M1.(a)   Manganate would oxidise / react with <u>Cl⁻</u>

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 (cm³) (2.00 × 10⁻³ × 1000 / 0.500)

Allow consequential marking on incorrect moles of H_2SO_4
Accept 4 cm³.
8 cm³ 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

<u>Larger</u> 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]

M2. MnO_4^- will oxidise the <u>chloride</u> 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]

M3.   (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)   <u>Li</u> reacts with <u>water</u>/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]

M4.(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$_2$SO$_4$ etc NOT NH$_4$Cl

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$_2$ $\longrightarrow$ 2Fe^{2+} + 2H$^+$
Allow multiples

1

(ii)   The 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]

M5.(a)   loses electrons / donates electrons
*penalise donates electron pair*

1

(b)   Zn

1

(most) negative E° / lowest E° / least positive
can only score M2 if M1 correct
do not allow e.m.f instead of E°

1

(c) $\underline{E^\circ}$ F$_2$ (/F$^-$) > $\underline{E^\circ}$ O$_2$ (/H$_2$O)
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
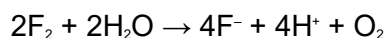
$$2F_2 + 2H_2O \rightarrow 4F^- + 4H^+ + O_2$$
> *allow 4HF in equation*
> *balanced equation scores M2 and M3*

(d) (i) order correct Zn Zn^{2+} Ag$_2$O Ag or reverse of this order
> *ignore ss , H$^+$ and H$_2$O, no. of moles*

all phase boundaries correct
> *allow Zn|Zn^{2+}||Ag$_2$O,Ag*
> *or Zn|Zn^{2+}||Ag$_2$O|H$^+$|Ag for M1 & M2*

e.g. Zn|Zn^{2+}||Ag$_2$O|Ag or Ag|Ag$_2$O||Zn^{2+}|Zn scores 2
> *M2 cannot be gained unless M1 scored*
> *allow H$^+$ either side of Ag$_2$O 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*

(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.*

(iii) <u>Reaction(s)</u> not reversible or H$_2$O electrolyses
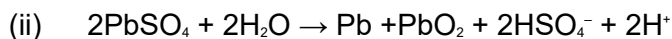> *do not allow hard to reverse*
> *mention of primary cell is not enough to show that reaction(s) are irreversible*

(e) (i) −0.46 (V)
> *Allow no units, penalise wrong units*

(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]

M6.(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*
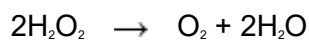> *CE = 0/2 if refers to oxidation state of H changing*

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]