Q16.

(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.

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

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

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
$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$	+1.33
$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$	+0.77
$2H^+(aq) + 2e^- \rightarrow H_2(g)$	0.00
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	–0.44
$Li^+(aq) + e^- \rightarrow Li(s)$	–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

$$Li(s) \mid Li^+(aq) \parallel Li^+(aq) \mid MnO_2(s) , LiMnO_2(s) \mid Pt(s)$$

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)

(d) A solution of iron(II) sulfate was prepared by dissolving 10.00 g of $FeSO_4.7H_2O$ (M_r = 277.9) in water and making up to 250 cm^3 of solution. The solution was left to stand, exposed to air, and some of the iron(II) ions became oxidised to iron(III) ions. A 25.0 cm^3 sample of the partially oxidised solution required 23.70 cm^3 of 0.0100 mol dm^{-3} potassium dichromate(VI) solution for complete reaction in the presence of an excess of dilute sulfuric acid.

Calculate the percentage of iron(II) ions that had been oxidised by the air.

(6)

(Total 14 marks)

Q18.

Nickel–cadmium cells are used to power electrical equipment such as drills and shavers. The electrode reactions are shown below.

$$NiO(OH) + H_2O + e^- \rightarrow Ni(OH)_2 + OH^- \qquad E^o = +0.52\ V$$

$$Cd(OH)_2 + 2e^- \rightarrow Cd + 2OH^- \qquad E^o = -0.88\ V$$

(a) Calculate the e.m.f. of a nickel–cadmium cell.

(1)

(b) Deduce an overall equation for the reaction that occurs in the cell when it is used.

(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	$E^{\ominus}$ /V
$O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$	+1.23
$O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$	+0.40
$2H^+(aq) + 2e^- \rightarrow H_2(g)$	0.00
$2H_2O(l) + 2e^- \rightarrow 2OH^-(aq) + H_2(g)$	– 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 re-chargeable 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
$Ce^{4+}(aq) + e^-$	⇌	$Ce^{3+}(aq)$	+1.70
$MnO^-(aq) + 8H^+(aq) + 5e^-$	⇌	$Mn^{2+}(aq) + 4H_2O(l)$	+1.51
$Cl_2(g) + 2e^-$	⇌	$2Cl^-(aq)$	+1.36
$VO_2^+(aq) + 2H^+(aq) + e^-$	⇌	$VO^{2+}(aq) + H_2O(l)$	+1.00
$Fe^{3+}(aq) + e^-$	⇌	$Fe^{2+}(aq)$	+0.77
$SO_4^{2-}(aq) + 4H^+(aq) + 2e^-$	⇌	$H_2SO_3(aq) + H_2O(l)$	+0.17

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

_____

(1)

(b) When the standard electrode potential for $Fe^{3+}(aq)$ / $Fe^{2+}(aq)$ 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 $Fe^{3+}(aq)/Fe^{2+}(aq)$ when measuring this potential?

_____

_____

_____

(3)

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

$$Pt|H_2SO_3(aq), SO_4^{2-}(aq)||MnO_4^-(aq), Mn^{2+}(aq)|Pt$$

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 $Fe^{2+}(aq)$ into $Fe^{3+}(aq)$ but could not convert $Mn^{2+}(aq)$ into $MnO_4^-(aq)$?

_____

(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) $Li \rightarrow Li^+ + e^-$

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) $Pt \mid SO_3^{2-}(aq), SO_4^{2-}(aq) \mid\mid ClO_3^-(aq), Cl^-(aq) \mid Pt$

State symbols an ',' not necessary

Allow | in place of ',' NOT ',' in place of |

Ignore H^+ and H_2O

Deduct one mark for each mistake (e.g. Pt missed twice counts as two mistakes)

Allow reverse order for whole cell

Pt | Cl^-, ClO_3^- || SO_4^{2-}, SO_3^{2-} | Pt

2

(ii) $ClO_3^- + 3SO_3^{2-} \rightarrow Cl^- + 3SO_4^{2-}$

1

Oxidising agent ClO_3^-

1

Reducing agent SO_3^{2-}

1

[12]

Q17.

(a) Hydrogen/H_2 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) $Li^+ + MnO_2 + e^- \rightarrow LiMnO_2$

Ignore state symbols

1

–0.13(V)

1

(c) Fe^{3+} ions reduced to Fe^{2+}

Can score from equation/scheme

1

Because $E(Fe^{3+}/Fe^{2+}) > E(H^+/H_2)/E$(hydrogen)

Allow emf/E_{cell} +ve/0.77V
Allow Fe^{3+} better oxidising agent than H^+
Allow H_2 better reducing agent than Fe^{2+}
Only award this explanation mark if previous mark given

1

(d) Moles $Cr_2O_7^{2-}$ = $\underline{23.7 \times 0.01/1000}$ = 2.37×10^{-4}

1

1 mol $Cr_2O_7^{2-}$ reacts with 6 mol Fe^{2+} so moles Fe^{2+} in 25 cm^3 = $6 \times 2.37 \times 10^{-4} = 1.422 \times 10^{-3}$

1

M1 × 6

Moles Fe^{2+} in 250 cm^3 = 1.422×10^{-2}

M2 × 10 or M4/10

1

Original moles Fe^{2+} = $\underline{10.00/277.9}$ = 0.0360

Independent mark

1

Moles Fe^{2+} oxidised = 0.0360 – 0.0142 = 0.0218

M4 – M3

1

% oxidised = (0.0218 × 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) $2NiO(OH) + 2H_2O + Cd \rightarrow 2Ni(OH)_2 + Cd(OH)_2$

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) $Pt|H_2(g)|OH^-(aq),H_2O(l)||O_2(g)|H_2O(l),OH^-(aq)|Pt$

H_2O not essential, allow reverse order

Correct but with Pt missing

1

Includes Pt with correct representation

1

(d) Uses $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$

And (2×) $2OH^- + H_2 \rightarrow 2H_2O + 2e^-$

1

$2H_2 + O_2 \rightarrow 2H_2O$

1

(e) Increases the surface area (so reaction faster)

1

(f) Overall reaction is the same ($2H_2 + O_2 \rightarrow 2H_2O$)

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 F^{3+} (aq) and Fe^{2+} (aq) have a concentration of 1 mol dm^{-3} **(1)** (QoL)
OR $[H^+]$ = 1 mol dm^{-3}

NOT zero current or 100 kPa

3

(c) +1.34 V **(1)**
$2\ MnO_4^- + 5\ H_2SO_3 \rightarrow 2\ Mn^{2+} + 5\ SO_4^{2-} + 3\ H_2O + 4\ H^+$
Correct species / order **(1)**
Balanced and cancelled **(1)**

Allow one for $2\ MnO_4^- + 5\ H_2SO_3 \rightarrow 2\ Mn^{2+} + 5\ SO_4^{2-}$

3

(d) (i) Ce^{4+} (aq) **(1)**

(ii) VO_2^+ (aq) **(1)**; Cl_2 **(1)**

Penalise additional answers to zero

3

(e) Pt | Fe^{2+} (aq), Fe^{3+} (aq) || Ce^{4+}(aq), Ce^{3+} (aq) | Pt
Correct species **(1)**
Correct order **(1)**

Deduct one mark for each error

2

[12]