3+}(\text{aq})$ | Pt
Correct species **(1)**
Correct order **(1)**



Deduct one mark for each error

2

[12]