M1. (a) Brown ppt/solid

1

Gas evolved/effervescence

1

$2[Fe(H_2O)_6]^{3+} + 3CO_3^{2-} \rightarrow 2Fe(H_2O)_3(OH)_3 + 3CO_2 + 3H_2O$

Must be stated, Allow CO_2 evolved. Do not allow CO_2 alone
Correct iron product (1) allow $Fe(OH)_3$ and in equation
Balanced equation (1)

2

(b) White ppt/solid

1

Colourless Solution

Only award M2 if M1 given or initial ppt mentioned

1

$[Al(H_2O)_6]^{3+} + 3OH^- \rightarrow Al(H_2O)_3(OH)_3 + 3H_2O$

Allow $[Al(H_2O)_6]^{3+} + 3OH^- \rightarrow Al(OH)_3 + 6H_2O$

1

$Al(H_2O)_3(OH)_3 + 3OH^- \rightarrow [Al(OH)_6]^{3-} + 3H_2O$

Allow formation of $[Al(H_2O)_{6-x}(OH)_x]^{(x-3)-}$ where x = 4,5,6
Allow product without water ligands
Allow formation of correct product from $[Al(H_2O)_6]^{3+}$

1

(c) Blue ppt/solid

1

(Dissolves to give a) deep blue solution

Only award M2 if M1 given or initial ppt mentioned

1

$[Cu(H_2O)_6]^{2+} + 2NH_3 \rightarrow Cu(H_2O)_4(OH)_2 + 2NH_4^+$

Allow $[Cu(H_2O)_6]^{2+} + 2NH_3 \rightarrow Cu(OH)_2 + 2NH_4^+ + 4H_2O$
Allow two equations: $NH_3 + H_2O \rightarrow NH_4^+ + OH^-$
then $[Cu(H_2O)_6]^{2+} + 2OH^- \rightarrow Cu(OH)_2 + 4H_2O$ etc

1

$Cu(H_2O)_4(OH)_2 + 4NH_3 \rightarrow [Cu(H_2O)_2(NH_3)_4]^{2+} + 2OH^- + 2H_2O$

Allow $[Cu(H_2O)_6]^{2+} + 4NH_3 \rightarrow [Cu(H_2O)_2(NH_3)_4]^{2+} + 4H_2O$

1

(d) Green/yellow <u>solution</u>

1

$[Cu(H_2O)_6]^{2+} + 4Cl^- \rightarrow [CuCl_4]^{2-} + 6H_2O$

1

[14]

M2. C

[1]

M3. (a) (i) Ammonia

If reagent is missing or incorrect cannot score M3

1

Starts as a pink (solution)

1

Changes to a yellow/straw (solution)

Allow pale brown

Do not allow reference to a precipitate

1

(ii) (dark) brown

Do not allow pale/straw/yellow-brown (i.e. these and other shades except for dark brown)

1

(b) (i) Ruby/red-blue/purple/violet/green

Do not allow red or blue

If ppt mentioned contradiction/CE =0

1

Green

If ppt mentioned contradiction/CE =0

1

$[Cr(H_2O)_6]^{3+} + 6OH^- \rightarrow [Cr(OH)_6]^{3-} + 6H_2O$

1

Formula of product

Can score this mark in (b) (ii)

1

(ii) $H_2O_2 + 2e^- \rightarrow 2OH^-$

1

$2[Cr(OH)_6]^{3-} + 3H_2O_2 \rightarrow 2CrO_4^{2-} + 8H_2O + 2OH^-$

Allow 1 mark out of 2 for a balanced half-equation such as $Cr(III) \rightarrow Cr(VI) + 3e^-$

or $Cr^{3+} + 4H_2O \rightarrow CrO_4^{2-} + 8H^+ + 3e^-$ *etc*

also for $2Cr(III) + 3H_2O_2 \rightarrow 2CrO_4^{2-}$ *(unbalanced)*

2

Yellow

Do not allow orange

1

(c) $2MnO_4^- + 6H^+ + 5H_2O_2 \rightarrow 2Mn^{2+} + 8H_2O + 5O_2$

if no equation and uses given ratio can score M2, M3, M4 & M5

1

Moles MnO_4^- = (24.35/1000) × 0.0187 = $\underline{4.55 \times 10^{-4}}$

Note value must be quoted to at least 3 sig. figs.

M2 is for 4.55×10^{-4}

1

Moles H_2O_2 = (4.55×10^{-4}) $\underline{\times 5/2}$ = 1.138×10^{-3}

M3 is for × 5/2 (or 7/3)

Mark consequential on molar ratio from candidate's equation

1

Moles H_2O_2 in 5 cm^3 original

M4 is for × 10

1

= (1.138×10^{-3}) $\underline{\times 10}$ = 0.01138

Original $[H_2O_2]$ = 0.01138 $\underline{\times (1000/5)}$ = 2.28 mol dm^{-3}

(allow 2.25-2.30)

M5 is for consequentially correct answer from (answer to mark 4) × (1000/5)

Note an answer of between 2.25 and 2.30 is worth 4 marks)

If candidate uses given ratio 3/7 max 4 marks:
***M1**: Moles of MnO_4^- = $\underline{4.55 \times 10^{-4}}$*
***M2**: Moles H_2O_2 = $(4.55 \times 10^{-4}) \underline{\times 7/3} = 1.0617 \times 10^{-3}$*
***M3**: Moles H_2O_2 in 5 cm^3 original*
= $(1.0617 \times 10^{-3}) \times 10 = 0.01062$
M4: Original $[H_2O_2] = 0.01062 \times (1000/5) = 2.12$ mol dm^{-3}
(allow 2.10 to 2.15)

1

[17]

M4.(a) $3C_2O_4^{2-} + [Co(H_2O)_6]^{2+} \rightarrow [Co(C_2O_4)_3]^{4-} + 6H_2O$

Accept multiples.
Equation must have cobalt(II) hexaaqua ion.

1

(b) Ethanedioate ion reduces iron(III) ion **or**
iron(III) ion oxidises ethanedioate ion

Allow answer using equations.

1

$E^{\ominus}(CO_2 / C_2O_4^{2-})$ more negative than $E^{\ominus}$ (Fe^{3+} / Fe^{2+}) **or**
$E^{\ominus}$ $(Fe^{3+} / Fe^{2+}) > E^{\ominus}$ $(CO_2 / C_2O_4^{2-})$
or e.m.f. positive **or** cell voltage = +1.26

1

[3]

M5. (a) W is $CuCl_4^{2-}$

1

Yellow-green/yellow/green

Not necessary to indicate solution
Do not allow precipitate/solid

1

$[Cu(H_2O)_6]^{2+} + 4Cl^- \rightarrow CuCl_4^{2-} + 6H_2O$

Allow + $4HCl \rightarrow 4H^+$

1

(b) X is $Cu(H_2O)_4(OH)_2$

Allow $Cu(OH)_2$/copper hydroxide

1

Blue precipitate/solid

Ignore shades

1

$[Cu(H_2O)_6]^{2+} + 2NH_3 \rightarrow Cu(H_2O)_4(OH)_2 + 2NH_4^+$

Allow any balanced equation/equations leading to this hydroxide or $Cu(OH)_2$
But must use ammonia

1

(c) Y is $[Cu(NH_3)_4(H_2O)_2]^{2+}$

1

Deep/dark/royal <u>blue solution</u>

QoL

1

$Cu(H_2O)_4(OH)_2 + 4NH_3 \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 2H_2O + 2OH^-$

Accept equation for formation from $Cu(OH)_2$

1

(d) Z is $CuCO_3$

Allow copper carbonate

1

Green solid/precipitate

Allow blue-green precipitate

1

$[Cu(H_2O)_6]^{2+} + CO_3^{2-} \rightarrow CuCO_3 + 6H_2O$

1

(e) (i) $Cu^{2+}(aq) + Fe(s) \rightarrow Cu(s) + Fe^{2+}(aq)$

Allow hydrated ions
State symbols not essential but penalise if wrong

1

Blue

Do not allow description of solids

1

Green

Allow yellow/(red-)brown/orange

1

(ii) Any two correct points about copper extraction from two of these three categories:

Any relevant mention of lower energy consumption

Do not allow reference to electricity alone or to temperature alone.

Any relevant mention of benefits of less mining (of copper ore)

Allow avoids depletion of (copper ore) resources

Less release of CO_2 (or CO) into the atmosphere

Not just greenhouse gases. Must mention CO_2 or CO

Max 2

[17]