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 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

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

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) <u>CO_2</u> released by combustion / fermentation / fuel cell / reaction with water

Can be answered with the aid of equations

1

(atmospheric) <u>CO_2</u> 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]