

Mark schemes

1

(a) (i) Zn^{2+}

$Zn^{2+}(aq)$

Apply List

1

(ii) 298 K /25°C

Ignore pressure

Ignore standard conditions

Ignore state symbols

1

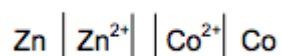
(Solutions at) unit concentration / 1 mol dm⁻³ (of Zn^{2+})

Ignore references to S.H.E

1

(b) Identifying it is the Zn/Zn^{2+} and Co^{2+}/Co half cells

1



Correct order with phase boundaries and salt bridge correct, no Pt

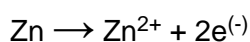
If this is correct it scores M1 and M2

Allow double dashed line for salt bridge

Extra phase boundaries loses M2

Ignore state symbols

1



M3 independent

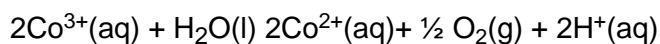
Allow $-2e^{-}$ on LHS

1

(c) Co^{3+}

Mark independently

1



Ignore state symbols

Allow multiples

1

Oxygen / O_2

Allow $\frac{1}{2} O_2$

1

- (d) $E^\ominus (\text{O}_2|\text{H}_2\text{O})$ electrode $< E^\ominus (\text{Au}^+|\text{Au})$
 OR $E^\ominus (\text{Au}^+|\text{Au}) > E^\ominus (\text{O}_2|\text{H}_2\text{O})$
 OR the $E^\ominus (\text{Au}^+|\text{Au})$ electrode potential is more positive than the $E^\ominus (\text{O}_2|\text{H}_2\text{O})$ electrode
 OR The emf (for the reaction of Au and oxygen) is -0.45 V (and therefore not spontaneous)
Mark independently

1

So oxygen is unable to oxidise gold

Ignore references to water

Allow gold cannot reduce oxygen

1

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2

- (a) (i) M1 Positive electrode $\text{O}_2 + 2\text{H}_2\text{O} + 4\text{e}^- \rightarrow 4\text{OH}^-$

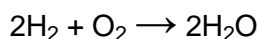
M2 Negative electrode $\text{H}_2 + 2\text{OH}^- \rightarrow 2\text{H}_2\text{O} + 2\text{e}^-$

Allow multiples, ignore state symbols

If equations both correct but at the wrong electrodes allow 1 mark

1

1



Mark independently

Must be this way round

1

- (ii) Increase (emf)

If decrease/no change then CE=0/2; if blank then mark on

1

$2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$ will move to the right

Or overall equation moves to the right

Allow $\text{O}_2 + 2\text{H}_2\text{O} + 4\text{e}^- \rightarrow 4\text{OH}^-$ will move to the right / oxygen half equation moves to the RHS / $E^\ominus \text{O}_2|\text{OH}^-$ half cell moves to the right

1

(b)



Must start at y-axis

1

- (c) (i) Unchanged 1
- (ii) Water is the only product / fuel cell does not give out pollutants such as NO_x or CO₂ or SO₂ or C or CO or C_xH_y or unburnt hydrocarbons
Not fuel cell does not give out pollutants unless pollutant stated 1

- (d) CO₂ is released because fossil fuels are burned to produce electricity to generate hydrogen
 OR
CO₂ is released when methane reacts with steam to produce hydrogen
Allow CO₂ is released to produce the hydrogen 1

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3

- (a) The ions in the ionic substance in the salt bridge move through the salt bridge
 To maintain charge balance / complete the circuit 1
- (b) F⁻ 1
- (c) $E^\ominus \text{SO}_4^{2-} / \text{SO}_2 < E^\ominus \text{Br}_2 / \text{Br}^-$
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

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4

- A [1]

5

- (a) Electron acceptor / gains electrons
do not allow electron pair acceptor 1
- (b) Fe²⁺ ions 1

Fe²⁺ / Fe or Fe²⁺ or it has smallest / most negative electrode potential / E^\ominus

Do not allow Fe / Fe²⁺

Cannot score M2 if M1 incorrect

1

(c) Pt|H₂|H⁺||Ag⁺|Ag

M1 for H₂ 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 O₂ (/ H₂O) 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

Au⁺ (ions) oxidise water OR water reduces Au⁺ (ions)

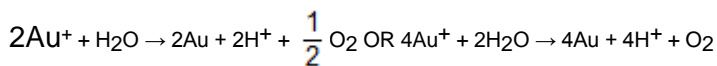
Allow water donates electrons to Au⁺

1

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

Penalise incorrect observations

1



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

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(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

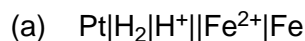
(e) $S_2O_3^{2-} + \frac{1}{2} I_2 \rightarrow I^- + \frac{1}{2} S_4O_6^{2-}$

Allow multiples

1

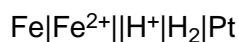
[6]

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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:



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 $E(\text{cell})$

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^-)

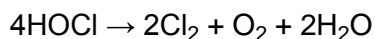
Allow oxidation state decreases by one OR two

Allow oxidation state changes by -1 OR -2

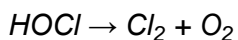
1



OR



Allow one mark for any incorrect equation that shows



Allow multiples

Ignore state symbols

Penalise one mark for uncanceled 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

O₂ (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

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(a) (i) $\text{H}_2 + 2\text{OH}^- \rightarrow 2\text{H}_2\text{O} + 2\text{e}^-$ / $\text{H}_2 \rightarrow 2\text{H}^+ + 2\text{e}^-$
Any order 1

$\text{O}_2 + 4\text{e}^- + 2\text{H}_2\text{O} \rightarrow 4\text{OH}^-$ / $\text{O}_2 + 4\text{H}^+ + 4\text{e}^- \rightarrow 2\text{H}_2\text{O}$ 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

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