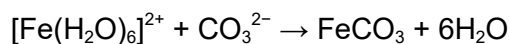


Allow equation with OH⁻ provided equation showing formation of OH⁻ from NH₃ given

1

Green precipitate

1



1

Green precipitate

effervescence incorrect so loses M4

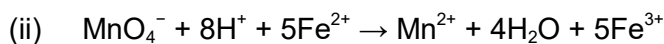
1

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

1

Just after the end-point 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 Fe^{2+} in $250 \text{ cm}^3 = 10 \times 1.91675 \times 10^{-3} = 0.0191675$ moles in 50 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

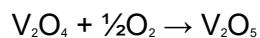
1



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)

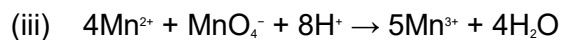
1

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

1

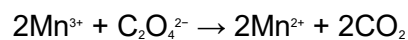
(ii) Mn^{2+} / Mn^{3+} ion(s)

1



Equations can be in either order

1



1

[9]

M3.(a) Cobalt has variable oxidation states

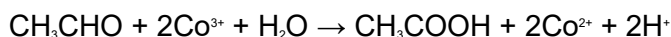
Allow exists as Co(II) and Co(III)

1

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

Allow (alternative route with) lower E_a

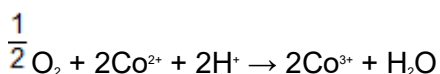
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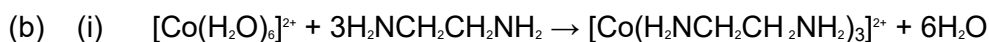
Allow multiples; allow molecular formulae

Allow equations with H_3O^+

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 AgCl₂ or AgNO₃), 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(NH₃)₆]Cl₃ (square brackets not essential)

1

Difference due to incomplete oxidation in the preparation

Allow incomplete reaction.

Allow formation [Co(NH₃)₅Cl]Cl₂ etc.

Some chloride ions act as ligands / replace NH₃ 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

$$\text{Moles of vanadium} = 50.0 \times 0.800 / 1000 = 4.00 \times 10^{-2}$$

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

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

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

1

Stage 2: moles of electrons added to 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

$$\text{Moles of electrons released when SO}_2 \text{ is oxidised} = 2.04 \times 10^{-2} \times 2$$

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

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 $4.08 \times 10^{-2} / 4.00 \times 10^{-2} = 1$ 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

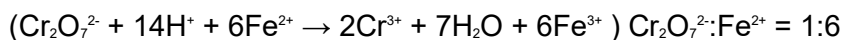
- (d) $\text{S}_2\text{O}_8^{2-} + 2\text{I}^- \longrightarrow 2\text{SO}_4^{2-} + \text{I}_2$
Allow multiples including fractions.
Ignore state symbols.
Allow the correct equation involving I_3^-
 $\text{S}_2\text{O}_8^{2-} + 3\text{I}^- \longrightarrow 2\text{SO}_4^{2-} + \text{I}_3^-$

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 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 $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$

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]