

**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 oxide 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  $\text{Al}^{3+}$

*Lose this mark if aluminium carbonate formed but mark on.*

1

Reaction given (either equation or products specified)

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

1

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**M3.(a)**  $\text{Pt}|\text{H}_2|\text{H}^+||\text{Fe}^{2+}|\text{Fe}$

*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:

$\text{Fe}|\text{Fe}^{2+}||\text{H}^+|\text{H}_2|\text{Pt}$

*Allow dashed lines for salt bridge*

*Ignore state symbols*

*Ignore 2 if used before  $\text{H}^+$*

2

- (b) Electron donor

*Allow (species that) loses electrons*

*Do not allow reference to electron pairs*

1

- (c)  $\text{Cl}_2$  / 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  $E(\text{cell})$*

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<sup>-</sup>)*

*Allow oxidation state decreases by one OR two*

*Allow oxidation state changes by -1 OR -2*

1

(e)  $4\text{HOCl} + 4\text{H}^+ + 4\text{OH}^- \rightarrow 2\text{Cl}_2 + \text{O}_2 + 6\text{H}_2\text{O}$

OR

$4\text{HOCl} \rightarrow 2\text{Cl}_2 + \text{O}_2 + 2\text{H}_2\text{O}$

*Allow one mark for any incorrect equation that shows*

*$\text{HOCl} \rightarrow \text{Cl}_2 + \text{O}_2$*

*Allow multiples*

*Ignore state symbols*

*Penalise one mark for uncancelled or uncombined species*

*(eg  $\text{H}_2\text{O} + \text{H}_2\text{O}$  instead of  $2\text{H}_2\text{O}$ )*

2

(f) (i) e.m.f. =  $0.40 - (-1.25) = \underline{1.65}$  (V) /  $\underline{+1.65}$  (V)

*Allow -1.65 (V)*

1

(ii)  $2\text{Zn} + \text{O}_2 \rightarrow 2\text{ZnO}$

*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

O<sub>2</sub> (electrode) has a more positive  $E^\ominus$  / oxygen (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]

- 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) Chloride ions react with copper ions / Cu<sup>2+</sup> **OR** [CuCl<sub>4</sub>]<sup>2-</sup> formed  
*If incorrect chemistry, mark = 0*

1

- (c) The Cu<sup>2+</sup> ions / CuSO<sub>4</sub> in the left-hand electrode more concentrated  
*Allow converse.*

1

So the reaction of  $\text{Cu}^{2+}$  with  $2\text{e}^-$  will occur (in preference at) left-hand electrode /  $\text{Cu} \rightarrow \text{Cu}^{2+} + \text{electrons}$  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 /  $\text{CuSO}_4$  in each electrode will be at the same concentration

1

- (e) (i)  $-3.05$  (V)  
Must have minus sign.  
 $-3.05$  only.

1

- (ii)  $\text{LiMnO}_2 \rightarrow \text{Li} + \text{MnO}_2$  correct equation  
Allow 1 for reverse equation.  
Allow multiples.

1

Correct direction

If  $\text{Li}^+$  not cancelled but otherwise correct, max = 1

If electrons not cancelled, CE = 0

$\text{LiMnO}_2 \rightarrow \text{Li} + \text{MnO}_2$  scores 2

$\text{Li}^+ + \text{LiMnO}_2 \rightarrow \text{Li}^+ + \text{Li} + \text{MnO}_2$  scores 1

$\text{Li} + \text{MnO}_2 \rightarrow \text{LiMnO}_2$  scores 1

1

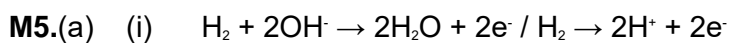
- (iii) Electricity for recharging the cell may come from power stations burning (fossil) fuel

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

Note combustion = burning.

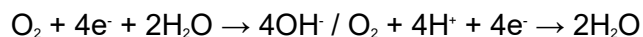
1

[9]



*Any order*

1



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 /  $\text{H}^+$  corrosive /  $\text{OH}^-$  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]