

## Mark schemes

1

- (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<sup>-3</sup>

*Ignore any references to temperature.*

*If eg Fe<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub> 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

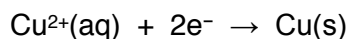
[5]

2

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

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

1



*Ignore state symbols.*

1

- (b) Moles of copper(II) reacted =  $(100 / 1000) \times 0.5 = 0.05$

1

Moles of zinc reacted = 0.05

1

Mass of zinc lost =  $0.05 \times 65.4 = 3.27 \text{ g}$

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

1

- (c) Allow cell to discharge until [Cu<sup>2+</sup>] 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

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3

- (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]

4

- (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 /  $\text{Cu}^{2+}$  **OR**  $[\text{CuCl}_4]^{2-}$  formed

*If incorrect chemistry, mark = 0*

1

- (c) The  $\text{Cu}^{2+}$  ions /  $\text{CuSO}_4$  in the left-hand electrode more concentrated

*Allow converse.*

1

So the reaction of  $\text{Cu}^{2+}$  with  $2e^-$  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

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5

(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  $\text{H}_2$  gas over a Pt electrode

*Need  $\text{H}_2$  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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(a) Diagram of an  $\text{Fe}^{3+} / \text{Fe}^{2+}$  electrode that includes the following parts labelled:  
Solution containing  $\text{Fe}^{2+}$  and  $\text{Fe}^{3+}$  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

all solutions unit / 1 mol dm<sup>-3</sup> concentration

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

*Ignore hydrogen electrode even if incorrect*

1



*Ignore state symbols*

1

Fe|Fe<sup>2+</sup>||Cu<sup>2+</sup>|Cu correct order

*Allow Cu|Cu<sup>2+</sup>||Fe<sup>2+</sup>|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*

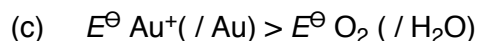
*Can only score M3 if M2 correct*

1

Copper electrode

*Allow any reference to copper*

1



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

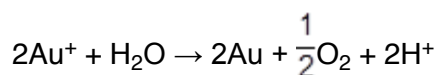
*Allow 1.68 > 1.23*

1

So Au<sup>+</sup> ions will oxidise water / water reduces Au<sup>+</sup>

*QoL*

1



*Allow multiples*

1

- (d)  $E^\ominus \text{Ag}^+ / \text{Ag} > E^\ominus \text{Fe}^{2+} / \text{Fe}$   
 Allow  $E_{\text{cell}} / \text{e.m.f.} = 1.24$   
 Allow  $0.80 > -0.44$

1

- And  $E^\ominus \text{Ag}^+ / \text{Ag} > E^\ominus \text{Fe}^{3+} / \text{Fe}^{2+}$   
 Allow  $E_{\text{cell}} / \text{e.m.f.} = 0.03$   
 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  $\text{Ag}^+$  ions will oxidise iron to iron(III)

1

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- (a) Electron acceptor / gains electrons / takes electrons away  
 Do not allow electron pair acceptor / gain of electrons / definition of redox (QWC)

1

- (b)  $\text{Cd}(\text{OH})_2$   
 Do not allow ' $\text{Cd}(\text{OH})_2 / \text{Cd}$ '

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)  $2\text{MnO}_2 + 2\text{H}_2\text{O} + \text{Zn} \rightarrow 2\text{MnO}(\text{OH}) + 2\text{OH}^- + \text{Zn}^{2+}$   
 Ignore state symbols  
 $e^-$  must be cancelled  
 (take care that  $\text{Zn}^{2+}$  is on RHS)

1

- (iii) Allows ions 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 reacts*  
*Do not allow just zinc corrodes* 1
- (d) (i) 3 / +3 / III 1
- $2\text{Ni}(\text{OH})_2 + \text{Cd}(\text{OH})_2 \rightarrow 2\text{NiO}(\text{OH}) + \text{Cd} + 2\text{H}_2\text{O}$   
*For correct nickel and cadmium species in correct order (allow H<sub>2</sub>O missing and OH<sup>-</sup> 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<sub>2</sub> unless explained* 1
- (e) (i)  $\text{C}_2\text{H}_5\text{OH} + 3\text{O}_2 \rightarrow 2\text{CO}_2 + 3\text{H}_2\text{O}$   
*Allow C<sub>2</sub>H<sub>6</sub>O* 1
- (ii)  $\text{C}_2\text{H}_5\text{OH} + 3\text{H}_2\text{O} \rightarrow 2\text{CO}_2 + 12\text{H}^+ + 12\text{e}^-$   
*Allow C<sub>2</sub>H<sub>6</sub>O* 1
- (iii) (+)0.23 (V) 1
- (iv) CO<sub>2</sub> released by combustion / fermentation / fuel cell / reaction with water  
*Can be answered with the aid of equations* 1
- (atmospheric) CO<sub>2</sub> taken up in photosynthesis 1

[17]