Equilibria, Energetics and Elements
Electrode Potentials and Fuel Cells

59 marks

1. Use the standard electrode potentials in the table below to answer the questions that follow.

I	$Fe^{2+}(aq) + 2e^- \rightleftharpoons Fe(s)$	$E^\ominus = -0.44$ V
II	$V^{3+}(aq) + e^- \rightleftharpoons V^{2+}(aq)$	$E^\ominus = -0.26$ V
III	$2H^+(aq) + 2e^- \rightleftharpoons H_2(g)$	$E^\ominus = 0.00$ V
IV	$O_2(g) + 4H^+(aq) + 4e^- \rightleftharpoons 2H_2O(l)$	$E^\ominus = +0.40$ V

An electrochemical cell was set up based on systems **I** and **II**.

(i) Write half-equations to show what has been oxidised and what has been reduced in this cell.

oxidation:

reduction:

[2]

(ii) Determine the cell potential of this cell.

E_{cell} = ... V

[1]

[Total 3 marks]

2. Use the standard electrode potentials in the table below to answer the questions that follow.

I	$Fe^{2+}(aq) + 2e^- \rightleftharpoons Fe(s)$	$E^\ominus = -0.44$ V
II	$V^{3+}(aq) + e^- \rightleftharpoons V^{2+}(aq)$	$E^\ominus = -0.26$ V
III	$2H^+(aq) + 2e^- \rightleftharpoons H_2(g)$	$E^\ominus = 0.00$ V
IV	$O_2(g) + 4H^+(aq) + 4e^- \rightleftharpoons 2H_2O(l)$	$E^\ominus = +0.40$ V

An electrochemical fuel cell was set up based on systems **III** and **IV**.

(i) Construct an equation for the spontaneous cell reaction. Show your working.

[2]

(ii) Fuels cells based on systems such as **III** and **IV** are increasingly being used to generate energy.

Discuss **two** advantages and **two** disadvantages of using fuels cells for energy rather than using fossil fuels.

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[4]

[Total 6 marks]

3. The standard electrode potential of $Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$ is +0.34 V.

(a) Define the term *standard electrode potential*.

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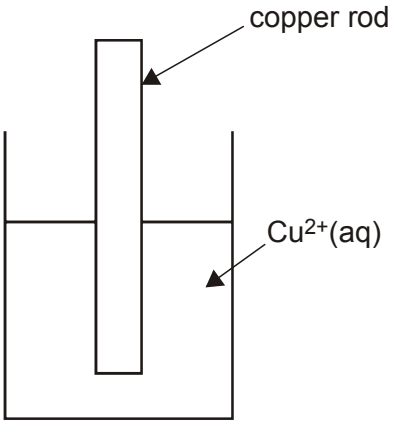
[3]

(b) Complete the diagram to show how the standard electrode potential of $Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$ could be measured.



[3]

[Total 6 marks]

4. Chromium is an important metallic element. Its compounds have a number of different oxidation states.

(a) (i) Give one use of chromium metal and state the property of chromium that makes it suitable for this use.

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[1]

(ii) Complete the electronic configuration of a chromium atom.

$1s^2 2s^2 2p^6$ .....

[1]

(b) The following equations relate to half-cells involving iron and chromium ions.

$$Fe^{3+} + e^- \rightleftharpoons Fe^{2+} \qquad E^\ominus = +0.77 \text{ V}$$

$$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightleftharpoons 2Cr^{3+} + 7H_2O \qquad E^\ominus = +1.33 \text{ V}$$

A cell was set up by combining these two half-cells.

(i) Derive a balanced equation for the reaction that would occur when the cell is in use.
Explain your reasoning in terms of oxidation and reduction.

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[3]

(ii) Determine the emf of the cell under standard conditions.

emf = ... V

[1]

[Total 6 marks]

5. The standard electrode potentials for some redox systems involving vanadium are shown below.
These are labelled **A**, **B**, **C** and **D**.

		$E^{\ominus}$/ V
A	$VO_2^+ + 2H^+ + e^- \rightleftharpoons VO^{2+} + H_2O$	+1.00
B	$V^{3+} + e^- \rightleftharpoons V^{2+}$	–0.26
C	$V^{2+} + 2e^- \rightleftharpoons V$	–1.20
D	$VO^{2+} + 2H^+ + e^- \rightleftharpoons V^{3+} + H_2O$	+0.34

(a) Which of the vanadium species shown in **A**, **B**, **C** and **D** is the most powerful oxidising agent?

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[1]

(b) A student wishes to set up a cell with a standard cell potential of 0.60V.

(i) Which two of the redox systems, **A**, **B**, **C** or **D**, should he choose?

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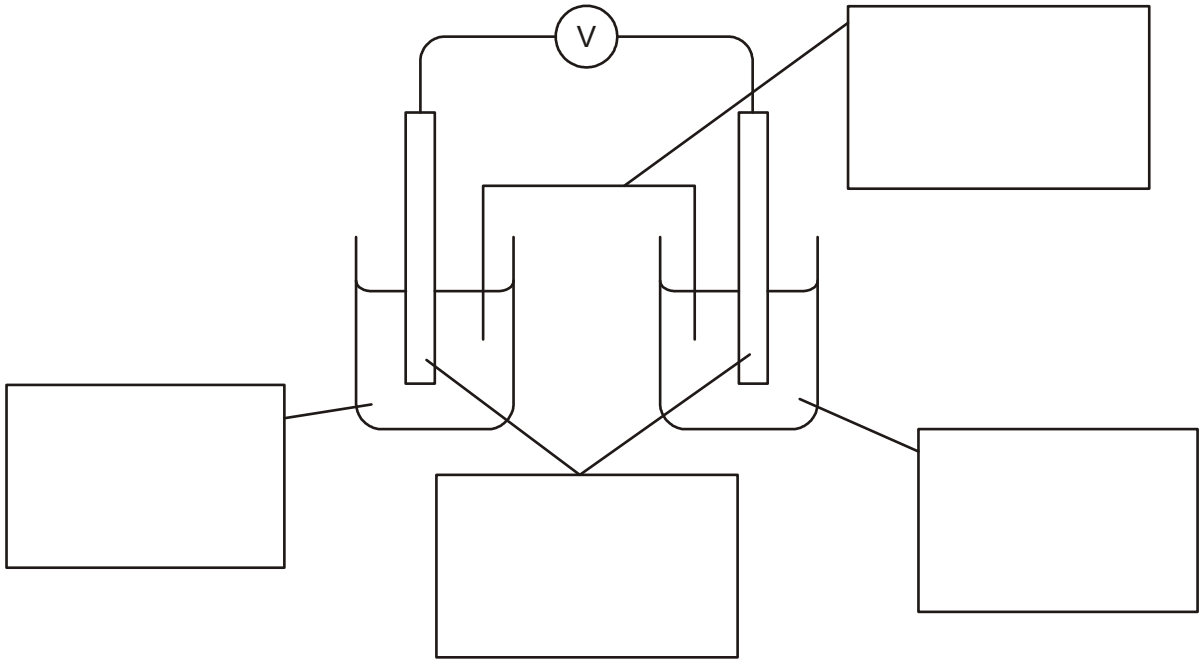
[1]

(ii) Complete the labelling of the following diagram which shows the cell with a standard cell potential of 0.60V.



[4]

(iii) The emf of this cell is only 0.60 V under standard conditions. What do you understand by the expression *standard conditions*?

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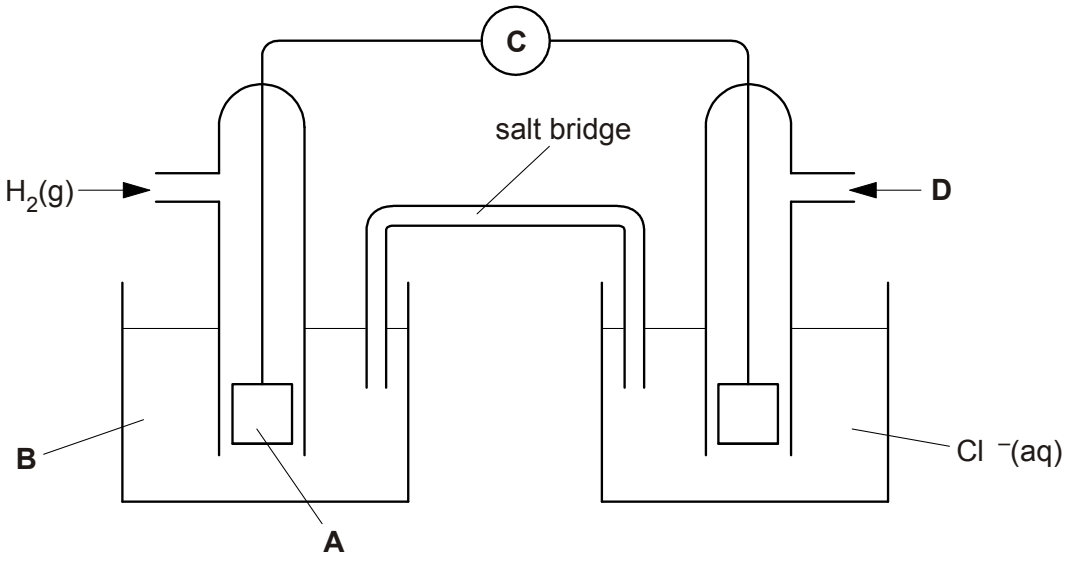
[1]

[Total 7 marks]

6. The standard electrode potential of the $\frac{1}{2}Cl_2/\ Cl^-$ half-cell may be measured using the following apparatus.



(a) Suggest suitable labels for **A**, **B**, **C** and **D**.

A .....

B .....

C .....

D .....

[2]

(b) The half cell reactions involved are shown below.

$$\frac{1}{2}Cl_2 + e^- \rightleftharpoons Cl^- \qquad E^\ominus = +1.36\ V$$

$$H^+ + e^- \rightleftharpoons \frac{1}{2}H_2 \qquad E^\ominus = 0.00V$$

(i) Use an arrow to show the direction of flow of electrons in the diagram of the apparatus. Explain your answer.

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[2]

(ii) The values of $E^{\ominus}$ are measured under standard conditions. What are the standard conditions?

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[2]

(c) The half cell reaction for $ClO_3^-/\frac{1}{2}Cl_2$ is shown below.

$$ClO_3^- + 6H^+ + 5e^- \rightleftharpoons \frac{1}{2}Cl_2 + 3H_2O \qquad E^{\ominus} = +1.47\ V$$

What does this tell you about the oxidising ability of ClO_3^- compared with Cl_2?

Explain your answer.

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[2]

[Total 8 marks]

7. Some standard electrode potentials are shown below.

	$E^{\ominus}$/V
$Ag^+ + e^- \rightleftharpoons Ag$	+ 0.80
$\frac{1}{2}Cl_2 + e^- \rightleftharpoons Cl^-$	+ 1.36
$Cu^{2+} + 2e^- \rightleftharpoons Cu$	+ 0.34
$Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$	+ 0.77
$\frac{1}{2}I_2 + e^- \rightleftharpoons I^-$	+ 0.54

(a) Define the term *standard electrode potential*.

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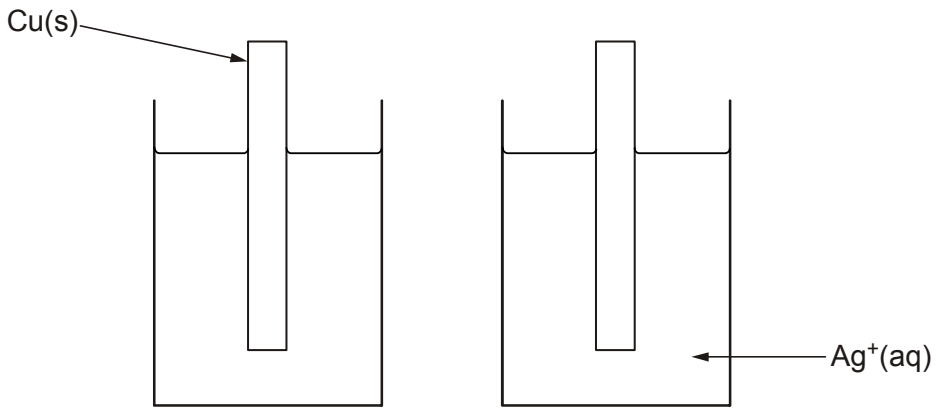
[3]

(b) The diagram below shows an incomplete cell consisting of Cu/Cu^{2+} and Ag/Ag^{+} half-cells.



(i) Complete and label the diagram to show how the cell potential of this cell could be measured.

[2]

(ii) On the diagram, show the direction of **electron** flow in the circuit if a current was allowed.

[1]

(iii) Calculate the standard cell potential.

standard cell potential = ……V

[1]

(iv) Write the overall cell reaction.

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[1]

(c) Chlorine will oxidise Fe^{2+} to Fe^{3+} but iodine will not. Explain why, using the electrode potential data.

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[2]

[Total 10 marks]

8. NO_2 reacts with oxygen and water to form nitric acid, HNO_3. In the atmosphere, this contributes to acid rain. Construct a balanced equation for this formation of nitric acid and use oxidation numbers to show that this is a redox reaction.

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[Total 2 marks]

9. Chlorine gas may be prepared in the laboratory by reacting hydrochloric acid with potassium manganate(VII). The following standard electrode potentials relate to this reaction.

$$\frac{1}{2}Cl_2 + e^- \rightleftharpoons Cl^- \qquad E^\ominus = +1.36\ V$$

$$MnO_4^- + 8H^+ + 5e^- \rightleftharpoons Mn^{2+} + 4H_2O \qquad E^\ominus = +1.52\ V$$

(a) Define the term *standard electrode potential*.

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[3]

(b) Determine the standard cell potential for a cell constructed from these two redox systems.

[1]

[Total 4 marks]

10. Chlorine gas may be prepared in the laboratory by reacting hydrochloric acid with potassium manganate(VII). The following standard electrode potentials relate to this reaction.

$$\frac{1}{2}Cl_2 + e^- \rightleftharpoons Cl^- \qquad E^\ominus = +1.36\ V$$

$$MnO_4^- + 8H^+ + 5e^- \rightleftharpoons Mn^{2+} + 4H_2O \qquad E^\ominus = +1.52\ V$$

(a) Use the half-equations above to:

(i) construct an ionic equation for the reaction between hydrochloric acid and potassium manganate(VII);

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[2]

(ii) determine the oxidation numbers of chlorine and manganese before and after the reaction has taken place;

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[2]

(iii) state what is oxidised and what is reduced in this reaction.

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[2]

(b) If potassium manganate(VII) and very dilute hydrochloric acid are mixed, there is no visible reaction. Suggest why there is no visible reaction in this case.

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[1]

Total 7 marks]