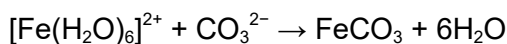


*Allow equation with OH<sup>-</sup> provided equation showing formation of OH<sup>-</sup> from NH<sub>3</sub> given*

1

Green precipitate

1



1

Green precipitate

*effervescence incorrect so loses M4*

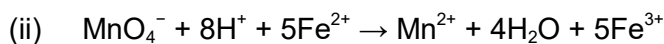
1

- (b) (i) Colourless / (pale) green changes to pink / purple (solution)  
*Do not allow pale pink to purple*

1

Just after the end-point  $\text{MnO}_4^-$  is in excess / present

1



1

Moles  $\text{KMnO}_4 = 18.7 \times 0.0205 / 1000 = (3.8335 \times 10^{-4})$

*Process mark*

1

Moles  $\text{Fe}^{2+} = 5 \times 3.8335 \times 10^{-4} = 1.91675 \times 10^{-3}$

*Mark for M2 × 5*

1

Moles  $\text{Fe}^{2+}$  in  $250 \text{ cm}^3 = 10 \times 1.91675 \times 10^{-3} = 0.0191675$  moles in  $50 \text{ cm}^3$

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

1

Original conc  $\text{Fe}^{2+} = 0.0191675 \times 1000 / 50 = 0.383 \text{ mol dm}^{-3}$

*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

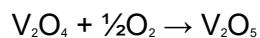
1



*Equations can be in either order*

*Allow multiples*

1



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)*

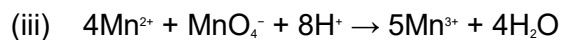
1

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

1

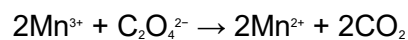
(ii)  $Mn^{2+} / Mn^{3+}$  ion(s)

1



*Equations can be in either order*

1



1

[9]

**M3.(a)** Cobalt has variable oxidation states

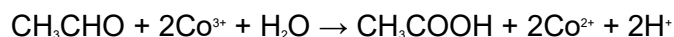
Allow exists as Co(II) and Co(III)

1

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

Allow (alternative route with) lower  $E_a$

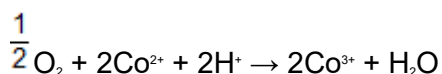
1



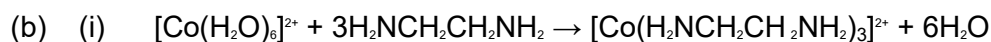
Allow multiples; allow molecular formulae

Allow equations with  $\text{H}_3\text{O}^+$

1



1



Do not allow en in equation, allow  $\text{C}_2\text{H}_6\text{N}_2$

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  $\text{H}_2\text{N}-----\text{NH}_2$

Allow linkage as  $-\text{C}-\text{C}-$  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 =  $(50 \times 0.203) / 1000 = \underline{0.01015}$  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<sub>2</sub> or AgNO<sub>3</sub>), lose this mark and can only score **M1**, **M4** and **M5***

1

Ratio = Cl<sup>-</sup> 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<sub>3</sub>)<sub>6</sub>]Cl<sub>3</sub> (square brackets not essential)

1

Difference due to incomplete oxidation in the preparation

*Allow incomplete reaction.*

*Allow formation [Co(NH<sub>3</sub>)<sub>5</sub>Cl]Cl<sub>2</sub> etc.*

*Some chloride ions act as ligands / replace NH<sub>3</sub> 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 ( $4s^23d^3$ ) 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 =  $50.0 \times 0.800 / 1000 = 4.00 \times 10^{-2}$

*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  $\text{SO}_2 = pV / RT = (98\,000 \times 506 \times 10^{-6}) / (8.31 \times 293)$

$= 2.04 \times 10^{-2}$

1

**Stage 2:** moles of electrons added to  $\text{NH}_4\text{VO}_3$

When  $\text{SO}_2$  (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  $\text{SO}_2$  is oxidised =  $2.04 \times 10^{-2} \times 2$

$= 4.08 \times 10^{-2}$

1

**Stage 3: conclusion**

But in  $\text{NH}_4\text{VO}_3$  vanadium is in oxidation state 5

1

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

1

[11]

**M5.(a)** Negative ions 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)  $\text{S}_2\text{O}_8^{2-} + 2\text{e}^- \longrightarrow 2\text{SO}_4^{2-}$   
*Allow multiples including fractions.*  
*Ignore state symbols.*

1

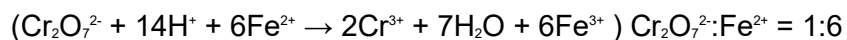
- (d)  $\text{S}_2\text{O}_8^{2-} + 2\text{I}^- \longrightarrow 2\text{SO}_4^{2-} + \text{I}_2$   
*Allow multiples including fractions.*  
*Ignore state symbols.*  
*Allow the correct equation involving  $\text{I}_3^-$*   
 $\text{S}_2\text{O}_8^{2-} + 3\text{I}^- \longrightarrow 2\text{SO}_4^{2-} + \text{I}_3^-$

1

[4]

**M6.(a)** moles of  $\text{Cr}_2\text{O}_7^{2-}$  per titration =  $21.3 \times 0.0150 / 1000 = \underline{3.195 \times 10^{-4}}$

1



*If 1:6 ratio incorrect cannot score M2 or M3*

1

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

*Process mark for M1  $\times$  6 (also score M2)*

1

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

*Process mark for M3  $\times$  10*

1

$$\text{mass of FeSO}_4 \cdot 7\text{H}_2\text{O} = 1.917 \times 10^{-2} \times 277.9 = 5.33 \text{ (g)}$$

*Mark for answer to M4  $\times$  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  $\text{FeSO}_4$  with fewer than 7 waters (not fully hydrated)

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

1

Such that for a given mass, the impurity would react with more dichromate than a similar mass of  $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$

OR for equal masses of the impurity and  $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ , the impurity would react with more dichromate.

*Must compare mass of impurity with mass of  $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$*

1

[7]