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]