

**Q1.**

Which compound can decolourise acidified potassium manganate(VII) solution?

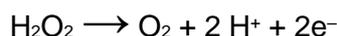
- A AgNO₃
- B CuSO₄
- C FeSO₄
- D Fe₂(SO₄)₃

(Total 1 mark)

Q2.

This question is about hydrogen peroxide, H₂O₂

The half-equation for the oxidation of hydrogen peroxide is



Hair bleach solution contains hydrogen peroxide.

A sample of hair bleach solution is diluted with water.

The concentration of hydrogen peroxide in the diluted solution is 5.00% of that in the original solution.

A 25.0 cm³ sample of the diluted hair bleach solution is acidified with dilute sulfuric acid.

This acidified sample is titrated with 0.0200 mol dm⁻³ potassium manganate(VII) solution.

The reaction is complete when 35.85 cm³ of the potassium manganate(VII) solution are added.

- (a) Give an ionic equation for the reaction between potassium manganate(VII) and acidified hydrogen peroxide.

Calculate the concentration, in mol dm⁻³, of hydrogen peroxide in the original hair bleach solution.

(If you were unable to write an equation for the reaction you may assume that the mole ratio of potassium manganate(VII) to hydrogen peroxide is 3:4

This is **not** the correct mole ratio.)

Concentration _____ mol dm⁻³

(5)



- (b) State why an indicator is **not** added in this titration.

(1)

- (c) Give the oxidation state of oxygen in hydrogen peroxide.

(1)

- (d) Hydrogen peroxide decomposes to form water and oxygen.

Give an equation for this reaction.

Calculate the amount, in moles, of hydrogen peroxide that would be needed to produce 185 cm³ of oxygen gas at 100 kPa and 298 K

The gas constant, $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$

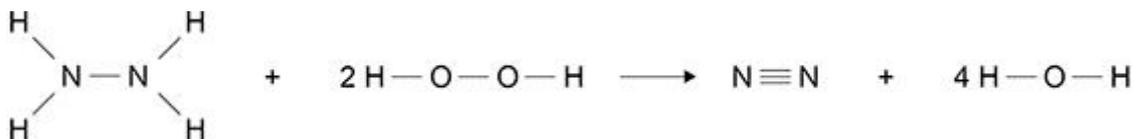
Equation

Amount _____ mol

(5)



- (e) Hydrazine (N_2H_4) is used as a rocket fuel that is oxidised by hydrogen peroxide. The equation for this reaction in the gas phase is



The enthalpy change for this reaction, $\Delta H = -789 \text{ kJ mol}^{-1}$

The table below shows some mean bond enthalpy values.

| | N-H | N-N | N≡N | O-H |
|---|------------|------------|------------|------------|
| Mean bond enthalpy / kJ mol^{-1} | 388 | 163 | 944 | 463 |

Define the term mean bond enthalpy.

Use the equation and the data in the table above to calculate a value for the O-O bond enthalpy in hydrogen peroxide.

Definition _____

Bond enthalpy _____ kJ mol^{-1}

(5)

(Total 17 marks)

**Q3.**

This question is about electrode potentials and electrochemical cells.

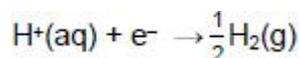
- (a) State the meaning of the term electrochemical series.

(1)

The table below shows some electrode potentials.

| | E° / V |
|--|----------------------|
| $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}(\text{aq}) + 2 \text{e}^- \rightarrow \text{Fe}(\text{s}) + 6 \text{H}_2\text{O}(\text{l})$ | -0.44 |
| $\text{H}^+(\text{aq}) + \text{e}^- \rightarrow \frac{1}{2} \text{H}_2(\text{g})$ | 0.00 |
| $[\text{Co}(\text{NH}_3)_6]^{3+}(\text{aq}) + \text{e}^- \rightarrow [\text{Co}(\text{NH}_3)_6]^{2+}(\text{aq})$ | +0.11 |
| $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}(\text{aq}) + \text{e}^- \rightarrow [\text{Fe}(\text{H}_2\text{O})_6]^{2+}(\text{aq})$ | +0.77 |
| $\text{VO}_2^+(\text{aq}) + 2 \text{H}^+(\text{aq}) + \text{e}^- \rightarrow \text{VO}^{2+}(\text{aq}) + \text{H}_2\text{O}(\text{l})$ | +1.00 |
| $[\text{Co}(\text{H}_2\text{O})_6]^{3+}(\text{aq}) + \text{e}^- \rightarrow [\text{Co}(\text{H}_2\text{O})_6]^{2+}(\text{aq})$ | +1.81 |

- (b) State **two** conditions needed for the following half-cell to have $E^\circ = 0.00 \text{ V}$



(1)

- (c) Identify the weakest reducing agent in the table above.

(1)

- (d) Use half-equations from the table above to deduce an equation for the reduction of VO_2^+ to form VO^{2+} in aqueous solution by iron.

(2)



- (e) Use data from the table above to explain why $[\text{Co}(\text{H}_2\text{O})_6]^{3+}(\text{aq})$ will undergo a redox reaction with $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}(\text{aq})$

Give an equation for this reaction.

Explanation _____

Equation

(2)

- (f) Suggest why the **two** cobalt(III) complex ions in the table above have different electrode potentials.

(1)

(Total 8 marks)

Q4.

This question is about ethanedioic acid (HOOCCOOH) and the ethanedioate ion ($-\text{OOC}\text{COO}-$).

- (a) Ethanedioic acid reacts with propane-1,3-diol ($\text{HOCH}_2\text{CH}_2\text{CH}_2\text{OH}$) to form a polyester.

Draw the repeating unit of this polyester.

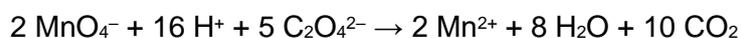
(2)



- (b) Explain why polyesters are biodegradable but polyalkenes are not biodegradable.

(2)

- (c) Sodium ethanedioate is used to find the concentration of solutions of potassium manganate(VII) by titration. The equation for this reaction is



A standard solution is made by dissolving 162 mg of $\text{Na}_2\text{C}_2\text{O}_4$ ($M_r = 134.0$) in water and making up to 250 cm^3 in a volumetric flask.

25.0 cm^3 of this solution and an excess of sulfuric acid are added to a conical flask. The mixture is warmed and titrated with potassium manganate(VII) solution. The titration is repeated until concordant results are obtained. The mean titre is 23.85 cm^3

Calculate the concentration, in mol dm^{-3} , of the potassium manganate(VII) solution.

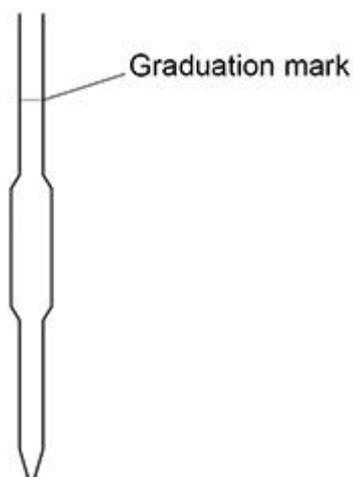
Concentration _____ mol dm^{-3}

(4)



- (d) **Figure 1** shows the 25.0 cm³ pipette used to measure the sodium ethanedioate solution.

Figure 1



On **Figure 1**, draw the meniscus of the solution when the pipette is ready to transfer 25.0 cm³ of the sodium ethanedioate solution.

(1)

- (e) Potassium manganate(VII) is oxidising and harmful.
Sodium ethanedioate is toxic.

Suggest safety precautions, other than eye protection, that should be taken when:

- filling the burette with potassium manganate(VII) solution
- dissolving the solid sodium ethanedioate in water.

Filling the burette _____

Dissolving the solid _____

(2)

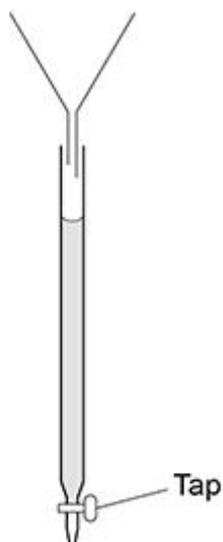
- (f) State the colour change seen at the end point of each titration.

(1)



- (g) **Figure 2** shows the burette containing potassium manganate(VII) solution.

Figure 2



Give **two** practical steps needed before recording the initial burette reading.

- 1 _____
- 2 _____

(2)

- (h) When $\text{Na}_2\text{C}_2\text{O}_4(\text{aq})$ is added to a solution containing $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$ ions, a reaction occurs in which all six water ligands are replaced by ethanedioate ions.

Explain why the replacement of the water ligands by ethanedioate ions is favourable. In your answer refer to:

- the enthalpy and entropy changes for the reaction
- how the enthalpy and entropy changes influence the free-energy change for the reaction.

(6)

(Total 20 marks)

**Q5.**

Which shows the correct oxidation state and co-ordination number of cobalt in $[\text{Co}(\text{NH}_3)_5\text{Cl}]\text{Cl}_2$?

| | oxidation state | co-ordination number | |
|----------|-----------------|----------------------|--------------------------|
| A | +2 | 5 | <input type="checkbox"/> |
| B | +2 | 6 | <input type="checkbox"/> |
| C | +3 | 5 | <input type="checkbox"/> |
| D | +3 | 6 | <input type="checkbox"/> |

(Total 1 mark)

Q6.

Which compound decolourises acidified potassium manganate(VII) solution?

- A** $\text{Al}_2(\text{SO}_4)_3$
- B** CuSO_4
- C** FeSO_4
- D** $\text{Fe}_2(\text{SO}_4)_3$

(Total 1 mark)

Q7.

The percentage by mass of iron in a steel wire is determined by a student.

The student

- reacts 680 mg of the wire with an excess of sulfuric acid, so that all of the iron in the wire forms $\text{Fe}^{2+}(\text{aq})$
- makes up the volume of the $\text{Fe}^{2+}(\text{aq})$ solution to exactly 100 cm^3
- takes 25.0 cm^3 portions of the $\text{Fe}^{2+}(\text{aq})$ solution
- titrates each portion with $0.0200 \text{ mol dm}^{-3}$ potassium manganate(VII) solution.

(a) Give the equation for the reaction between iron and sulfuric acid.

(1)



- (b) The titration results are shown in the table.

| | 1 | 2 | 3 |
|----------------------------------|-------|-------|-------|
| Final volume / cm ³ | 22.90 | 45.60 | 22.60 |
| Initial volume / cm ³ | 0.00 | 22.90 | 0.00 |
| Titre / cm ³ | 22.90 | 22.70 | 22.60 |

Calculate the mean titre.

Mean titre _____ cm³

(1)

- (c) Give the overall ionic equation for the oxidation of Fe²⁺ by manganate(VII) ions, in acidic conditions.

(1)

- (d) State the colour change seen at the end point of the titration.

(1)

- (e) Name the piece of apparatus used for these stages of the method.

Taking the 25.0 cm³ portions _____

Adding the potassium manganate(VII) solution _____

(1)



- (f) The balance used to weigh the 680 mg of iron wire has an uncertainty of ± 0.005 g

A container was weighed and its mass was subtracted from the total mass of the container and wire.

Calculate the percentage uncertainty in using the balance.

% uncertainty _____

(1)

(Total 6 marks)

Q8.

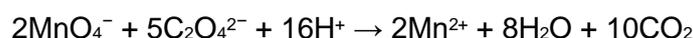
This question is about compounds containing ethanedioate ions.

- (a) A white solid is a mixture of sodium ethanedioate ($\text{Na}_2\text{C}_2\text{O}_4$), ethanedioic acid dihydrate ($\text{H}_2\text{C}_2\text{O}_4 \cdot 2\text{H}_2\text{O}$) and an inert solid. A volumetric flask contained 1.90 g of this solid mixture in 250 cm^3 of aqueous solution.

Two different titrations were carried out using this solution.

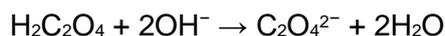
In the first titration 25.0 cm^3 of the solution were added to an excess of sulfuric acid in a conical flask. The flask and contents were heated to 60 $^\circ\text{C}$ and then titrated with a 0.0200 mol dm^{-3} solution of potassium manganate(VII). When 26.50 cm^3 of potassium manganate(VII) had been added the solution changed colour.

The equation for this reaction is



In the second titration 25.0 cm^3 of the solution were titrated with a 0.100 mol dm^{-3} solution of sodium hydroxide using phenolphthalein as an indicator. The indicator changed colour after the addition of 10.45 cm^3 of sodium hydroxide solution.

The equation for this reaction is



Calculate the percentage by mass of sodium ethanedioate in the white solid.

Give your answer to the appropriate number of significant figures.

Show your working.



Percentage by mass of sodium ethanedioate _____ %

(8)

- (b) Ethanedioate ions react with aqueous iron(III) ions in a ligand substitution reaction.

Write an equation for this reaction.

Suggest why the value of the enthalpy change for this reaction is close to zero.

(2)

- (c) Draw the displayed formula of the iron complex produced in the reaction in part (b)

Indicate the value of the O—Fe—O bond angle.

State the type of isomerism shown by the iron complex.

Bond angle _____

Type of isomerism _____

(3)

- (d) Ethanedioate ions are poisonous because they react with iron ions in the body.
Ethanedioate ions are present in foods such as broccoli and spinach.

Suggest one reason why people who eat these foods do not suffer from poisoning.

(1)

(Total 14 marks)



Mark Scheme

Q1.

C



[1]

Q2.



ignore state symbols

1

M2 $n(\text{MnO}_4^-) = \frac{0.020 \times 35.85}{1000} = 7.17 \times 10^{-4} \text{ (mol)}$

1

M3 $n(\text{H}_2\text{O}_2) = 7.17 \times 10^{-4} \times 5/2 = 1.793 \times 10^{-3} \text{ (mol)}$

$M3 = M2 \times 5/2$

1

M4 $\text{conc}(\text{H}_2\text{O}_2 \text{ in sample}) = \frac{1.793 \times 10^{-3}}{25 \times 10^{-3}} = 0.0717 \text{ (mol dm}^{-3}\text{)}$

$M4 = \frac{M3 \times 100}{25}$

1

M5 $\text{original conc of H}_2\text{O}_2 (= 0.0717 \times 20 = 1.43 \text{ (mol dm}^{-3}\text{)})$

$M5 = \frac{M4 \times 100}{5}$

allow 1.43–1.44

1

alternative answer using 3:4 ratio given on question paper

$M3 = 7.17 \times 10^{-4} \times 4/3 = 9.56 \times 10^{-4}$

$M4 = 0.0382 \text{ (mol dm}^{-3}\text{)}$

$M5 = 0.765 \text{ (mol dm}^{-3}\text{)}$

(b) KMnO_4 is self-indicating

or

KMnO_4 is no longer decolourised at end point

or

(solution) changes (from colourless) to (pale) pink/purple at end point

1

(c) –1

1



allow multiples

ignore state symbols

1

M2 $V = 185 \times 10^{-6} \text{ (m}^3\text{)} \text{ and } P = 100\,000 \text{ (Pa)}$



| | | |
|---------------|---|-------------|
| | <i>unit conversions</i> | 1 |
| M3 | $n = \frac{PV}{RT} = \frac{100\,000 \times 185 \times 10^{-6}}{8.31 \times 298}$ <i>rearrangement of ideal gas equation</i> | 1 |
| M4 | $n(\text{O}_2) = 7.47 \times 10^{-3} \text{ (mol)}$ <i>calculation</i> | 1 |
| M5 | $n(\text{H}_2\text{O}_2) = (7.47 \times 10^{-3} \times 2) = 0.0149 \text{ mol}$ <i>allow M4 × 2 to 2 sig fig or more</i> <i>if incorrect rearrangement in M3 can score M1, M2 and M5</i> | 1 |
| (e) M1 | enthalpy (change) to break <u>1 mol</u> bonds (in gaseous state) <i>allow heat energy (change) to break <u>1 mol</u> bonds</i> <i>allow the enthalpy needed to break <u>1 mol</u> bonds</i> <i>do not accept enthalpy released</i> | 1 |
| M2 | averaged over a range of compounds / molecules | 1 |
| M3 | $-789 = 4(388) + 163 + 4(463) + 2(\text{O}-\text{O}) - 944 - 8(463)$ <i>or</i> $-789 = 4(388) + 163 + 2(\text{O}-) - 944 - 4(463)$ <i>or</i> $-789 = 3567 + 2(\text{O}-\text{O}) - 4648$ <i>or</i> $-789 = 1715 + 2(\text{O}-\text{O}) - 2796$ | 1 |
| M4 | $2(\text{O}-\text{O}) = \underline{292} \text{ (kJ mol}^{-1}\text{)}$ | 1 |
| M5 | $\text{O}-\text{O} = 146 \text{ (kJ mol}^{-1}\text{)}$ $M5 = M4 \div 2$ | 1 |
| | | [17] |

Q3.

(a) (List of) electrode potentials/ E^\ominus in (numerical) order

OR half cells/equations in (numerical) order of electrode potential/ E^\ominus

Do not allow EMF in order

1

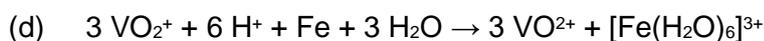
(b) Any 2 from
 298 K **or** 25 °C
 $[\text{H}^+] = 1 \text{ mol dm}^{-3}$
 100 kPa

Ignore 1 atm

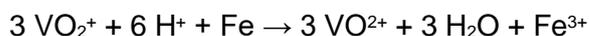
1

*Do not penalise absence of brackets*

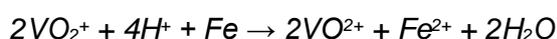
1



or

1 mark for Fe^{3+} as product and one mark for equation.*Ignore state symbols**Allow 1 mark for balanced equation that gives Fe^{2+} as product*

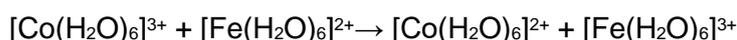
or



2

*Allow electrode potential for Co^{3+} greater than for Fe^{3+} OR $1.81 > 0.77$ / EMF cell = 1.04 V*

1

*Insist of reference to E^\ominus in M1*

1

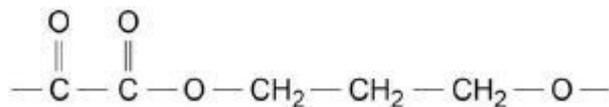
(f) Different ligands

Penalise different concentrations/oxidation states

1

[8]**Q4.**

(a)

**M1** ester link including C-O-C*ignore brackets and 'n'**allow $(\text{CH}_2)_3$* *-O- at either end but **not** both*

1

M2 rest of structure including trailing bonds***not** M2 if more than one repeating unit****allow** for one mark $-\text{OOC}\text{COOCH}_2\text{CH}_2\text{CH}_2-$ as long as trailing bonds included*

1

(b) polyesters: C=O/C-O **OR** polar bonds / chain **AND**
polyalkenes: (only) C-C **OR** non-polar bonds / chain



not just 'polyesters are polar'

not M1 if C=C mentioned

1

(polyesters) susceptible to nucleophilic attack / can be hydrolysed

1

(c) **M1** amount of $\text{Na}_2\text{C}_2\text{O}_4 = \frac{0.162}{134.0} = 0.00121 \text{ mol}$
 $M1 \times \frac{2}{5}$

1

M2 stoichiometry $\left(\frac{2}{5}\right)$ (4.84×10^{-4})

1

M3 scaling ($\div 10$)

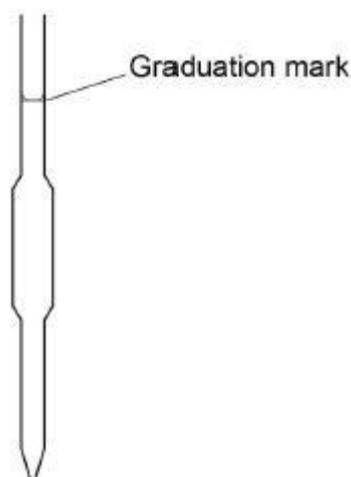
$= 0.00121 \times \frac{2}{5} \div 10 = 4.84 \times 10^{-5} \text{ mol}$
 $M2 \div 10$ (conc/40)
 $M3 \times \frac{1000}{23.85}$

1

M4 concentration of $\text{MnO}_4^- = \frac{4.84 \times 10^{-5}}{\frac{23.85}{1000}} = 0.00203 \text{ mol dm}^{-3}$
 Min 2 sig figs

1

(d)



Meniscus curved with the bottom of the curve on the horizontal line

1

(e) (burette) fill below/at eye level

ignore make sure tap closed / funnel / gloves

1

(solution) wear gloves

allow wash/rinse hands after any spillage **not** fume cupboard

ignore lab coat / stir carefully



(f) colourless to pink/pale purple

not just purple

not 'clear' for 'colourless'

1

(g) remove funnel

1

ensure jet is filled / no (air) bubbles

allow open tap to fill space below tap

1

1

(h)

| | |
|---|--|
| This question is marked using Levels of Response. Refer to the Mark Scheme Instructions for Examiners for guidance. | |
| Level 3 5-6 marks | All stages are covered and each stage is generally correct and virtually complete. Answer is communicated coherently and shows a logical progression from Stage 1 to Stages 2 and 3 Covers at least 2 point for stage 1, 1 for stage 2 and 2 for stage 3. If given equation must show correct stoichiometry for six marks |
| Level 2 3-4 marks | All stages are covered but stage(s) may be incomplete or may contain inaccuracies OR two stages are covered and are generally correct and virtually complete. Answer is communicated mainly coherently and shows a logical progression from Stage 1 to Stages 2 and 3. |
| Level 1 1-2 marks | Two stages are covered but stage(s) may be incomplete or may contain inaccuracies OR only one stage is covered but is generally correct and virtually complete. Answer includes isolated statements but these are not presented in a logical order. |
| Level 0 | Insufficient correct chemistry to gain a mark. |

Stage 1 - ΔH

1a ΔH negligible

1b make & break same number of bonds 1c make & break same type of bonds / bonds have similar enthalpies

Stage 2 - ΔS

2a increase in entropy

2b increase in particles in solution / from 4 to 7 particles (ecf from incorrect equation showing increase in no. of moles)

**Stage 3 - ΔG**

3a $\Delta G = \Delta H - T\Delta S$

3b ΔG negative (for forward reaction)

3c correct discussion of why ΔG is negative based on ΔH and TΔS

6

[20]

Q5.

D

[1]

Q6.

C

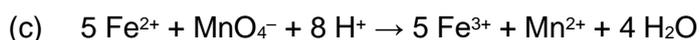
[1]

Q7.*Allow $\text{Fe} + 2\text{H}^+ \rightarrow \text{Fe}^{2+} + \text{H}_2$* *Allow $\text{Fe} + 2\text{H}^+ + \text{SO}_4^{2-} \rightarrow \text{Fe}^{2+} + \text{SO}_4^{2-} + \text{H}_2$* *Allow $\text{Fe} + \text{H}_2\text{SO}_4 \rightarrow \text{Fe}^{2+} + \text{SO}_4^{2-} + \text{H}_2$* *Allow $\text{Fe} + 2\text{H}^+ + \text{SO}_4^{2-} \rightarrow \text{FeSO}_4 + \text{H}_2$* *Allow multiples**Ignore state symbols*

1



1

*Allow multiples**Ignore state symbols**NOT if electrons shown*

1

(d) colourless / (pale) green to (hint of) pink

*NOT to purple**Allow to pale / hint of purple*

1

(e) pipette

burette

*both needed**Allow (graduated/volumetric) pipette**Allow (graduated/volumetric) burette**NOT dropping pipette*

1

(f) 1.47(%)



Allow 1.5(%)

1

[6]

Q8.

(a) Moles $\text{MnO}_4^- = \frac{26.50 \times 0.02}{1000} = 5.30 \times 10^{-4}$

1

Moles in 25cm^3 sample / pipette $\text{C}_2\text{O}_4^{2-}$ (from acid and salt)
 $= 5.30 \times 10^{-4} \times \underline{5/2} = (1.325 \times 10^{-3})$

1

Moles $\text{NaOH} = \frac{10.45 \times 0.1}{1000} (= 1.045 \times 10^{-3})$

1

So moles $\text{C}_2\text{O}_4^{2-}$ from acid in 25cm^3 sample / pipette
 $= 1.045 \times 10^{-3} \div \underline{2} = 5.225 \times 10^{-4}$

1

Hence moles $\text{C}_2\text{O}_4^{2-}$ in sodium ethanedioate in 25cm^3

$= 1.325 \times 10^{-3} - 5.225 \times 10^{-4} (= 8.025 \times 10^{-4})$

1

So moles $\text{C}_2\text{O}_4^{2-}$ in sodium ethanedioate in original sample
 $= 8.025 \times 10^{-4} \times \underline{10} (= 8.025 \times 10^{-3})$

1

Mass $\text{Na}_2\text{C}_2\text{O}_4 = 8.025 \times 10^{-3} \times \underline{134.0} = 1.075(35)\text{g}$

So % sodium ethanedioate in original sample

1

$\frac{1.075(35)}{1.90} \times 100 = 56.6\%$ to 3 sig fig

1

The first CE is penalised by 2 marks; further errors are penalised by one mark each

$M2 = M1 \times 5/2$

$M4 = M3 \div 2$

$M5 = M2 - M4$ (do not allow if negative and do not allow $= M4 - M2$)

If no subtraction, max = 5 (M1, M2, M3, M4 and M6)

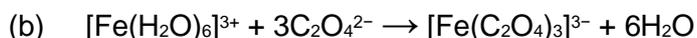
If incorrect subtraction, max = 6 (M1, M2, M3, M4, M6 and M7)

$M6 = M5 \times 10$

(M6 can be scored by multiplying M2 and M4 by 10 before subtraction (giving $1.325 \times 10^{-2} - 5.225 \times 10^{-3} = 8.025 \times 10^{-3}$)

$M7 = M6 \times 134$

$M8 = (M7/1.90) \times 100$ Allow 56.5 – 56.8%

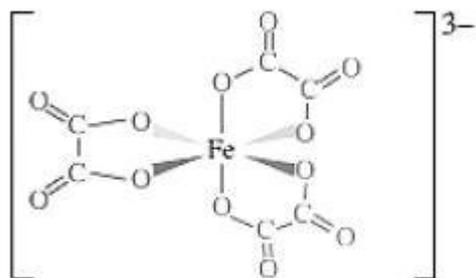


1

There are 6 Fe–O bonds broken and then made / same number and type of bond being broken and made.



1



(c)

Ignore all charges even if wrong
Ignore absence of square brackets
Candidates do not need to show 3D shape

1

90° or 180°

1

optical

1

(d) The ethanedioic acid is only present in small quantities/low concentration in these foods.

1

[14]