1 (a) In each of **P** and **Q** the oxidation state of Cr is +3 / both contain Cr^{3+}

If oxidation states are different lose M1 and M2

1

In each of **P** and **Q** the electron configuration is the same / d^3 / $3d^3$

Do not allow just same number of electrons

1

Ligands are different

1

Different energies of (d) electrons / different split of (d) electron energy levels / different energy gap of (d) electrons / different (d) orbital energy

1

Different wavelengths / frequencies / energies of light / colours (of light) are absorbed (by the d electrons)

Reference to emission and / or uv light but not to visible loses M5 and M6

1

Different wavelengths / frequencies / energies of light / colours (of light) are transmitted / reflected

1

(b) $[Co(NH_3)_6]^{2+} + 3NH_2CH_2CH_2NH_2 \rightarrow [Co(NH_2CH_2CH_2NH_2)_3]^{2+} + 6NH_3$

Allow $NH_2C_2H_4NH_2$ and $CH_2NH_2CH_2NH_2$

Allow partial substitution

Do not allow en or other formulae for M1 but can score M2

1

4 particles form 7 particles / increase in number of particles

Allow molecules, entities, ions, moles instead of particles

Do not allow atoms

Can score M2 if numbers match candidates incorrect equation provided number of particles increases

1

disorder / entropy increases / ΔS positive

Cannot score M3 if number of particles stated or in equation is the same or decreases

1

ΔH is approx. zero / no net change in bond enthalpies

Allow same number and type of bonds broken and formed

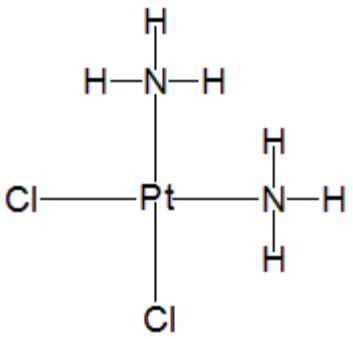
1

ΔG is negative / $\Delta G <= 0$

Mark M4 and M5 independently

1

(c) (i)



Correct displayed structure

Must show all three N–H bonds on each N

Ignore arrows and lone pairs, attempt to show shape

Ignore charges on atoms in structure for M1

1

Bond angle 90°

Allow 87 to 93 degrees

Allow this angle for any complex with 4 ligands eg if NH_2 or Cl used instead of NH_3

1

Charge of zero

Award this mark if no charge shown on structure but if charges shown on ligands in M1 must state that overall charge = 0

Allow M3 only if cisplatin is correct OR if trans form OR if NH_3 not displayed OR if NH_2 used instead of NH_3

1

(ii) $(NH_3)_2PtCl_2 + H_2O \rightarrow [(NH_3)_2PtCl(H_2O)]^+ + Cl^-$

If formula of cisplatin is incorrect, mark consequentially provided

H_2O replaces Cl^- and charge on complex increases by one

1

(iii) Use in small amounts / short bursts / target the application / monitor the patients

Allow: Give patient time between doses

1

(d) $V_2O_5 + SO_2 \rightarrow V_2O_4 + SO_3$ / $V_2O_5 + SO_2 \rightarrow 2VO_2 + SO_3$

Allow multiples

1

$V_2O_4 + \frac{1}{2}O_2 \rightarrow V_2O_5$ / $2VO_2 + \frac{1}{2}O_2 \rightarrow V_2O_5$

1

Acts as a catalyst / lowers the activation energy

1

Speeds up the (overall) reaction (between SO_2 and oxygen)

1

[20]

2 (a) moles of $Cr_2O_7^{2-}$ per titration = 21.3 × 0.0150 / 1000 = $\underline{3.195 \times 10^{-4}}$

1

($Cr_2O_7^{2-} + 14H^+ + 6Fe^{2+} \rightarrow 2Cr^{3+} + 7H_2O + 6Fe^{3+}$) $Cr_2O_7^{2-}$:Fe^{2+} = 1:6

If 1:6 ratio incorrect cannot score M2 or M3

1

moles of $Fe^{2+} = 6 \times 3.195 \times 10^{-4} = 1.917 \times 10^{-3}$

Process mark for M1 × 6 (also score M2)

1

original moles in 250 $cm^3 = 1.917 \times 10^{-3} \times 10 = 1.917 \times 10^{-2}$

Process mark for M3 × 10

1

mass of $FeSO_4.7H_2O = 1.917 \times 10^{-2} \times 277.9 = 5.33$ (g)

Mark for answer to M4 × 277.9

(allow 5.30 to 5.40)

*Answer **must** be to at least 3 sig figs*

Note that an answer of 0.888 scores M1, M4 and M5 (ratio 1:1 used)

1

(b) (Impurity is a) reducing agent / reacts with dichromate / impurity is a version of $FeSO_4$ with fewer than 7 waters (not fully hydrated)

Allow a reducing agent or compound that that converts Fe^{3+} into Fe^{2+}

1

Such that for a given mass, the impurity would react with more dichromate than a similar mass of $FeSO_4.7H_2O$

OR for equal masses of the impurity and $FeSO_4.7H_2O$, the impurity would react with more dichromate.

Must compare mass of impurity with mass of $FeSO_4.7H_2O$

1

[7]

3 (a) Negative ions <u>repel</u> one another

1

(b) Positive ions <u>attract</u> 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]

4

(a) $\Delta E = hv$

Allow = hf

1

$v = \Delta E / h = 2.84 \times 10^{-19} / 6.63 \times 10^{-34} = 4.28 \times 10^{14}$ s^{-1} / Hz

Allow 4.3×10^{14} s^{-1} / Hz

Answer must be in the range:

$4.28 - 4.30 \times 10^{14}$

1

(b) (One colour of) light is absorbed (to excite the electron)

If light emitted, CE = 0

1

The remaining colour / frequency / wavelength / energy is transmitted (through the solution)

Allow light reflected is the colour that we see.

1

(c) Bigger

1

Blue light would be absorbed

OR light that has greater energy than red light would be absorbed
OR higher frequency (of light absorbed / blue light) leads to higher *ΔE*

Can only score M2 if M1 is correct.

1

(d) Any **three** from:

- (Identity of the) metal
- Charge (on the metal) / oxidation state / charge on complex
- (Identity of the) ligands
- Co-ordination number / number of ligands
- Shape

3 max

[9]

5

(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 = <u>0.01015</u> 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]

6 (a) Percentage of oxygen is 42.5% **(M1)**

Allow if shown clearly in the calculation.

1

Co 13.0 / 58.9 = 0.221, N 18.6 / 14 = 1.329,

K 25.9 / 39.1 = 0.662, O 42.5 / 16 = 2.656 **(M2)**

Allow alternative method if chemically correct.

*If A_r has been divided by the percentage, chemical error, lose **M2** and **M3**.*

1

$CoN_6K_3O_{12}$ **(M3)**

Allow in any order.

Correct answer without working scores this mark only.

1

(b) $Co(NO_2)_6^{3-}$

Allow a correct diagram bonding through N or O

Do not allow $CoN_6O_{12}^{3-}$

Must have correct overall charge.

Allow consequential answer from part(a) if the charge on the anion is correct.

1

[4]

7 (a) $FeSO_4 + Na_2C_2O_4 \rightarrow FeC_2O_4 + Na_2SO_4$

Allow multiples, including fractions.

Allow $Fe^{2+} + C_2O_4^{2-} \rightarrow FeC_2O_4$

Allow correct equation which includes water of crystallisation.

1

(b) M_r $FeSO_4.7H_2O = 277.9$

Allow if shown clearly in the calculation.

Allow 278

1

Moles = $6.95 / 277.9 = 2.5(0) \times 10^{-2}$

Do not penalise precision but must be to a minimum of two significant figures.

Allow correct calculation using incorrect M_r.

Correct answer without working scores this mark only.

1

(c) $3(.00) \times 10^{-2}$

1

(d) Theoretical mass = $2.50 \times 10^{-2} \times 179.8 = 4.50$g
as long as 2.50×10^{-2} is the smaller of parts (b) and (c) **(M1)**

Allow consequential answer from parts (b) and (c).

Allow theoretical mass = (smaller of parts (b) and (c)) × 179.8

*If larger of parts (b) and (c) used, lose **M1** but can score **M2**.*

Allow answers based on moles of reactant and product.

1

Yield = $3.31 \times 100 / 4.50 = 73.6\%$ **(M2)**

Award this mark only if answer given to 3 significant figures.

Correct answer without working scores this mark only, provided answer given to 3 significant figures.

1

(e) Some left in solution / some lost during filtration

Do not allow 'incomplete reaction'.

Do not allow 'reaction is reversible'.

1

(f) MnO_4^- will oxidise the iron(II) ion and the ethanedioate ion

1

MnO_4^- does not oxidise the Cu^{2+} ion / larger volume needed for iron(II) ethanedioate

1

[9]

8 (a) Water in the gaseous state from the precipitate absorbed by drying agent

OR

Water vapour from the precipitate absorbed by drying agent

Allow 'water vapour reacts with drying agent'.

Do not allow 'absorb water' without qualification.

1

(b) (Blue to) pink / pink colour observed

1

[2]

9 (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]

10 (a) (i) Two rings only around nitrogen or sulfur

Lose this mark if more than 2 atoms are ringed.

Do not allow two atoms at the same end of the ion.

1

(ii) 275.8

Accept this answer only. Do not allow 276

1

(iii) Carboxylate / COO^-

Allow salt of carboxylic acid or just carboxylic acid.

1

(b) (32.1 / 102.1) = 31.4%

Do not penalise precision but do not allow 1 significant figure.

1

(c) Zineb is mixed with a solvent / water

Max=2 if M1 missed

1

Use of column / paper / TLC

Lose M1 and M2 for GLC

1

Appropriate collection of the ETU fraction
OR Appropriate method of detecting ETU

Allow ETU is an early fraction in a column or collecting a range of samples over time, lowest retention time / travels furthest on paper or TLC (allow 1 mark for having the longest retention time in GLC).

1

Method of identification of ETU (by comparison with standard using chromatography)

If method completely inappropriate, only M1 is accessible

1

[8]

11 (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 from reactants

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]

12 (a) A ligand is an electron pair / lone pair donor

Allow uses lone / electron pair to form a co-ordinate bond

1

A bidentate ligand donates two electron pairs (to a transition metal ion) from different atoms / two atoms (on the same molecule / ion)

QoL

1

(b) $CoCl_4^{2-}$ diagram

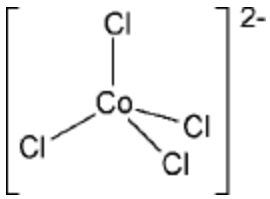
1

Tetrahedral shape

1

109°28'

1



Four chlorines attached to Co with net 2− charge correct

Charge can be placed anywhere, eg on separate formula

Penalise excess charges

Allow 109° to 109.5°

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

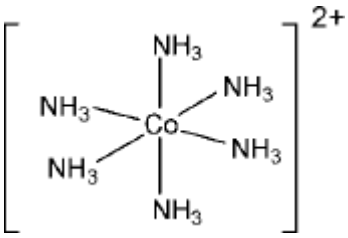
1

Octahedral shape

1

90°

1



Six ammonia / NH_3 molecules attached to Co with 2+ charge correct

Allow 180° if shown clearly on diagram

CE= 0 if wrong complex but mark on if only charge is incorrect

(c) In different complexes the d orbitals / d electrons (of the cobalt) will have different energies / d orbital splitting will be different

1

Light / energy is absorbed causing an electron to be excited

1

Different frequency / wavelength / colour of light will be absorbed / transmitted / reflected

1

(d) 1 mol of H_2O_2 oxidises 2 mol of Co^{2+}

Or $H_2O_2 + 2Co^{2+} \rightarrow 2OH^- + 2Co^{3+}$

1

M_r $CoSO_4.7H_2O$ = 281

If M_r wrong, max 3 for M1, M4, M5

1

Moles Co^{2+} = 9.87 / 281 = 0.03512

1

Moles H_2O_2 = 0.03512 / 2 = 0.01756

M4 is method mark for (M3) / 2 (also scores M1)

1

Volume H_2O_2 = (moles × 1000) / concentration
= 0.01756 × 1000) / 5.00

= 3.51 cm^3 / (3.51 × 10^{-3} dm^3)

Units essential for answer

M5 is method mark for (M4) x 1000 / 5

Allow 3.4 to 3.6 cm^3

If no 2:1 ratio or ratio incorrect Max 3 for M2, M3 & M5

Note: Answer of 7 cm^3 scores 3 for M2, M3, M5 (and any other wrong ratio max 3)

Answer of 16.8 cm^3 scores 3 for M1, M4, M5 (and any other wrong M_r max 3)

Answer of 33.5 cm^3 scores 1 for M5 only (so wrong M_r AND wrong ratio max 1)

1

[16]

13 (a) Co-ordinate / dative / dative covalent / dative co-ordinate

Do not allow covalent alone

1

(b) (lone) pair of electrons on oxygen/O

If co-ordination to O^{2-}, CE=0

1

forms co-ordinate bond with Fe / donates electron pair to Fe

'Pair of electrons on O donated to Fe' scores M1 and M2

1

(c) 180° / 180 / 90

Allow any angle between 85 and 95

Do not allow 120 or any other incorrect angle

Ignore units eg °C

1

(d) (i) 3 : 5 / 5 FeC_2O_4 reacts with 3 MnO_4^-

Can be equation showing correct ratio

1

(ii) **M1** Moles of MnO_4^- per titration = 22.35 × 0.0193/1000 = 4.31×10^{-4}

Method marks for each of the next steps (no arithmetic error allowed for M2):

Allow 4.3×10^{-4} (2 sig figs)

Allow other ratios as follows:

eg from given ratio of 7/3

1

M2 moles of FeC_2O_4= ratio from (d)(i) used correctly × 4.31×10^{-4}

M2 *= 7/3 × 4.31×10^{-4} = 1.006×10^{-3}*

1

M3 moles of FeC_2O_4 in 250 cm^3 = M2 ans × 10

M3 *= $1.006 \times 10^{-3} \times 10 = 1.006 \times 10^{-2}$*

1

M4 Mass of $FeC_2O_4.2H_2O$ = M3 ans × 179.8

M4 *= $1.006 \times 10^{-2} \times 179.8 = 1.81$ g*

1

M5 % of $FeC_2O_4.2H_2O$ = (M4 ans/1.381) × 100

M5 *= 1.81 × 100/1.381 = 131 % (130 to 132)*

1

(OR for M4 max moles of $FeC_2O_4.2H_2O$ = 1.381/179.8 (= 7.68×10^{-3})
for M5 % of $FeC_2O_4.2H_2O$ = (M3 ans/above M4ans) × 100)

eg using correct ratio 5/3:

Moles of $FeC_2O_4 = 5/3 \times 4.31 \times 10^{-4} = 7.19 \times 10^{-4}$

Moles of FeC_2O_4 in 250 $cm^3 = 7.19 \times 10^{-4} \times 10 = 7.19 \times 10^{-3}$

Mass of $FeC_2O_4.2H_2O = 7.19 \times 10^{-3} \times 179.8 = 1.29$ g

% of $FeC_2O_4.2H_2O = 1.29 \times 100/1.381 = 93.4$ (allow 92.4 to 94.4)

Note correct answer (92.4 to 94.4) scores 5 marks

Allow consequentially on candidate's ratio

eg ***M2*** $= 5/2 \times 4.31 \times 10^{-4} = 1.078 \times 10^{-3}$

M3 $= 1.0078 \times 10^{-3} \times 10 = 1.078 \times 10^{-2}$

M4 $= 1.078 \times 10^{-2} \times 179.8 = 1.94$ g

M5 $= 1.94 \times 100/1.381 = 140$ % (139 to 141)

Other ratios give the following final % values

1:1 gives 56.1% (55.6 to 56.6)

5:1 gives 281% (278 to 284)

5:4 gives 70.2% (69.2 to 71.2)

[10]