M1.(a)*For reactions 1 to 3 must show complex ions as reactants and products*

Take care to look for possible identification on flow chart

Reaction 1

ammonia solution

1

W is $[Co(NH_3)_6]^{2+}$

1

$[Co(H_2O)_6]^{2+} + 6NH_3 \rightarrow [Co(NH_3)_6]^{2+} + 6H_2O$

Correct equation scores all 3 marks

1

Reaction 2

Allow oxygen, Do not allow air

H_2O_2

1

X is $[Co(NH_3)_6]^{3+}$

1

$2[Co(NH_3)_6]^{2+} + H_2O_2 \rightarrow 2[Co(NH_3)_6]^{3+} + 2OH^-$

Allow $2[Co(NH_3)_6]^{2+} + \frac{1}{2}O_2 + H_2O \rightarrow 2[Co(NH_3)_6]^{3+} + 2OH^-$

Correct equations score all 3 marks

1

Reaction 3

HCl

Do not allow Cl^- *but mark on*

1

Y is $[CoCl_4]^{2-}$

1

$[Co(H_2O)_6]^{2+} + 4Cl^- \rightarrow [CoCl_4]^{2-} + 6H_2O$/

Correct equation scores previous mark

$[Co(H_2O)_6]^{2+} + 4HCl \rightarrow [CoCl_4]^{2-} + 6H_2O + 4H_+$

This equation scores all three marks

1

Reaction 4

Na_2CO_3 Or $NaOH/NH_3$

Do not allow $CaCO_3$ as a reagent but mark on

1

Z is $CoCO_3$ $Co(OH)_2/Co(H_2O)_4(OH)_2$

1

$[Co(H_2O)_6]^{2+} + CO_3^{2-} \rightarrow CoCO_3 + 6H_2O$ $[Co(H_2O)_6]^{2+} + 2OH^- \rightarrow Co(H_2O)_4(OH)_2 + 2H_2O$ etc

Allow waters to stay co-ordinated to Co. This mark also previous mark

Or $[Co(H_2O)_6]^{2+} + Na_2CO_3 \rightarrow CoCO_3 + 6H_2O + 2Na^+$

Allow $Co^{2+} + CO_3^{2-} \rightarrow CoCO_3$

1

(b) $SO_3^{2-} + ½O_2 \rightarrow SO_4^{2-}$

Allow multiples

1

The activation energy is lower (for the catalysed route)

Or Co^{3+} attracts SO_3^{2-}/Co^{2+} attracts SO_3^{2-}/oppositely charged ions attract

1

$½O_2 + 2Co^{2+} + 2H^+ \rightarrow H_2O + 2Co^{3+}$

1

$2Co^{3+} + SO_3^{2-} + H_2O \rightarrow 2Co^{2+} + SO_4^{2-} + 2H^+$

Allow these equations in either order

1

[16]

M2. (a) $2Fe^{2+} + S_2O_8^{2-} \rightarrow 2Fe^{3+} + 2SO_4^{2-}$

1

$2Fe^{3+} + 2I^- \rightarrow 2Fe^{2+} + I_2$

1

two negative ions repel / lead to reaction that is slow / lead to reaction that has high E_a

1

iron able to act because changes its oxidation state

allow iron has variable oxidation state

1

With iron ions have alternative route / route with lower activation energy

1

(b) (i) $[Fe(H_2O)_6]^{3+} \rightarrow [Fe(H_2O)_5OH]^{2+} + H^+$

can have H_2O on LHS and H_3O^+ on R

do not penalise further hydrolysis equations

allow high charge density

1

Fe^{3+} ion has high<u>er</u> charge (to size ratio) (than Fe^{2+})

1

increases polarisation of co-ordinated water / attracts O releasing an H^+ ion / weakens O–H bond

1

(ii) $Cr_2O_7^{2-} + 14H^+ + 6Fe^{2+} \rightarrow 2Cr^{3+} + 7H_2O + 6Fe^{3+}$

or 6 mol Fe(II) react with 1 mol dichromate

If factor of 6 not used max = 3 for M2, M4 and M5

e.g. 1:1 gives ans= 8.93 to 8.98% (scores 3)

1

moles dichromate = 23.6 × 0.218/1000 = 5.14×10^{-4}

1

moles iron = 5.14×10^{-4} × 6 = 0.00309

M3 also scores M1

1

mass iron = 0.00309 × 55.8 = 0.172

Mark is for moles of iron × 55.8 conseq

Allow use of 56 for iron

1

% by mass of iron = 0.172 × 100/0.321 = 53.7%

Answer must be to at least 3 sig figures allow 53.6 to 53.9

Mark is for mass of iron × 100/0.321 conseq

1

(c) brown precipitate / solid

Allow red-brown / orange solid

Not red or yellow solid

1

bubbles (of gas) / effervescence/ fizz

Allow gas evolved / given off

Do not allow just gas or CO_2 or CO_2 gas

1

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

Allow

$2[Fe(H_2O)_6]^{3+} + 3CO_3^{2-} \rightarrow 2Fe(OH)_3 + 3CO_2 + 9H_2O$

Use of Na_2CO_3

e.g. … + $3Na_2CO_3 \rightarrow$ .. + .. + .. + $6Na^+$

1

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M3. (a) Same phase/state

1

(b) Because only exist in one oxidation state

Allow do not have variable oxidation states

1

(c) $2I^- + S_2O_8^{2-} \rightarrow I_2 + 2SO_4^{2-}$

Ignore state symbols
Allow multiples

1

(d) Both (ions)have a negative charge

Or both have the same charge
Or (ions) repel each other
Do not allow both molecules have the same charge (contradiction)

1

(e) $2Fe^{2+} + S_2O_8^{2-} \rightarrow 2Fe^{3+} + 2SO_4^{2-}$

1

$2Fe^{3+} + 2I^- \rightarrow 2Fe^{2+} + I_2$

1

Equations can be in any order

Positive and negative (ions)/oppositely charged (ions)

Mark independently

1

(f) Equations 1 and 2 can occur in any order

Allow idea of Fe^{3+} converted to Fe^{2+} then Fe^{2+} converted back to Fe^{3+}

1

[8]

M4. (a) Incomplete (or partially filled) d orbitals/sub-shells

Do not allow d shell

1

(b) Variable oxidation states

1

(c) (i) $[H_3N–Ag–NH_3]^+$

Allow $[Cl–Ag–Cl]^-$ or similar Cu(I) ion

Allow compounds in (i), (ii) and (iii) (eg Cl-Be-Cl)

Allow no charge shown, penalise wrong charge(s)

1

(ii) Cis platin drawn out as square planar

Allow NiX_4^{2-} etc

1

(iii) $[CuCl_4]^{2-}$ drawn out as tetrahedral ion

Or $[CoCl_4]^{2-}$ drawn out

1

(d) (i) $SO_2 + 1/2O_2 \rightarrow SO_3$

Allow multiples

Allow $SO_2 + 1/2O_2 + H_2O \rightarrow H_2SO_4$

ignore state symbols

1

(ii) In a different phase/state (from the reactants)

1

(iii) $V_2O_5 + SO_2 \rightarrow V_2O_4 + SO_3$

can be in either order

1

$V_2O_4 + 1/2O_2 \rightarrow V_2O_5$

allow multiples

1

(iv) Surface area is increased

1

By use of powder or granules or finely divided

Allow suspending/spreading out onto a mesh or support

1

(e) (i) Forms two or more co-ordinate bonds

Allow more than one co-ordinate bond or <u>donates</u> more than 1 electron pair.

Do not allow "has more than one electron pair"

Allow uses more than one atom to bond (to TM)

1

(ii) Number of product particles > Number of reactant particles

Allow molecules/entities instead of particles

Penalise incorrect numbers (should be 2→5)

1

Disorder increases or entropy increases
(or entropy change is positive)

Allow ΔG must be negative because ΔH = 0 and ΔS is +ve

1

(iii) 6

1

Cyanide strongly bound to Co (by co-ordinate/covalent bond)

1

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