Q1.

This question is about vanadium ions.

The table below shows some standard electrode potential values.

	***E*°/ V**
$O_2(g) + 4 H^+(aq) + 4 e^- \rightarrow 2 H_2O(l)$	+1.23
$VO_2^+(aq) + 2 H^+(aq) + e^- \rightarrow VO^{2+}(aq) + H_2O(l)$	+1.00
$VO^{2+}(aq) + 2 H^+(aq) + e^- \rightarrow V^{3+}(aq) + H_2O(l)$	+0.34
$V^{3+}(aq) + e^- \rightarrow V^{2+}(aq)$	–0.26
$Fe^{2+}(aq) + 2 e^- \rightarrow Fe(s)$	–0.44
$Zn^{2+}(aq) + 2 e^- \rightarrow Zn(s)$	–0.76
$V^{2+}(aq) + 2 e^- \rightarrow V(s)$	–1.20
$Mg^{2+}(aq) + 2 e^- \rightarrow Mg(s)$	–2.38

(a) Use the data in the table above to explain why Zn reduces an aqueous solution of VO_2^+ ions to V^{2+} ions, but does not reduce it any further.

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(2)

(b) Identify the species in the table above that can reduce an aqueous solution of VO_2^+ to V

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(1)

(c) Two half-cells Fe^{2+}(aq) / Fe(s) and VO^{2+}(aq) / V^{3+}(aq) are connected.

Calculate the EMF of this cell.

Give the conventional representation for this cell.

Give a half-equation for the reaction that occurs at the negative electrode.

EMF ___________

Cell representation

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Half-equation

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(3)

(d) 0.151 g of impure NH_4VO_3 is added to dilute sulfuric acid to form a solution containing aqueous VO_2^+ ions.

All the VO_3^- ions are converted to VO_2^+ ions.

These VO_2^+ ions are reduced to aqueous V^{2+} ions by reaction with an excess of zinc.

$$2\ VO_2^+(aq) + 8\ H^+(aq) + 3\ Zn(s) \rightarrow 3\ Zn^{2+}(aq) + 2\ V^{2+}(aq) + 4\ H_2O(l)$$

The excess of zinc is removed by filtration and washed.

The filtrate, containing the V^{2+} ions, is titrated with a 0.0200 mol dm^{-3} solution of acidified $KMnO_4$

29.43 cm^3 of $KMnO_4$ solution are needed to oxidise all the V^{2+} ions to VO_2^+ ions.

The ionic equation for the reaction of MnO_4^- ions with V^{2+} ions is

$$3\ MnO_4^-(aq) + 5\ V^{2+}(aq) + 4\ H^+(aq) \rightarrow 2\ H_2O(l) + 3\ Mn^{2+}(aq) + 5\ VO_2^+(aq)$$

Calculate the percentage purity of the NH_4VO_3
Give your answer to 3 significant figures.

Percentage purity ____________________

(4)

(Total 10 marks)

Q2.

This question is about metals and their compounds.

(a) State why the atomic radius of calcium is greater than the atomic radius of magnesium.

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(1)

(b) Magnesium reacts with steam.

Give an equation, including state symbols, for this reaction.

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(1)

(c) Similar-sized pieces of barium and magnesium are added to separate 100 cm^3 samples of dilute sulfuric acid. In each case the sulfuric acid is in excess.

The barium reacts quickly at first. After a few minutes the reaction stops, even though there is still some unreacted barium in the flask.

The magnesium reacts more slowly than the barium, but the reaction continues until all the magnesium has reacted.

Explain why

- the barium initially reacts more quickly than the magnesium
- the barium reaction stops before all the barium has reacted.

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(3)

(d) A metal nitrate **X**$(NO_3)_2$ completely decomposes when heated.

$$2\,\mathbf{X}(NO_3)_2(s) \rightarrow 2\,\mathbf{X}O(s) + 4\,NO_2(g) + O_2(g)$$

A 0.832 g sample of **X**$(NO_3)_2$ decomposes on heating to produce a total of 348 cm^3 of gas at 298 K and 100 kPa

Deduce the identity of metal **X**.

The ideal gas constant, $R = 8.31\ J\ K^{-1}\ mol^{-1}$

Identity of metal **X** ______________________

(6)

(e) Sodium reacts with aluminium and hydrogen to form solid $NaAlH_4$

Give an equation for this reaction.

Suggest why $NaAlH_4$ has a high melting point.

Equation

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Suggestion ____

____

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____

(3)

(f) Give the equation for the reaction between H_3PO_4 and an excess of NaOH

____

(1)

Lithium is an important metal used in cells to power mobile phones.

(g) In a lithium cell, a lithium cobalt oxide electrode and a lithium electrode are used.

Give the equation for the reaction that occurs at the positive electrode.

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(1)

(h) Commercial electrochemical cells can be rechargeable or non-rechargeable.

State why lithium cells can be recharged.

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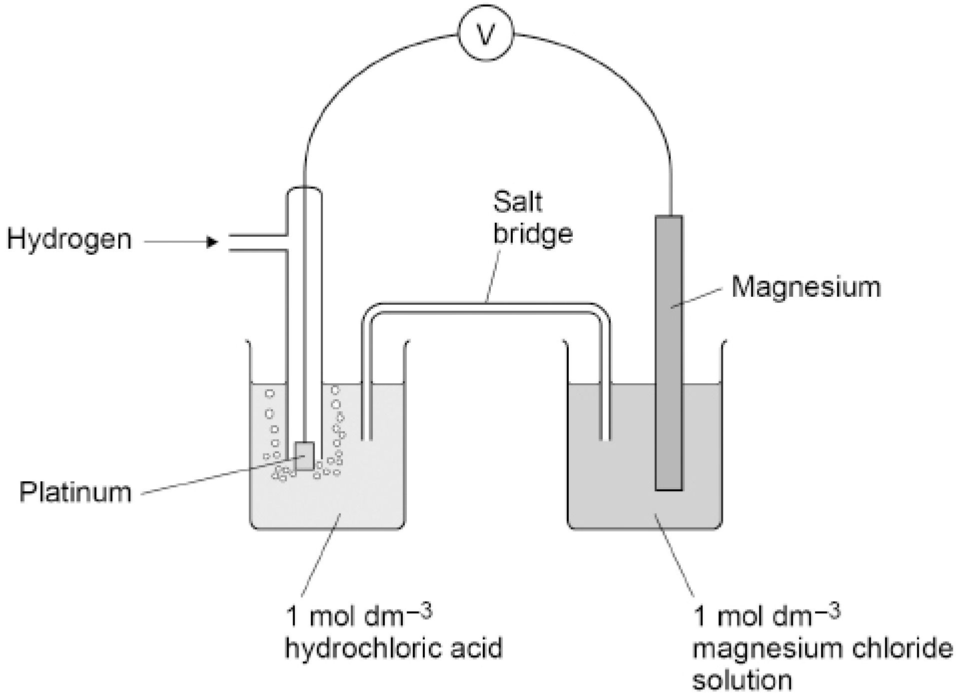
(1)
(Total 17 marks)

Q3.

The figure below shows a cell used to measure the standard electrode potential for the half-cell

$$Mg^{2+}(aq) + 2\ e^{-} \rightarrow Mg(s)$$



(a) State the purpose of the salt bridge.

Identify an ionic compound that could be used in the salt bridge.

Purpose ____

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Identity ____

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(2)

(b) State how, if at all, the EMF of this cell will change if the surface area of the platinum electrode is increased.

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(1)

The standard electrode potential, E° for the half-cell is shown.

$$Mg^{2+}(aq) + 2\ e^- \rightarrow Mg(s) \qquad E^\circ = -2.38\ V$$

(c) Water is added to the beaker containing the magnesium chloride solution.

What is the effect on the magnitude of the EMF of the cell?

Tick ✓ **one** box.

EMF increases ☐

EMF stays the same ☐

EMF decreases ☐

(1)

(d) The voltmeter **V** shown in the diagram above is replaced by a bulb.

Give an equation for the overall reaction that occurs when the cell is operating.

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(1)

(Total 5 marks)

Q4.

This question is about fuel cells.

In a methanol–oxygen fuel cell, the overall reaction is

$$CH_3OH(l) + 1\tfrac{1}{2}\ O_2(g) \text{ " } CO_2(g) + 2\ H_2O(l) \qquad \text{EMF} = +1.20\ \text{V}$$

(a) At the positive electrode, oxygen reacts with hydrogen ions to form water.

Give a half-equation for this reaction.

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(1)

(b) At the negative electrode, methanol reacts with water to produce carbon dioxide and hydrogen ions.

Give a half-equation for this reaction.

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(1)

(c) The standard electrode potential for the CO_2 / CH_3OH electrode is +0.03 V

Calculate the standard electrode potential for the O_2 / H_2O electrode.

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(1)

(d) State why a fuel cell does **not** need to be electrically recharged.

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(1)

(e) Suggest **one** advantage of using methanol, rather than hydrogen, in a fuel cell for use in cars.

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(1)

(Total 5 marks)

Q5.

This question is about cells.

(a) The half-equations for two electrodes that combine to make a non-rechargeable cell are

$Zn^{2+}(aq) + 2e^{-} \rightarrow Zn(s)$ $E^{\circ} = -0.76$ V

$2\ MnO_2(s) + 2\ NH_4^{+}(aq) + 2e^{-} \rightarrow Mn_2O_3\ (s) + 2\ NH_3(aq) + H_2O(l)$ $E^{\circ} = +0.52$ V

Identify the oxidising agent in this cell.

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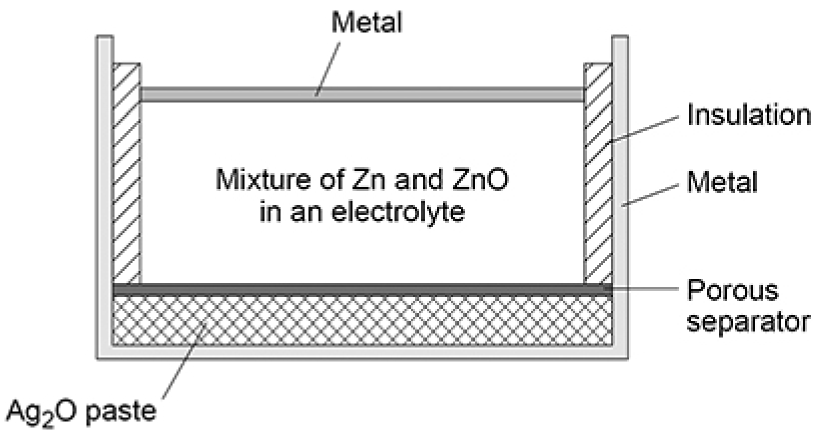
(1)

The diagram below shows a cross-section through a rechargeable silver–zinc cell.



(b) Suggest the function of the porous separator in above diagram.

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(1)

(c) The standard electrode potentials for two half-equations for the silver–zinc cell are

$Ag_2O(s) + H_2O(l) + 2e^{-} \rightarrow 2\ Ag(s) + 2\ OH^{-}(aq)$ $E^{\circ} = +0.34$ V

$ZnO(s) + H_2O(l) + 2e^{-} \rightarrow Zn(s) + 2\ OH^{-}(aq)$ $E^{\circ} = -1.26$ V

Give an equation for the overall reaction that occurs when the cell is recharging.

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(1)

The EMF of an alkaline hydrogen–oxygen fuel cell is +1.23 V
The standard electrode potential for one of the electrodes in the alkaline hydrogen–oxygen fuel cell is

$$2\ H_2O(l) + 2e^- \rightarrow 2\ OH^-(aq) + H_2(g) \qquad E^\circ = -0.83\ V$$

(d) Give the half-equation for the other electrode and calculate its standard electrode potential.

Equation

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E^θ ____

(2)

(e) Suggest why the EMF values of the acidic and alkaline hydrogen–oxygen fuel cells are the same.

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(1)

(Total 6 marks)