**1**

(a) Manganate would oxidise / react with $\underline{Cl}^-$

1

Because $E^\ominus$ for $MnO_4^-$ is more positive than that for $Cl^2$ / 1.51 – 1.36 = +0.15 (V)

*Must refer to data from the table for M2.*

1

(b) Moles of $H^+$ = 25 × 0.0200 × 8 / 1000 = 4.00 × $10^{-3}$

1

Moles of $H_2SO_4$ = 2.00 × $10^{-3}$ (4.00 × $10^{-3}$ / 2)

*Allow consequential marking on incorrect moles of $H^+$*

1

Volume $H_2SO_4$ = 4.00 ($cm^3$) (2.00 × $10^{-3}$ × 1000 / 0.500)

*Allow consequential marking on incorrect moles of $H_2SO_4$*

*Accept 4 $cm^3$.*

*8 $cm^3$ scores 2 marks.*

*Do not penalise precision.*

*Correct answer without working scores M3 only.*

1

(c) (i) $MnO_4^- + 4H^+ + 3e^- \rightarrow MnO_2 + 2H_2O$

*Allow multiples, including fractions.*

*Ignore state symbols.*

1

(ii) Can't see end point due to brown colour

1

$\underline{\text{Larger}}$ titre (than expected)

*Allow the idea that with two reactions can't make use of titre in calculations.*

*Do not allow 'an inaccurate result' without qualification.*

1

(d) Solution (very) dilute / lots of water

1

**[9]**

**2**

(a) HCl 1.0 mol $dm^{-3}$

*Allow $H_2SO_4$ 0.5 mol $dm^{-3}$*

*Allow $HNO_3$ 1.0 mol $dm^{-3}$*

*Allow name or formula*

*Concentration can be given after "conditions"*

1

(Hydrogen at) 100kPa / 1 bar

1

298 K

**1**

(b) Pt / Platinum

*Mark on if no answer for M1*

*If wrong answer for M1, only mark on if electrode is Au, Ag, Pb or Ti*

**1**

Inert / unreactive / does not create a potential difference

**1**

Conducts electricity / allows electron flow / conducts / conductor

**1**

(c) KCl

*Allow NaCl, $KNO_3$, $Na_2SO_4$ etc NOT $NH_4Cl$*

**1**

Does not react with either electrode / solution in electrode

*Allow unreactive / inert*

**1**

Ions can move

*Allow conducts electricity / electrical connection / carries charge*

*Do not allow just connects / completes the circuit*

*Do not allow conducts / carries electrons*

*Mark these independently*

**1**

(d) $Pt|H_2|H^+||Fe^{3+},Fe^{2+}|Pt$

*Ignore state symbols*

*Order must be correct*

*| must be correct but allow | instead of , separating $Fe^{3+}$ from $Fe^{2+}$*

*Allow , instead of | separating $H_2$ and $H^+$*

**1**

(e) (i) $2Fe^{3+} + H_2 \rightarrow 2Fe^{2+} + 2H^+$

*Allow multiples*

**1**

(ii) The $\underline{Fe}^{3+}$ ions would be used up / reaction completed

*Answer must relate to reactants in (e)(i) equation if given*

*Allow reactant / reactants used up*

*Do not allow concentration of $Fe^{3+}$ decreases*

*Allow concentration of $Fe^{3+}$ falls to zero*

**1**

**[12]**

**3**

(a) $H_2O_2$

*Ignore state symbols*

**1**

(b) $E^{\ominus}$ $Cl_2/Cl^-$ > $E^{\ominus}$ $O_2/H_2O$

*Allow potential for chlorine/$Cl_2$ greater than for oxygen/$O_2$*

*Allow 1.36 > 1.23 / E cell = 0.13*

**1**

$Cl_2 + H_2O \longrightarrow 2Cl^- + 1/2O_2 + 2H^+$

*Allow multiples*

*Allow + HCl*

**1**

(c) Activation energy is high / light/UV provides the activation energy / light breaks chlorine molecule / Cl–Cl bond

*If light used to break Cl–Cl bond award 1 mark and ignore product e.g. $Cl^-$*

**1**

(d) <u>O (–1)</u> (in $H_2O_2$ )

*Must give oxidation state of O in $H_2O_2$= –1*

**1**

Changes to <u>O(–2)</u> (in water)

*Must give oxidation state of O in water = –2*

*CE = 0/2 if refers to oxidation state of H changing*

**1**

(e) $E^{\ominus}$ $H_2O_2/H_2O$ > $E^{\ominus}$ $O_2/H_2O_2$

*Allow stated in words*

*Allow 1.77 > 0.68 / E cell = 1.09*

**1**

$2H_2O_2 \longrightarrow O_2 + 2H_2O$

*Allow multiples*

*$H^+$ and $e^-$ must be cancelled*

**1**

**[8]**

**4**

(a) loses electrons / donates electrons

*penalise donates electron pair*

**1**

(b) Zn

**1**

(most) negative $E^o$ / lowest $E^o$ / least positive

*can only score M2 if M1 correct*

*do not allow e.m.f instead of $E^o$*

**1**

(c) $\underline{E^o\ F_2}$ ($/F^-$) > $\underline{E^o\ O_2}$ ($/H_2O$)

*or e.m.f is positive or e.m.f = 1.64 V*

**1**

Fluorine reacts to form oxygen (can score from equation in M3 even if equation unbalanced provided no contradiction)
or fluorine oxidises water
or fluorine is a more powerful oxidising agent than oxygen

**1**

$2F_2 + 2H_2O \rightarrow 4F^- + 4H^+ + O_2$

*allow 4HF in equation*

*balanced equation scores M2 and M3*

**1**

(d) (i) order correct Zn $Zn^{2+}$ $Ag_2O$ Ag or reverse of this order

*ignore ss , $H^+$ and $H_2O$, no. of moles*

**1**

all phase boundaries correct

*allow $Zn|Zn^{2+}||Ag_2O,Ag$*

*or $Zn|Zn^{2+}||Ag_2O|H^+|Ag$ for M1 & M2*

e.g. $Zn|Zn^{2+}||Ag_2O|Ag$ or $Ag|Ag_2O||Zn^{2+}|Zn$ scores 2

*M2 cannot be gained unless M1 scored*

*allow $H^+$ either side of $Ag_2O$ with comma or |*

*for M2 penalise*

- *wrong phase boundary (allow dashed lines for salt bridge)*
- *Pt*
- *use of + (from half equation)*
- *water/$H^+$ outside Ag in Ag electrode*

**1**

(ii) 1.1 (V)

*Allow no units, penalise wrong units*

*allow correct answer even if no answer to (d)(i) or answer to (d)(i) incorrect*

*allow –1.1 if silver electrode on Left in (d)(i) even if the species are in the wrong order.*

**1**

(iii) Reaction(s) not reversible or $H_2O$ electrolyses

*do not allow hard to reverse*

*mention of primary cell is not enough to show that reaction(s) are irreversible*

**1**

(e) (i) –0.46 (V)

*Allow no units, penalise wrong units*

**1**

(ii) $2PbSO_4 + 2H_2O \rightarrow Pb + PbO_2 + 2HSO_4^- + 2H^+$

lead species correct on correct sides of equation

**1**

equation balanced and includes $H_2O$,

$HSO_4^-$ and H+ (or $H_2SO_4$)

*allow ions / species must be fully cancelled out or combined*

*allow 1/2 for balanced reverse equation*

**1**

(f) (i) reagents / $PbO_2$ / $H_2SO_4$ /acid / ions used up
(or concentration decreases)

**1**

(ii) fuel cell

*Ignore any other words*

**1**

(iii) reagents / fuel supplied continuously

**1**

concentrations (of reagents) remain constant

**1**

**[17]**

**5** $MnO_4^-$ will oxidise the chloride ion / reaction of $MnO_4^-$ and $Cl^-$ feasible

*Accept converse argument with $Cr_2O_7^{2-}$*

*Accept calculations of overall E° values.*

**1**

Larger volume needed

1

**[2]**

**6** (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*

*$Pt \mid Cl^-, ClO_3^- \mid\mid SO_4^{2-}, SO_3^{2-} \mid Pt$*

**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]**

**7** (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 $Cr_2O_7^{2-}$ = $\underline{23.7 \times 0.01/1000}$ = $2.37 \times 10^{-4}$

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 $cm^3$ = $1.422 \times 10^{-2}$

*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]**

**8**

(a) $3C_2O_4^{2-} + [Co(H_2O)_6]^{2+} \rightarrow [Co(C_2O_4)_3]^{4-} + 6H_2O$

*Accept multiples.*
*Equation must have cobalt(II) hexaaqua ion.*

1

(b) Ethanedioate ion reduces iron(III) ion **or**
iron(III) ion oxidises ethanedioate ion

*Allow answer using equations.*

1

$E^{\ominus}$ ($CO_2$ / $C_2O_4^{2-}$) more negative than $E^{\ominus}$ ($Fe^{3+}$ / $Fe^{2+}$) **or**
$E^{\ominus}$ ($Fe^{3+}$ / $Fe^{2+}$) > $E^{\ominus}$ ($CO_2$ / $C_2O_4^{2-}$)
**or** e.m.f. positive **or** cell voltage = +1.26

1

**[3]**