Q1.

This question is about electrode potentials and electrochemical cells.

(a) State the meaning of the term electrochemical series.

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(1)

The table below shows some electrode potentials.

	E° **/ V**
$[Fe(H_2O)_6]^{2+}(aq) + 2\,e^- \rightarrow Fe(s) + 6\,H_2O(l)$	–0.44
$H^+(aq) + e^- \rightarrow \frac{1}{2}\,H_2(g)$	0.00
$[Co(NH_3)_6]^{3+}(aq) + e^- \rightarrow [Co(NH_3)_6]^{2+}(aq)$	+0.11
$[Fe(H_2O)_6]^{3+}(aq) + e^- \rightarrow [Fe(H_2O)_6]^{2+}(aq)$	+0.77
$VO_2^+(aq) + 2\,H^+(aq) + e^- \rightarrow VO^{2+}(aq) + H_2O(l)$	+1.00
$[Co(H_2O)_6]^{3+}(aq) + e^- \rightarrow [Co(H_2O)_6]^{2+}(aq)$	+1.81

(b) State **two** conditions needed for the following half-cell to have E° = 0.00 V

$$H^+(aq) + e^- \rightarrow \frac{1}{2}H_2(g)$$

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(1)

(c) Identify the weakest reducing agent in the table above.

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(1)

(d) Use half-equations from the table above to deduce an equation for the reduction of VO_2^+ to form VO^{2+} in aqueous solution by iron.

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(2)

(e) Use data from the table above to explain why $[Co(H_2O)_6]^{3+}(aq)$ will undergo a redox reaction with $[Fe(H_2O)_6]^{2+}(aq)$

Give an equation for this reaction.

Explanation ___

Equation

(2)

(f) Suggest why the **two** cobalt(III) complex ions in the table above have different electrode potentials.

(1)
(Total 8 marks)

Q2.

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

The table below shows some electrode potential data.

	$E^{\ominus}$ / 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).

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(1)

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

Deduce the oxidation state of chlorine in $LiClO_4$

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(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.

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(1)

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

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(1)

(Total 7 marks)

Q3.

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.

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(1)

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

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(1)

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

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(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.

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(2)

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

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(1)
(Total 6 marks)

Q4.

Standard electrode potentials are measured by comparison with the standard hydrogen electrode.

(a) State the substances and conditions needed in a standard hydrogen electrode.

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(3)

It is difficult to ensure consistency with the setup of a standard hydrogen electrode. A Cu^{2+}(aq) / Cu(s) electrode (E° = +0.34 V) can be used as a secondary standard.

A student does an experiment to measure the standard electrode potential for the TiO^{2+}(aq) / Ti(s) electrode using the Cu^{2+}(aq) / Cu(s) electrode as a secondary standard.

A suitable solution containing the acidified TiO^{2+}(aq) ion is formed when titanium(IV) oxysulfate ($TiOSO_4$) is dissolved in 0.50 mol dm^{-3} sulfuric acid to make 50 cm^3 of solution.

(b) Describe an experiment the student does to show that the standard electrode potential for the $TiO^{2+}(aq) / Ti(s)$ electrode is −0.88 V

The student is provided with:

- the $Cu^{2+}(aq) / Cu(s)$ electrode set up ready to use
- solid titanium(IV) oxysulfate (M_r = 159.9)
- 0.50 mol dm^{-3} sulfuric acid
- a strip of titanium
- laboratory apparatus and chemicals.

Your answer should include details of:

- how to prepare the solution of acidified $TiO^{2+}(aq)$
- how to connect the electrodes
- measurements taken
- how the measurements should be used to calculate the standard electrode potential for the $TiO^{2+}(aq) / Ti(s)$ electrode.

(6)

(c) Give the half-equation for the electrode reaction in the $TiO^{2+}(aq) / Ti(s)$ electrode in acidic conditions.

(1)

(d) The table shows some electrode potential data.

Electrode reaction	***E*$^\ominus$ / V**
$2\,H^+(aq) + 2\,e^- \rightarrow H_2(g)$	0.00
$Cu^{2+}(aq) + 2\,e^- \rightarrow Cu(s)$	+0.34
$NO_3^-(aq) + 4\,H^+(aq) + 3\,e^- \rightarrow NO(g) + 2\,H_2O(l)$	+0.96

Use the data in the table to explain why copper does **not** react with most acids but does react with nitric acid.

Give an equation for the reaction between copper and nitric acid.

Explanation

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___

___

Equation

___

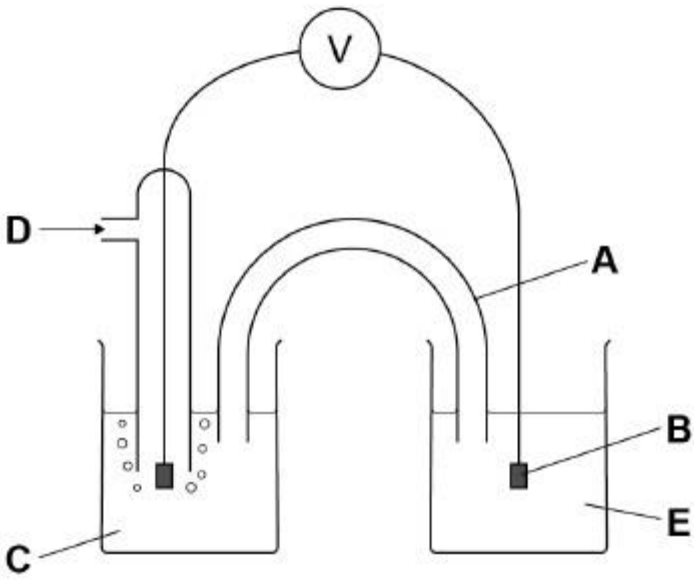
___

(3)

(Total 13 marks)

Q5.

The diagram represents the cell used to measure the standard electrode potential for the Fe^{3+}/Fe^{2+} electrode.



(a) Name the piece of apparatus labelled **A**.

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(1)

(b) State the purpose of **A**.

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____

(1)

(c) Name the substance used as electrode **B** in the diagram above.

____

(1)

(d) Complete **Table 1** to identify **C**, **D** and **E** from the diagram above. Include the essential conditions for each.

Table 1

	Identity	Conditions
C		
D		

E		

(4)

(e) The standard electrode potential, $E^\ominus$, for the Fe^{3+}/Fe^{2+} electrode is +0.77 V

Give the ionic equation for the overall reaction in the cell in the diagram above.

State the change that needs to be made to the apparatus in the diagram to allow the cell reaction to go to completion.

Ionic equation

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Change

____

____

(2)

(f) A student sets up a cell as shown in the cell representation.

$$Zn(s)|Zn^{2+}(aq)||Cu^{2+}(aq)|Cu(s)$$

The student measures the cell EMF, E_{cell}, with several different concentrations of Cu^{2+} ions and Zn^{2+} ions.

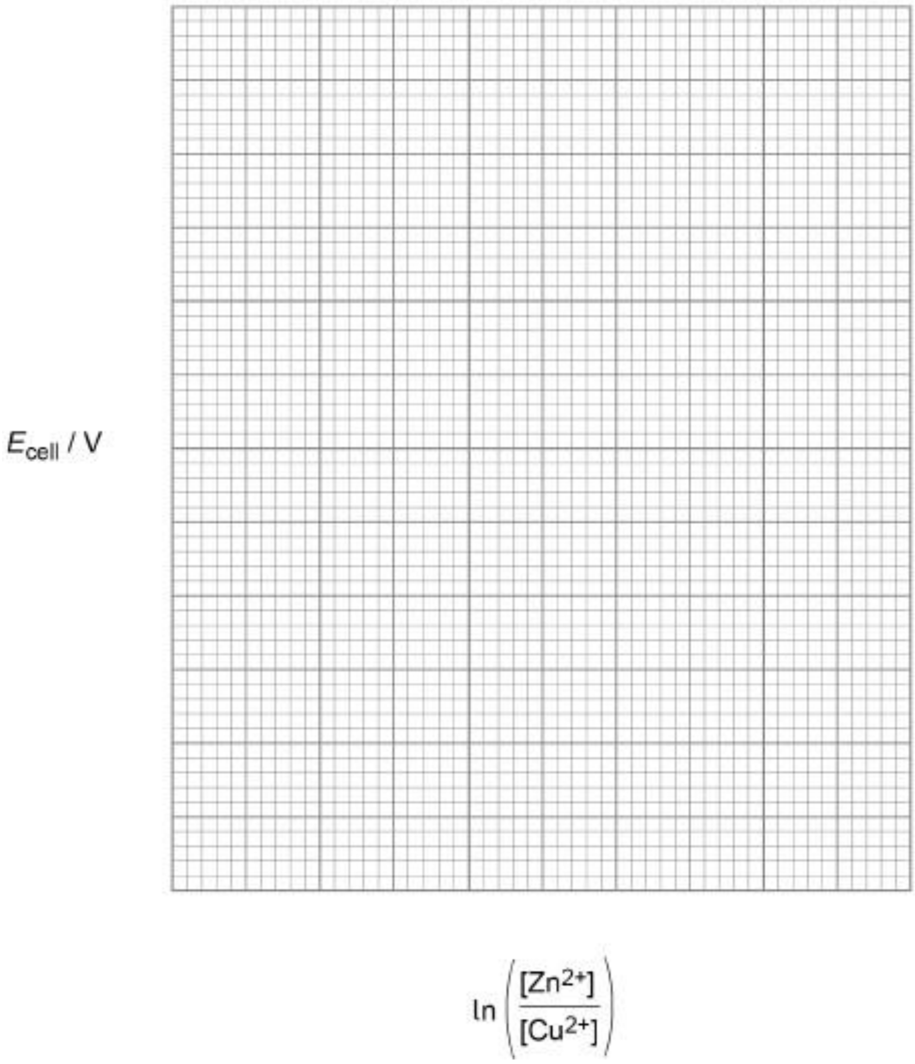
The results are shown in **Table 2**.

Table 2

Experiment	**$[Zn^{2+}]$ / mol dm^{-3}**	**$[Cu^{2+}]$ / mol dm^{-3}**	$\ln\left(\frac{[Zn^{2+}]}{[Cu^{2+}]}\right)$	**E_{cell} / V**
1	0.010	1.0	−4.61	1.16
2	0.10	1.0	−2.30	1.13
3	1.0	1.0	0.00	1.10
4	1.0	0.10		1.07
5	1.0	0.010	4.61	1.04

Complete **Table 2** to show the value missing from experiment **4**.

Plot a graph of E_{cell} against ln ($[Zn^{2+}]/[Cu^{2+}]$) on the grid.



(3)

(g) This equation shows how E_{cell} varies with concentration for this reaction.

$$E_{cell} = (-4.3 \times 10^{-5} \times T)\ \ln\left(\frac{[Zn^{2+}]}{[Cu^{2+}]}\right) + E^{\ominus}{}_{cell}$$

This equation is in the form of the equation for a straight line, y = mx + c

Calculate the gradient of your plotted line on the graph in part **(f)**.

You must show your working.

Use your gradient to calculate the temperature, T, at which the measurements of E_{cell} were taken.
(If you were unable to calculate a gradient you should use the value -0.016 V
This is **not** the correct value.)

Gradient ______________________________ V

T ______________________________ K

(3)

(h) In experiment **2** in **Table 2** the electrode potential of the Cu^{2+}/Cu electrode is +0.33 V

Use data from **Table 2** in part **(f)** to calculate the electrode potential for the Zn^{2+}/Zn electrode in experiment **2**.

Give one reason why your calculated value is different from the standard electrode potential for Zn^{2+}/Zn electrode.

Electrode potential ______________________________ V

Reason

____

____

____

(2)

(Total 17 marks)

Q6.

The $E^\ominus$ values for two electrodes are shown.

$$Fe^{2+}(aq) + 2\,e^- \rightarrow Fe(s) \quad E^\ominus = -0.44\ V$$

$$Cu^{2+}(aq) + 2\,e^- \rightarrow Cu(s) \quad E^\ominus = +0.34\ V$$

What is the EMF of the cell $Fe(s)|Fe^{2+}(aq)||Cu^{2+}(aq)|Cu(s)$?

A +0.78 V ○

B +0.10 V ○

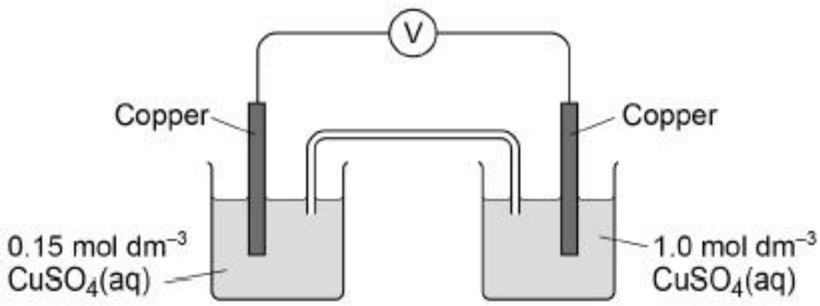
C −0.10 V ○

D −0.78 V ○

(Total 1 mark)

Q7.

A student set up the cell shown in the diagram.



The student recorded an initial voltage of +0.16 V at 25 °C

(a) Explain how the salt bridge provides an electrical connection between the two solutions.

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(1)

(b) The standard electrode potential for the Cu^{2+}/Cu electrode is

$$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s) \qquad E^\ominus = +\ 0.34\ V$$

Calculate the electrode potential of the left-hand electrode in the diagram.

Electrode potential ____________________ V

(1)

(c) Both electrodes contain a strip of copper metal in a solution of aqueous Cu^{2+} ions.

State why the left-hand electrode does **not** have an electrode potential of +0.34 V

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___

(1)

(d) Give the conventional representation for the cell in the diagram.
Include all state symbols.

___

(1)

(e) When the voltmeter is replaced by a bulb, the EMF of the cell in the diagram decreases over time to 0 V

Suggest how the concentration of copper(II) ions in the left-hand electrode changes when the bulb is alight.
Give **one** reason why the EMF of the cell decreases to 0 V

Change in concentration of copper(II) ions in the left-hand electrode

___

___

Reason why the EMF decreases to 0 V ___

___

___

___

(2)
(Total 6 marks)

Q8.

Which ion **cannot** catalyse the reaction between iodide (I^-) and peroxodisulfate ($S_2O_8^{2-}$)?

Use the data below to help you answer this question.

Half-equation	$E^\ominus$ **/ V**
$S_2O_8^{2-} + 2e^- \rightarrow 2SO_4^{2-}$	+2.01
$Co^{3+} + e^- \rightarrow Co^{2+}$	+1.82
$Fe^{3+} + e^- \rightarrow Fe^{2+}$	+0.77
$I_2 + 2e^- \rightarrow 2I^-$	+0.54
$Cr^{3+} + e^- \rightarrow Cr^{2+}$	–0.41

A Co^{2+} ☐

B Cr^{2+} ☐

C Fe^{2+} ☐

D Fe^{3+} ☐

(Total 1 mark)

Q9.

The table shows some standard electrode potential data.

Electrode half-equation	E^θ **/ V**
$Cl_2(g) + 2e^- \longrightarrow 2Cl^-(aq)$	+1.36
$Ag^+(aq) + e^- \longrightarrow Ag(s)$	+0.80
$Fe^{3+}(aq) + e^- \longrightarrow Fe^{2+}(aq)$	+0.77
$Sn^{2+}(aq) + 2e^- \longrightarrow Sn(s)$	−0.14
$Fe^{2+}(aq) + 2e^- \longrightarrow Fe(s)$	−0.44

(a) Use data from the table to deduce the species that is the best oxidising agent.

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(1)

(b) Write the conventional representation for the cell used to measure the standard electrode potential for the conversion of tin(II) ions to tin.

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(2)

(c) A cell was made by connecting two half-cells with a salt bridge. One half-cell consisted of silver in a solution of silver nitrate solution and the other consisted of tin in a solution of tin(II) nitrate solution.

Calculate the EMF of this cell and write a half-equation for the reaction that occurs at the negative electrode.

EMF ___

Half-equation

___

(2)

(d) Use data from the table above to write an equation for the reaction of silver(I) ions with iron(II) ions.

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(1)
(Total 6 marks)

Q10.

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)

Q11.

The following cell has an EMF of +0.46 V.

$$Cu \mid Cu^{2+} \parallel Ag^{+} \mid Ag$$

Which statement is correct about the operation of the cell?

A Metallic copper is oxidised by Ag^+ ions. ☐

B The silver electrode has a negative polarity. ☐

C The silver electrode gradually dissolves to form Ag^+ ions. ☐

D Electrons flow from the silver electrode to the copper electrode via an external circuit. ☐

(Total 1 mark)