M1.(a) The ions in the ionic substance in the salt bridge move through the salt bridge

1

To maintain charge balance / complete the circuit

1

(b) F^-

1

(c) $E^\ominus$ SO_4^{2-} / SO_2 $E^\ominus$ Br_2 / Br^-

Allow correct answer expressed in words, eg electrode potential for sulfate ions / sulfur dioxide is less than that for bromine / bromide

1

(d) 1.23 (V)

1

(e) A fuel cell converts more of the available energy from combustion of hydrogen into kinetic energy of the car / an internal combustion engine wastes more (heat) energy

1

[6]

M2.(a) To remove the <u>oxide</u> layer on the aluminium

Do not allow 'cleaning' or 'removal of grease'.

Do not allow 'removal of impurities' without qualification.

1

(b) An appropriate method for delivering H_2 gas over a Pt electrode

Need H_2 gas and Pt electrode labelled (allow gas delivered directly below the electrode).

1

The Pt electrode must clearly be in contact with a solution of a named acid.

Ignore any concentration or pressure values.

Ignore absence of bubbles.

Allow if electrode is below outer acid level.

1

(c) The carbonate ion reacts with the acid (in the SHE) / reaction between carbonate and Al^{3+}

Lose this mark if aluminium carbonate formed but mark on.

1

Reaction given (either equation or products specified)

OR H^+ / Al^{3+} concentrations change / cell e.m.f. altered

1

[5]

M3.(a) $Pt|H_2|H^+||Fe^{2+}|Fe$

Allow 1 for correct order of symbols but lose second mark for a wrong phase boundary(s) / Pt missing / extra Pt on RHS, additional phase boundary

Note, allow one mark only for correct symbol in reverse:

$Fe|Fe^{2+}||H^+|H_2|Pt$

Allow dashed lines for salt bridge

Ignore state symbols

Ignore 2 if used before H^+

2

(b) Electron donor

Allow (species that) loses electrons

Do not allow reference to electron pairs

1

(c) Cl_2 / chlorine

If M1 blank or incorrect cannot score M2

1

(Species on RHS / electron donor) has most positive / largest $E^{\ominus}$ / has highest potential

Do not allow reference to e.m.f. or E(cell)

1

(d) (i) Cl / chlorine

1

(ii) Chlorine +1 to chlorine 0

CE if chlorine not identified in part (i)

Allow chlorine +1 to chlorine –1 (in Cl^-)

Allow oxidation state decreases by one OR two

Allow oxidation state changes by –1 OR –2

1

(e) $4HOCl + 4H^+ + 4OH^- \rightarrow 2Cl_2 + O_2 + 6H_2O$

OR

$4HOCl \rightarrow 2Cl_2 + O_2 + 2H_2O$

Allow one mark for any incorrect equation that shows $HOCl \rightarrow Cl_2 + O_2$

Allow multiples

Ignore state symbols

Penalise one mark for uncancelled or uncombined species (eg $H_2O + H_2O$ instead of $2H_2O$)

2

(f) (i) e.m.f. = 0.40 – (–1.25) = <u>1.65</u> (V) / <u>+1.65</u> (V)

Allow –1.65 (V)

1

(ii) $2Zn + O_2 \rightarrow 2ZnO$

Allow multiples

Ignore state symbols

Do not allow uncancelled species

If more than one equation given, choose the best

1

(iii) **A** / stainless lid

If M1 incorrect or blank CE=0

1

$\underline{O_2}$ (electrode) has a more positive $E^{\ominus}$ / <u>oxygen</u> (electrode) requires / gains electrons from external circuit

Or reference to the overall equation and a link to electrons going into A

Allow oxygen is reduced and reduction occurs at the positive electrode

OR <u>Zinc</u> (electrode) has more negative $E^{\ominus}$

Do not allow reference to e.m.f. or E(cell)

1

(iv) (Cell) reaction(s) cannot be reversed / zinc oxide cannot be reduced to zinc by passing a current through it / zinc cannot be regenerated

Allow danger from production of gas / oxygen produced / hydrogen produced

1

[14]

M4.(a) It has mobile ions / ions can move through it / free ions

Do not allow movement of electrons.

Allow specific ions provided they are moving but do not react.

1

(b) <u>Chloride</u> ions react with <u>copper ions</u> / <u>Cu^{2+}</u> ***OR*** $[CuCl_4]^{2-}$ formed

If incorrect chemistry, mark = 0

1

(c) The Cu^{2+} ions / $CuSO_4$ in the <u>left-hand</u> electrode more concentrated

Allow converse.

1

So the reaction of Cu^{2+} with $2e^-$ will occur (in preference at) left-hand electrode / $Cu \rightarrow Cu^{2+}$ + electrons at right-hand electrode

Allow left-hand electrode positive / right-hand electrode negative.

Also reduction at left-hand electrode / oxidation at right-hand electrode.

Also left-hand electrode has oxidising agent / right-hand electrode has reducing agent.

Allow E left-hand side > E right-hand side

1

(d) (Eventually) the copper ions / $CuSO_4$ in each electrode will be at the same concentration

1

(e) (i) −3.05 (V)

Must have minus sign.

−3.05 only.

1

(ii) $LiMnO_2 \rightarrow Li + MnO_2$ correct equation

Allow 1 for reverse equation.

Allow multiples.

1

Correct direction

If Li^+ not cancelled but otherwise correct, max = 1

If electrons not cancelled, CE = 0

$LiMnO_2 \rightarrow Li + MnO_2$ scores 2

$Li^+ + LiMnO_2 \rightarrow Li^+ + Li + MnO_2$ scores 1

$Li + MnO_2 \rightarrow LiMnO_2$ scores 1

1

(iii) Electricity for recharging the cell may come from power stations burning (fossil) fuel

Allow any reference to burning (of carbon-containing) fuels.

Note combustion = burning.

1

[9]

M5.(a) (i) $H_2 + 2OH^- \rightarrow 2H_2O + 2e^-$ / $H_2 \rightarrow 2H^+ + 2e^-$

Any order

1

$O_2 + 4e^- + 2H_2O \rightarrow 4OH^-$ / $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$

1

(ii) Hydrogen (electrode) produces electrons

Ignore reference to salt bridge

Do not allow at negative / positive electrode – must identify hydrogen and oxygen

1

Oxygen (electrode) accepts electrons

Allow electrons flow to the oxygen electrode

1

(b) Hydrogen / the fuel / reactants supplied continuously / fed in

Do not accept oxygen supplied as the only statement

1

(c) In the fuel cell, a greater proportion of the energy available from the hydrogen–oxygen reaction is converted into useful energy

Allow less energy wasted / more efficient

Do not allow reference to safety

1

(d) Hydrogen is flammable / H^+ corrosive / OH^- corrosive / hydrogen explosive

1

[7]

M6.(a) Solar cells do not supply electrical energy all the time

1

Rechargeable cells can store electrical energy for use when the solar cells are not working

1

(b) Prevent pollution of the environment by toxic or dangerous substances / recycling of valuable components

Do not allow 'will not use up landfill sites'.

1

[3]

M1.(a) Diagram of an Fe^{3+} / Fe^{2+} electrode that includes the following parts labelled:
Solution containing Fe^{2+} and Fe^{3+} ions

1

Platinum electrode connected to one terminal of a voltmeter

Must be in the solution of iron ions (one type will suffice)

1

Salt bridge

Do not allow incorrect material for salt bridge and salt bridge must be in the solution (ie it must be shown crossing a meniscus)

1

298 K and 100 kPa / 1 bar

1

<u>all solutions</u> unit / 1 mol dm^{-3} concentration

Allow zero current / high resistance voltmeter as alternative to M4 or M5

Ignore hydrogen electrode even if incorrect

1

(b) $Cu^{2+} + Fe \rightarrow Cu + Fe^{2+}$

Ignore state symbols

1

$Fe|Fe^{2+}||Cu^{2+}|Cu$ correct order

Allow $Cu|Cu^{2+}||Fe^{2+}|Fe$

1

Phase boundaries and salt bridge correct, no Pt

Allow single / double dashed line for salt bridge

Penalise phase boundary at either electrode end

Can only score M3 if M2 correct

1

Copper electrode

Allow any reference to copper

1

(c) $E^{\ominus}$ Au^{+}(/ Au) > $E^{\ominus}$ O_2 (/ H_2O)

Allow E cell / e.m.f. = 0.45 V

Allow 1.68 > 1.23

1

So Au^{+} ions will oxidise water / water reduces Au^{+}

QoL

1

$2Au^{+} + H_2O \rightarrow 2Au + \frac{1}{2}O_2 + 2H^{+}$

Allow multiples

1

(d) $E^{\ominus}$ Ag^{+}(/ Ag) > $E^{\ominus}$ Fe^{2+}(/ Fe)

Allow E cell / e.m.f. = 1.24

Allow 0.80 > −0.44

1

And $E^{\ominus}$ Ag^{+}(/ Ag) > $E^{\ominus}$ Fe^{3+}(/ Fe^{2+})

Allow E cell / e.m.f. = 0.03

Allow 0.80 > 0.77

1

So silver ions will oxidise iron (to iron(II) ions) and then oxidise Fe(II) ions (further to Fe(III) ions producing silver metal)

Allow Ag^{+} ions will oxidise iron to iron(III)

1

[15]

M2.(a) Electron acceptor / gains electrons / takes electrons away

Do not allow electron pair acceptor / gain of electrons / definition of redox (QWC)

1

(b) $Cd(OH)_2$

Do not allow 'Cd(OH)$_2$/Cd'

1

Species (on LHS) with the least positive/most negative electrode potential / lowest *E* / smallest *E*

Only allow this mark if M1 answer given correctly or blank

Do not allow negative emf

1

(c) (i) 1.5 (V) / 1.50

1

(ii) $2MnO_2 + 2H_2O + Zn \rightarrow 2MnO(OH) + 2OH^- + Zn^{2+}$

Ignore state symbols

e^- must be cancelled

(take care that Zn^{2+} is on RHS)

1

(iii) Allows <u>ions</u> to pass (through it) or words to that effect

Penalise passage of electrons

Allow mention of particular ions

1

(iv) Allows electrons to flow / makes electrical contact / conductor

Allow acts as an (inert) electrode / anode / cathode

1

(v) Zn is 'used up' / has reacted / oxidised

Allow idea that zinc <u>reacts</u>

Do not allow just zinc corrodes

1

(d) (i) 3 / +3 / III

1

$2Ni(OH)_2 + Cd(OH)_2 \rightarrow 2NiO(OH) + Cd + 2H_2O$

For correct nickel and cadmium species in correct order (allow H_2O missing and OH^- not cancelled)

1

For balanced equation (also scores M2)

Allow max 1 for M2 and M3 if correct balanced equation but reversed.

Ignore state symbols

1

(ii) Metal / metal compounds are re-used / supplies are not depleted / It (the cell) can be re-used

Allow does not leak / no landfill problems / less mining / less energy to extract metals / less waste

Do not allow less CO_2 unless explained

1

(e) (i) $C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$

Allow C_2H_6O

1

(ii) $C_2H_5OH + 3H_2O \rightarrow 2CO_2 + 12H^+ + 12e^-$

Allow C_2H_6O

1

(iii) (+)0.23 (V)

1

(iv) $\underline{CO_2}$ released by combustion / fermentation / fuel cell / reaction with water

Can be answered with the aid of equations

1

(atmospheric) $\underline{CO_2}$ taken up in <u>photosynthesis</u>

1

[17]

M3.(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_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]

M4. (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]

M1. (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]

M2. (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]

M3. (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]

M4.(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]

M1.(a) Electron acceptor / gains electrons

do not allow electron pair acceptor

1

(b) Fe^{2+} ions

1

Fe^{2+} / Fe or Fe^{2+} or it has smallest / most negative <u>electrode potential</u> / <u>*E*°</u>

Do not allow Fe / Fe^{2+}

Cannot score M2 if M1 incorrect

1

(c) $Pt|H_2|H^+||Ag^+|Ag$

M1 for H_2 H^+ Ag^+ Ag in correct order

1

allow dashed phase boundaries

$2H^+$ loses one mark (M2)

M2 for Pt correct and correct phase boundaries

Ignore state symbols. M1 must be correct to score M2

If answer correct but all in reverse order allow 1 mark out of two

1

Any **two** correct conditions

- 298 K / 25 °C
- 100 kPa
- both solutions of unit concentration
- zero current

Allow 1 bar

Do not apply list principle, mark correct answers.

2

(d) E Au^+(/ Au) > E O_2 (/ H_2O) OR e.m.f. / *E*cell = 0.45 V

If both species in electrode given, must be in correct order i.e. Au+ / Au

1

<u>Au^+ (ions) oxidise water</u> OR <u>water reduces Au^+ (ions)</u>

Allow water donates electrons to Au+

1

Gold metal / solid / precipitate **OR** bubbles / effervescence of (oxygen gas) / gas produced

Penalise incorrect observations

1

$2Au^{+} + H_2O \rightarrow 2Au + 2H^{+} + \frac{1}{2} O_2$ OR $4Au^{+} + 2H_2O \rightarrow 4Au + 4H^{+} + O_2$

Allow multiples

1

(e) (i) 1.24 (V)

Do not allow −1.24

1

(ii) Chloride ions / Cl^{-} react with / form a precipitate with silver ions / Ag+ / form AgCl

Penalise reaction of chloride ions with iron ions or iron

1

(f) E O_2 (/ H_2O) > E Fe^{3+} (/ Fe^{2+}) (or e.m.f / *E*cell = 0.46 V)

Species in electrode if all given must be in correct order

1

Therefore the iron(II) ions are oxidised (or converted) into iron(III) ions (by oxygen)

If chloride ions oxidised to chlorine, lose M2

M2 can be obtained or lost from equation.

Ignore observations.

1

[15]

M2.(a) Platinum electrode

1

Solution in beaker is a mixture of named soluble iron(II) compound and named soluble iron(III) compound

Allow correct formulae for the iron compounds.

1

Concentrations of Fe(II) and Fe(III) ions are both 1 mol dm^{-3}

Ignore any references to temperature.

If eg $Fe_2(SO_4)_3$ used then concentration must be 0.5

1

(b) Purpose: Allow movement of ions between electrodes

Allow to maintain an electric circuit.

Do not allow reference to movement of electrons in salt bridge.

1

Requirement: Must not react with the electrolyte / ions in solution

Do not allow 'must not react' without further qualification.

1

[5]

M3.(a) (Biocide) reacts with bacteria / used up killing bacteria

Max two marks

Chlorine given off / evaporates

Do not allow "chlorine has reacted with water" alone.

Chlorine has reacted with water to form (HCl and) O_2

Do not allow products of HCl and HOCl alone

2

(b) the concentration of the remaining solution (after a sample has been removed) is unchanged.

1

(c) So that all chlorine was reacted / reduced

*Do **not** allow 'all of the iodide was oxidised'*

1

(d) The E° value for the iodine half-equation is more positive than that for the thiosulfate

Allow = 0.45

Must refer to values

1

(e) $S_2O_3^{2-} + \frac{1}{2} I_2 \rightarrow I^- + \frac{1}{2} S_4O_6^{2-}$

Allow multiples

1

[6]

M4.(a) $Pt|H_2|H^+||Fe^{2+}|Fe$

Allow 1 for correct order of symbols but lose second mark for a wrong phase boundary(s) / Pt missing / extra Pt on RHS, additional phase boundary

Note, allow one mark only for correct symbol in reverse:

$Fe|Fe^{2+}||H^+|H_2|Pt$

Allow dashed lines for salt bridge

Ignore state symbols

Ignore 2 if used before H^+

2

(b) Electron donor

Allow (species that) loses electrons

Do not allow reference to electron pairs

1

(c) Cl_2 / chlorine

If M1 blank or incorrect cannot score M2

1

(Species on RHS / electron donor) has most positive / largest $E^\ominus$ / has highest potential

Do not allow reference to e.m.f. or E(cell)

1

(d) (i) Cl / chlorine

1

(ii) Chlorine +1 to chlorine 0

CE if chlorine not identified in part (i)

Allow chlorine +1 to chlorine –1 (in Cl^-)

Allow oxidation state decreases by one OR two

Allow oxidation state changes by –1 OR –2

1

(e) $4HOCl + 4H^+ + 4OH^- \rightarrow 2Cl_2 + O_2 + 6H_2O$

OR

$4HOCl \rightarrow 2Cl_2 + O_2 + 2H_2O$

Allow one mark for any incorrect equation that shows $HOCl \rightarrow Cl_2 + O_2$

Allow multiples

Ignore state symbols

Penalise one mark for uncancelled or uncombined species (eg $H_2O + H_2O$ instead of $2H_2O$)

2

(f) (i) e.m.f. = 0.40 – (–1.25) = <u>1.65</u> (V) / <u>+1.65</u> (V)

Allow –1.65 (V)

1

(ii) $2Zn + O_2 \rightarrow 2ZnO$

Allow multiples

Ignore state symbols

Do not allow uncancelled species

If more than one equation given, choose the best

1

(iii) **A** / stainless lid

If M1 incorrect or blank CE=0

1

<u>O_2</u> (electrode) has a more positive $E^\ominus$ / <u>oxygen</u> (electrode) requires / gains electrons from external circuit

Or reference to the overall equation and a link to electrons going into A

Allow oxygen is reduced and reduction occurs at the positive electrode

OR Zinc (electrode) has more negative $E^{\ominus}$

Do not allow reference to e.m.f. or E(cell)

1

(iv) (Cell) reaction(s) cannot be reversed / zinc oxide cannot be reduced to zinc by passing a current through it / zinc cannot be regenerated

Allow danger from production of gas / oxygen produced / hydrogen produced

1

[14]

M5.(a) The ions in the ionic substance in the salt bridge move through the salt bridge

1

To maintain charge balance / complete the circuit

1

(b) F^-

1

(c) $E^{\ominus}$ SO_4^{2-} / SO_2 $E^{\ominus}$ Br_2 / Br^-

Allow correct answer expressed in words, eg electrode potential for sulfate ions / sulfur dioxide is less than that for bromine / bromide

1

(d) 1.23 (V)

1

(e) A fuel cell converts more of the available energy from combustion of hydrogen into kinetic energy of the car / an internal combustion engine wastes more (heat) energy

1

[6]

M6.A

[1]

M1.(a) $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$

*If equations reversed, allow **M1** only.*

1

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

Ignore state symbols.

1

(b) Moles of copper(II) reacted = (100 / 1000) × 0.5 = 0.05

1

Moles of zinc reacted = 0.05

1

Mass of zinc lost = 0.05 × 65.4 = 3.27 g

*Correct final answer without working scores **M3** only.*

1

(c) Allow cell to discharge until $[Cu^{2+}]$ is 0.5

Alternative: Allow cell to discharge completely.

1

Confirmed by colorimetric measurement or other suitable method

Solution colourless or use of chemical test to determine absence of copper(II)

1

Weigh the Zn electrode before and after the experiment

Weigh Zn electrodes before and after and halve the mass change.

1

[8]

M2.(a) It has mobile ions / ions can move through it / free ions

Do not allow movement of electrons.

Allow specific ions provided they are moving but do not react.

1

(b) Chloride ions react with copper ions / Cu^{2+} ***OR*** $[CuCl_4]^{2-}$ formed

If incorrect chemistry, mark = 0

1

(c) The Cu^{2+} ions / $CuSO_4$ in the left-hand electrode more concentrated

Allow converse.

1

So the reaction of Cu^{2+} with $2e^-$ will occur (in preference at) left-hand electrode / $Cu \rightarrow Cu^{2+}$ + electrons at right-hand electrode

Allow left-hand electrode positive / right-hand electrode negative.

Also reduction at left-hand electrode / oxidation at right-hand electrode.

Also left-hand electrode has oxidising agent / right-hand electrode has reducing agent.

Allow E left-hand side > E right-hand side

1

(d) (Eventually) the copper ions / $CuSO_4$ in each electrode will be at the same concentration

1

(e) (i) −3.05 (V)

Must have minus sign.

−3.05 only.

1

(ii) $LiMnO_2 \rightarrow Li + MnO_2$ correct equation

Allow 1 for reverse equation.

Allow multiples.

1

Correct direction

If Li^+ not cancelled but otherwise correct, max = 1

If electrons not cancelled, CE = 0

$LiMnO_2 \rightarrow Li + MnO_2$ scores 2

$Li^+ + LiMnO_2 \rightarrow Li^+ + Li + MnO_2$ scores 1

$Li + MnO_2 \rightarrow LiMnO_2$ scores 1

1

(iii) Electricity for recharging the cell may come from power stations <u>burning</u> (fossil) fuel

Allow any reference to <u>burning</u> (of carbon-containing) fuels.

Note combustion = burning.

1

[9]

M3.(a) Electron acceptor / gains electrons / takes electrons away

Do not allow electron pair acceptor / gain of electrons / definition of redox (QWC)

1

(b) $Cd(OH)_2$

Do not allow 'Cd(OH)$_2$/Cd'

1

Species (on LHS) with the least positive/most negative electrode potential / lowest *E* / smallest *E*

Only allow this mark if M1 answer given correctly or blank

Do not allow negative emf

1

(c) (i) 1.5 (V) / 1.50

1

(ii) $2MnO_2 + 2H_2O + Zn \rightarrow 2MnO(OH) + 2OH^- + Zn^{2+}$

Ignore state symbols

e^- must be cancelled

(take care that Zn^{2+} is on RHS)

1

(iii) Allows <u>ions</u> to pass (through it) or words to that effect

Penalise passage of electrons

Allow mention of particular ions

1

(iv) Allows electrons to flow / makes electrical contact / conductor

Allow acts as an (inert) electrode / anode / cathode

1

(v) Zn is 'used up' / has reacted / oxidised

Allow idea that zinc <u>reacts</u>

Do not allow just zinc corrodes

1

(d) (i) 3 / +3 / III

1

$2Ni(OH)_2 + Cd(OH)_2 \rightarrow 2NiO(OH) + Cd + 2H_2O$

For correct nickel and cadmium species in correct order (allow H_2O missing and OH^- not cancelled)

1

For balanced equation (also scores M2)

Allow max 1 for M2 and M3 if correct balanced equation but reversed.

Ignore state symbols

1

(ii) Metal / metal compounds are re-used / supplies are not depleted / It (the cell) can be re-used

Allow does not leak / no landfill problems / less mining / less energy to extract metals / less waste

Do not allow less CO_2 unless explained

1

(e) (i) $C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$

Allow C_2H_6O

1

(ii) $C_2H_5OH + 3H_2O \rightarrow 2CO_2 + 12H^+ + 12e^-$

Allow C_2H_6O

1

(iii) (+)0.23 (V)

1

(iv) $\underline{CO_2}$ released by combustion / fermentation / fuel cell / reaction with water

Can be answered with the aid of equations

1

(atmospheric) $\underline{CO_2}$ taken up in <u>photosynthesis</u>

1

[17]

M4.(a) To remove the <u>oxide</u> layer on the aluminium

Do not allow 'cleaning' or 'removal of grease'.

Do not allow 'removal of impurities' without qualification.

1

(b) An appropriate method for delivering H_2 gas over a Pt electrode

Need H_2 gas and Pt electrode labelled (allow gas delivered directly below the electrode).

1

The Pt electrode must clearly be in contact with a solution of a named acid.

Ignore any concentration or pressure values.

Ignore absence of bubbles.

Allow if electrode is below outer acid level.

1

(c) The carbonate ion reacts with the acid (in the SHE) / reaction between carbonate and Al^{3+}

Lose this mark if aluminium carbonate formed but mark on.

1

Reaction given (either equation or products specified)

OR H^+ / Al^{3+} concentrations change / cell e.m.f. altered

1

[5]

M5.(a) Diagram of an Fe^{3+} / Fe^{2+} electrode that includes the following parts labelled:

Solution containing Fe^{2+} and Fe^{3+} ions

1

Platinum electrode connected to one terminal of a voltmeter

Must be in the solution of iron ions (one type will suffice)

1

Salt bridge

Do not allow incorrect material for salt bridge and salt bridge must be in the solution (ie it must be shown crossing a meniscus)

1

298 K and 100 kPa / 1 bar

1

<u>all solutions</u> unit / 1 mol dm^{-3} concentration

Allow zero current / high resistance voltmeter as alternative

to M4 or M5
Ignore hydrogen electrode even if incorrect

1

(b) $Cu^{2+} + Fe \rightarrow Cu + Fe^{2+}$
Ignore state symbols

1

$Fe|Fe^{2+}||Cu^{2+}|Cu$ correct order
Allow $Cu|Cu^{2+}||Fe^{2+}|Fe$

1

Phase boundaries and salt bridge correct, no Pt
Allow single / double dashed line for salt bridge
Penalise phase boundary at either electrode end
Can only score M3 if M2 correct

1

Copper electrode
Allow any reference to copper

1

(c) $E^{\ominus}$ Au^{+}(/ Au) > $E^{\ominus}$ O_2 (/ H_2O)
Allow E cell / e.m.f. = 0.45 V
Allow 1.68 > 1.23

1

So Au^{+} ions will oxidise water / water reduces Au^{+}
QoL

1

$2Au^{+} + H_2O \rightarrow 2Au + \frac{1}{2}O_2 + 2H^{+}$
Allow multiples

1

(d) $E^{\ominus}$ Ag^{+}(/ Ag) > $E^{\ominus}$ Fe^{2+}(/ Fe)

Allow E cell / e.m.f. = 1.24

Allow 0.80 > −0.44

1

And $E^{\ominus}$ Ag^{+}(/ Ag) > $E^{\ominus}$ Fe^{3+}(/ Fe^{2+})

Allow E cell / e.m.f. = 0.03

Allow 0.80 > 0.77

1

So silver ions will oxidise iron (to iron(II) ions) and then oxidise Fe(II) ions (further to Fe(III) ions producing silver metal)

Allow Ag^{+} ions will oxidise iron to iron(III)

1

[15]

M1.(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 $H^+ = 25 \times 0.0200 \times 8 / 1000 = 4.00 \times 10^{-3}$

1

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

Allow consequential marking on incorrect moles of H^+

1

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

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

$\underline{Larger}$ 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]

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) 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]

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_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) $2Fe^{3+} + H_2 \longrightarrow 2Fe^{2+} + 2H^+$

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]

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_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]

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) O (–1) (in H_2O_2)

Must give oxidation state of O in H_2O_2= –1

1

Changes to O(–2) (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]

M1. (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]

M2. D

[1]

M3. (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]

M4. (a) (i) HgO

1

(ii) $Hg^{2+} + 2e^- \rightarrow Hg$

1

(iii) $2H_2O + SO_2 \rightarrow H_2SO_4 + 2e^-$ etc

1

(iv) $Cl_2 + 2e^- \rightarrow 2Cl^-$

1

(b) (i) Vanadium species: VO_2^+

1

Oxidation state: 5

1

Half-equation: $V^{2+} + 2H_2O \rightarrow VO_2^+ + 4H^+ + 3e^-$

1

(ii) Cell e.m.f 0.06 V

1

Change in e.m.f , Increases

1

More Fe^{3+} ions to accept electrons

1

Fe^{3+}/Fe^{2+} electrode becomes more positive

1

(c) (i) $2H_2 \rightarrow 4H^+ + 4e^-$

1

$4e^- + O_2 + 2H_2O \rightarrow 4OH^-$

1

Overall equation $2H_2 + O_2 \rightarrow 2H_2O$

(ii) Unchanged

1

(d) Economic disadvantage; Use of CH_4 or cost of producing or high temp

1

Environmental disadvantage; Makes CO_2

1

(e) Cost of manufacture of solar cells

1

[17]

M5. (a) (i) 0.60 V

1

(ii) $H_2O + H_2SO_3 \rightarrow SO_4^{2-} + 4H^+ + 2e^-$

1

(b) (i) $2IO_3^- + 2H^+ 5H_2O_2 \rightarrow 5O_2 + I_2 + 6H_2O$ Species

1

Balanced

1

(ii) The concentration of the ions change or are no longer standard or the e.m.f is determined when no current flows

1

(iii) Unchanged

1

(iv) Increased

1

Equilibrium IO_3^-/I_2 displaced to the right

1

Electrons more readily accepted or more reduction occurs or electrode becomes more positive (Q o L)

1

(c) VO_2^+

1

5 or V

1

$V^{2+} + 2H_2O \rightarrow VO_2^+ + 4H^+ 3e^-$

1

[12]

M6. (a) (i) Fe^{2+}

1

(ii) F_2O

1

(iii) Fe^{2+}

1

Cl^-

1

Use list principle if more than two answers

(b) (i) e.m.f. = *E*(rhs) – *E*(lhs)

1

= 1.52 – 0.77 = 0.75

(0.75 scores first mark also)

1

(ii) $Fe^{2+} \rightarrow Fe^{3+} + e^-$

1

(iii) Decrease

(Increase is CE, no further marks)

1

Equilibrium (or reaction) shifts to R

(or L if refers to half equation in table)
(or in favour of more Fe^{3+})
(or more Fe^{3+} formed)
(or more electrons formed)

1

Electrode potential (for Fe^{3+}/Fe^{2+}) less positive (or decreases)

1

[10]

M1. (a) most powerful reducing agent: Zn;

1

(b) (i) reducing species: Fe^{2+}

1

(ii) oxidising species: Cl_2;

1

(c) (i) standard electrode potential 1.25 V;

1

(ii) equation: $Tl^{3+} + 2\ Fe^{2+} \rightarrow 2Fe^{3+} + Tl +$ balanced;

1

correct direction;

1

(d) (i) moles $KMnO_4 = 16.2 \times 0.0200 \times 10^{-3} = 3.24 \times 10^{-4}$;

1

moles H_2O_2 = Moles $KMnO_4 \times 5 / 2 = 8.10 \times {}^{-4}$;

1

8.10×10^{-4} moles H_2O_2 in 25 cm^3
$8.10 \times 10^{-4} \times 1000 / 25$ in 1000 $cm^3 = 0.0324$ mol dm^{-3};

1

hence g dm^{-3} = mol $dm^{-3} \times M_r = 0.0324 \times 34 = 1.10$;
(penalise use of an incorrect H_2O_2 to $KMnO_4$ ratio by two marks)

1

(ii) PV = nRT;

1

hence V = nRT / P
$= 8.10 \times 10^{-4} \times 8.31 \times 298/98000$;

1

$= 2.05 \times 10^{-5}$;

1

units m^3;

(mark consequentially to answers in (c)(i))
(allow correct answers with other units)
(answers to (c)(i) and (ii) must be to 3 significant figures; penalise once only)

1

[14]

M2. (a) *Cell e.m.f.*: 1.93 (v) CE if negative value given **(1)**

Half equation: $Mg \rightarrow Mg^{2+} + 2\ e^-$ **(1)**

or ⇌

Ignore state symbols

Mark on after an AE

2

(b) *Change in e.m.f.*: increases **(1)**

Mark on even if incorrect

Explanation: Equilibrium displaced to Mg^{2+} or to the left **(1)**

cell reaction or overall reaction goes to the right
Electrode is more negative or E decreases
or gives more electron
or forms more Mg^{2+} ions
Mark separately

3

(c) *Cell e.m.f.* : –0.84 (V) **(1)**

Explanation: Fe is giving electrons **or** forming Fe^{2+}
or reaction goes in the reverse direction **(1)**

Mark on after AE

N.B. In (a) and (c) mark on if no value given, but CE in both (a) and (c) if e.m.f. = 0

2

[7]

M3.(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]

M4.D

[1]

M5.C

[1]

M6. C

[1]

M7. (a) *Hydrogen ion concentration*: 1.00 mol dm^{-3} **(1)**

Hydrogen gas pressure: 100 kPa **(1)**

2

(b) *Explanation of change*: Equilibrium displaced to left **(1)**
to reduce constraint **(1)**

Change in electrode potential: Becomes negative or decreases **(1)**
allow more negative

3

(c) (i) 0.43V **(1)**

(ii) *Half-equation*: $2Br^- \rightarrow Br_2 + 2e^-$ **(1)**

Overall equation: $2BrO_3^- + 10Br^- + 12H^+ \rightarrow 6Br_2 + 6H_2O$ **(2)**
or $BrO_3^- + 5Br^- + 6H^+ \rightarrow 3Br_2 + 3H_2O$

*species **(1)***
*balanced **(1)***

4

[9]

M8. D

[1]

M9. B

[1]

M1.A

[1]

M2.D

[1]

M3.C

[1]

M4.B

[1]

M5.D

[1]

M6.C

[1]

M7.D

[1]