M1.(a) $[Fe(H_2O)_6]^{2+} + 2NH_3 \rightarrow Fe(H_2O)_4(OH)_2 + 2NH_4^+$

Allow equation with OH^- provided equation showing formation of OH^- from NH_3 given

1

Green precipitate

1

$[Fe(H_2O)_6]^{2+} + CO_3^{2-} \rightarrow FeCO_3 + 6H_2O$

1

Green precipitate

effervescence incorrect so loses M4

1

(b) (i) Colourless / (pale) green changes to pink / purple (solution)

Do not allow pale pink to purple

1

Just after the end−point MnO_4^- is in excess / present

1

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

1

Moles $KMnO_4$ = 18.7 × 0.0205 / 1000 = (3.8335 × 10^{-4})

Process mark

1

Moles Fe^{2+} = 5 × 3.8335 × 10^{-4} = 1.91675 × 10^{-3}

Mark for M2 × 5

1

Moles Fe^{2+} in 250 cm^3 = 10 × 1.91675 × 10^{-3} = 0.0191675 moles in 50 cm^3

Process mark for moles of iron in titration (M3) × 10

1

Original conc Fe^{2+} = 0.0191675 × 1000 / 50 = 0.383 mol dm^{-3}

Answer for moles of iron (M4) × 1000 / 50

Answer must be to at least 2 sig. figs. (0.38)

1

[11]

M2.(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]

M3.(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]

M4.(a) **Y**

1

(b) **X**

1

(c) Jump in trend of ionisation energies after removal of fifth electron

Fits with an element with 5 outer electrons ($4s^2 3d^3$) like V

1

(d) Explanation: Two different colours of solution are observed

1

Because each colour is due to vanadium in a different oxidation state

1

(e) **Stage 1:** mole calculations in either order

Moles of vanadium = 50.0 × 0.800 / 1000 = 4.00×10^{-2}

Extended response

Maximum of 5 marks for answers which do not show a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.

1

Moles of SO_2 = pV / RT = ($98\ 000 \times 506 \times 10^{-6}$) / (8.31×293)

= 2.04×10^{-2}

1

Stage 2: moles of electrons added to NH_4VO_3

When SO_2 (sulfur(IV) oxide) acts as a reducing agent, it is oxidised to sulfate(VI) ions so this is a two electron change

1

Moles of electrons released when SO_2 is oxidised = $2.04 \times 10^{-2} \times 2$

= 4.08×10^{-2}

1

Stage 3: conclusion

But in NH_4VO_3 vanadium is in oxidation state 5

1

4.00×10^{-2} mol vanadium has gained 4.08×10^{-2} mol of electrons therefore 1 mol vanadium has gained 4.08×10^{-2} / $4.00 \times 10 - 2 = 1$ mol of electrons to the nearest integer, so new oxidation state is $5 - 1 = 4$

1

[11]

M5.(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]

M6.(a) moles of $Cr_2O_7^{2-}$ per titration = $21.3 \times 0.0150 / 1000 = \underline{3.195 \times 10^{-4}}$

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]