M1.(a) $2MnO_4^- + 16H^+ + 5C_2O_4^{2-} \rightarrow 2Mn^{2+} + 8H_2O + 10CO_2$

1

Mn^{2+} OR Mn^{3+}

If catalyst incorrect can only score M1 and M3

1

(Possible because) Mn can exist in variable oxidation states

1

E_a lowered because oppositely charged ions attract

These marks can be gained in any order

1

Mn^{3+} (reduced) to Mn^{2+} by $C_2O_4^{2-}$ / equation

M5 may appear before M2

1

Mn^{2+} (oxidised (back)) to Mn^{3+} by MnO_4^- / equation

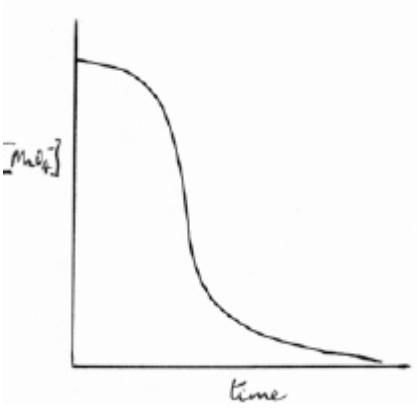
M5 and M6 can be scored in unbalanced equations or in words showing:

$Mn^{3+} + C_2O_4^{2-} \rightarrow Mn^{2+}$

$Mn^{2+} + MnO_4^- \rightarrow Mn^{3+}$

1

(b) **Graph marks**



S-shaped curve must not rise significantly and must not fall rapidly initially.

Starts on concentration axis **and** is levelling out (can level out on time axis or above but parallel to time axis)

Cannot score graph marks (M1 and M2) if no axes and / or no labels

1
1

Explanation marks

Slope / rate increases as catalyst (concentration) forms

1

Slope / rate decreases as (concentration) of MnO_4^- ions / reactant(s) decreases (OR reactants are being used up)

Explanation marks can be awarded independent of graph.

1

[10]

M2.(a) $2MnO_4^- + 16H^+ + 5C_2O_4^{2-} \longrightarrow 2Mn^{2+} + 8H_2O + 10CO_2$

For all species correct / moles and species correct but charge incorrect

1

For balanced equation including all charges (also scores first mark)

1

(b) Manganate(VII) ions are coloured (purple)

1

All other reactants and products are **not** coloured (or too faintly coloured to detect)

Allow (all) other species are colourless

Allow Mn^{2+} are colourless / becomes colourless / pale pink

1

(c) The catalyst for the reaction is a reaction product

1

Reaction starts off slowly / gradient shallow

1

Then gets faster/rate increases / gradient increases

Allow concentration of MnO_4^- decreases faster / falls rapidly

1

(d) Mn^{2+} ions

Allow Mn^{3+} ions

1

(e) $MnO_4^- + 8H^+ + 4Mn^{2+} \longrightarrow 5Mn^{3+} + 4H_2O$

Allow multiples

1

$2Mn^{3+} + C_2O_4^{2-} \longrightarrow 2Mn^{2+} + 2CO_2$

1

[10]

M3.(a) Negative ions repel one another

1

(b) Positive ions attract negative ions in catalysed process

Allow activation energy decreases.

Allow alternative route with lower E_a

Ignore references to heterogenous catalysis.

1

(c) $S_2O_8^{2-} + 2e^- \longrightarrow 2SO_4^{2-}$

Allow multiples including fractions.

Ignore state symbols.

1

(d) $S_2O_8^{2-} + 2I^- \longrightarrow 2SO_4^{2-} + I_2$

Allow multiples including fractions.

Ignore state symbols.

Allow the correct equation involving I_3^-

$S_2O_8^{2-} + 3I^- \longrightarrow 2SO_4^{2-} + I_3^-$

1

[4]

M4.(a) Variable / many oxidation states

1

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

Equations can be in either order

Allow multiples

1

$V_2O_4 + ½O_2 \rightarrow V_2O_5$

1

(c) (i) In a different phase / state <u>from reactants</u>

1

(ii) Impurities poison / deactivate the catalyst / block the active sites

Allow (adsorbs onto catalyst AND reduces surface area)

1

(d) (i) The catalyst is a reaction product

1

(ii) Mn^{2+} / Mn^{3+} ion(s)

1

(iii) $4Mn^{2+} + MnO_4^- + 8H^+ \rightarrow 5Mn^{3+} + 4H_2O$

Equations can be in either order

1

$2Mn^{3+} + C_2O_4^{2-} \rightarrow 2Mn^{2+} + 2CO_2$

1

[9]

M5.(a) Cobalt has variable oxidation states

Allow exists as Co(II) and Co(III)

1

(It can act as an intermediate that) lowers the activation energy

Allow (alternative route with) lower E_a

1

$CH_3CHO + 2Co^{3+} + H_2O \rightarrow CH_3COOH + 2Co^{2+} + 2H^+$

Allow multiples; allow molecular formulae

Allow equations with H_3O+

1

$\frac{1}{2}O_2 + 2Co^{2+} + 2H^+ \rightarrow 2Co^{3+} + H_2O$

1

(b) (i) $[Co(H_2O)_6]^{2+} + 3H_2NCH_2CH_2NH_2 \rightarrow [Co(H_2NCH_2CH_2NH_2)_3]^{2+} + 6H_2O$

Do not allow en in equation, allow $C_2H_8N_2$

1

The number of particles increases / changes from 4 to 7

Can score M2 and M3 even if equation incorrect or missing provided number of particles increases

1

So the entropy change is positive / disorder increases / entropy increases

1

(ii) Minimum for **M1** is 3 bidentate ligands bonded to Co

Ignore all charges for M1 and M3 but penalise charges on any ligand in M2

1

Ligands need not have any atoms shown but diagram must show 6 bonds from ligands to Co, 2 from each ligand

Minimum for **M2** is one ligand identified as H_2N-----NH_2

Allow linkage as −C−C− or just a line.

1

Minimum for **M3** is one bidentate ligand showing two arrows from separate nitrogens to cobalt

1

(c) Moles of cobalt = (50 × 0.203) / 1000 = 0.01015 mol

Allow 0.0101 to 0.0102

1

Moles of AgCl = 4.22/143.4 = 0.0294

Allow 0.029

*If not AgCl (eg $AgCl_2$ or $AgNO_3$), lose this mark and can only score **M1, M4** and **M5***

1

Ratio = Cl^- to Co = 2.9 : 1

*Do not allow 3 : 1 if this is the only answer but if 2.9:1 seen somewhere in answer credit this as **M3***

1

$[Co(NH_3)_6]Cl_3$ (square brackets not essential)

1

Difference due to incomplete oxidation in the preparation

Allow incomplete reaction.

Allow formation $[Co(NH_3)_5Cl]Cl_2$ etc.

Some chloride ions act as ligands / replace NH_3 in complex.

Do not allow 'impure sample' or reference to practical deficiencies

1

[15]

M6.(a) Stoppered flask or similar with side arm

Allow gas outlet through stopper.

1

Calibrated container for collection eg gas syringe

Allow collection over water, but must use calibrated vessel for collection.

Lose 1 mark if apparatus is not gas tight.

1

(b) Plot a graph of 'volume (of gas)' against 'time'

1

Determine the slope (gradient) at the beginning

1

(c) Repeat with same volume **or** concentration of hydrogen peroxide and at the same temperature

Ignore references to results.

Do not allow 'keep everything the same' or words to that effect. Must mention volume or concentration and temperature.

1

Add cobalt(II) chloride to one experiment

1

[6]