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

$Zn \mid Zn^{2+} \parallel Co^{2+} \mid Co$

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

$Zn \longrightarrow Zn^{2+} + 2e^{(-)}$

M3 independent

Allow $-2e^-$ on LHS

1

(c) $\underline{Co^{3+}}$

Mark independently

1

$2Co^{3+}(aq) + H_2O(l)\ 2Co^{2+}(aq) + ½\ O_2(g) + 2H^+(aq)$

Ignore state symbols

Allow multiples

1

Oxygen /O_2

Allow ½ O_2

1

(d) $E^{\ominus}$ (O_2(|H_2O)) electrode < $E^{\ominus}$ (Au^+(|Au))

OR $E^{\ominus}$ (Au^+(|Au)) > $E^{\ominus}$ (O_2(|H_2O))

OR the $E^{\ominus}$ (Au^+|Au) electrode potential is more positive than the $E^{\ominus}$ (O_2|H_2O) electrode

OR The emf (for the reaction of Au and oxygen) is –0.45 V (and therefore not spontaneous)

Mark independently

1

So <u>oxygen</u> is unable to oxidise gold

Ignore references to water

Allow gold cannot reduce <u>oxygen</u>

1

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2 (a) (i) M1 Positive electrode $O_2 + 2H_2O + 4e^- \longrightarrow 4OH^-$

M2 Negative electrode $H_2 + 2OH^- \longrightarrow 2H_2O + 2e^-$

Allow multiples, ignore state symbols

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

1
1

$2H_2 + O_2 \longrightarrow 2H_2O$

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

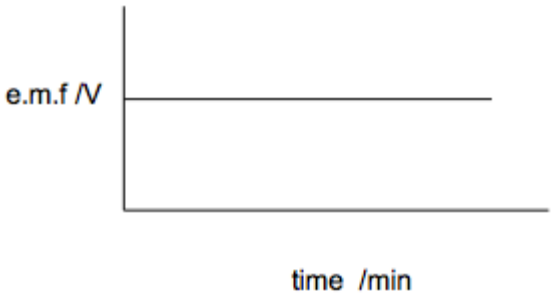
$2H_2 + O_2 \longrightarrow 2H_2O$ will move to the right

Or overall equation moves to the right

Allow $O_2 + 2H_2O + 4e^- \longrightarrow 4OH^-$ will move to the right / oxygen half equation moves to the RHS / $E^{\ominus}$ O_2|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 CO_2 or SO_2 or C or CO or C_xH_y or unburnt hydrocarbons

Not fuel cell does not give out pollutants unless pollutant stated

1

(d) CO_2 is released because fossil fuels are burned to produce electricity to generate hydrogen
OR

CO_2 is released when methane reacts with steam to produce hydrogen

Allow CO_2 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

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

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4 A

[1]

5 (a) Electron acceptor / gains electrons

do not allow electron pair acceptor

1

(b) Fe^{2+} ions

1

Fe^{2+} / Fe or Fe^{2+} or it has smallest / most negative electrode potential / E°

Do not allow Fe / Fe^{2+}

Cannot score M2 if M1 incorrect

1

(c) $Pt|H_2|H^+||Ag^+|Ag$

M1 for H_2 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 O_2 (/ H_2O) 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

<u>Au^+ (ions) oxidise water</u> OR <u>water reduces Au^+</u> (ions)

Allow water donates electrons to Au+

1

<u>Gold</u> metal / solid / precipitate **OR** <u>bubbles</u> / effervescence of (oxygen gas) / gas produced

Penalise incorrect observations

1

$2Au^+ + H_2O \rightarrow 2Au + 2H^+ + \frac{1}{2} O_2$ OR $4Au^+ + 2H_2O \rightarrow 4Au + 4H^+ + O_2$

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

[15]

6

(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^o 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]

7 (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) = 1.65 (V) / +1.65 (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

O_2 (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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8 (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]