Mark scheme

<table>
<tr><th colspan="3">Question</th><th>Answer/Indicative content</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>1</td><td></td><td>i</td><td>$Fe^{2+} \rightarrow Fe^{3+} + e^-$ ✓
OR $Fe^{2+} - e^- \rightarrow Fe^{3+}$

$C_2O_4^{2-} \rightarrow 2CO_2 + 2e^-$ ✓
OR $C_2O_4^{2-} - 2e^- \rightarrow 2CO_2$</td><td>2</td><td>For both half-equations,

ALLOW multiples
ALLOW e for e^-
IGNORE state symbols.

ALLOW $C_2O_4^{2-} \rightarrow C_2O_4^- + e^-$
$C_2O_4^{2-} \rightarrow C_2O_4 + 2e^-$
$2H_2O + C_2O_4^{2-} \rightarrow 2CO_3^{2-} + 4H^+ + 2e^-$
ALLOW $2C_2O_4^{2-} \rightarrow C_4O_8^{2-} + 2e^-$

<u>Examiner's Comments</u>

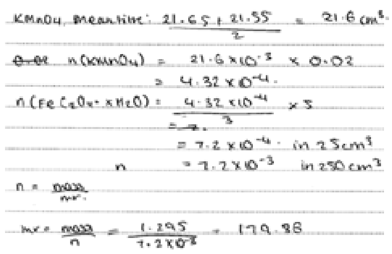
Most candidates were given a mark for one of their half-equations.

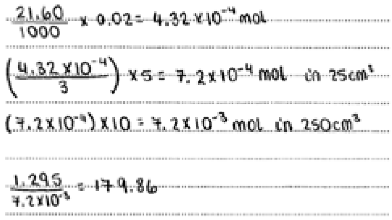
The half-equation for the oxidation of iron(II) ions was correct more often than that for ethanedioate ions. Strangely, a significant number of half-equations started with Fe metal instead of Fe^{2+} ions. The mark scheme allowed for variations in the oxidation of ethanedioate ions, with several alternative equations being given from the correct equation forming CO_2 receiving a mark.</td></tr>
<tr><td></td><td></td><td>ii</td><td><table><tr><th></th><th>1</th><th>2</th><th>3</th></tr><tr><td>Final reading/ cm^3</td><td>23.55</td><td>45.40</td><td>22.75</td></tr><tr><td>Initial reading/ cm^3</td><td>1.90</td><td>23.55</td><td>1.20</td></tr><tr><td>Titre / cm^3</td><td>21.65</td><td>21.85</td><td>21.55</td></tr></table></td><td>3</td><td>**<u>Examiner's Comments</u>**

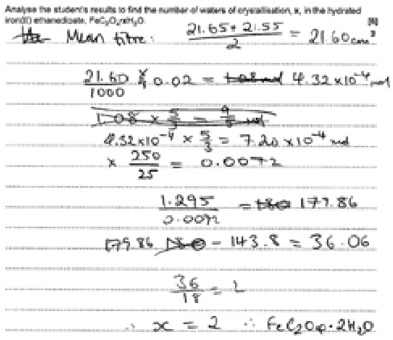
Most candidates were given all 3 marks for their titration tables. One mark was allocated to the readings, the other 2 for the correct titres.

Candidates are expected to record burette readings to 2 decimal places with the last figure being 0 or 5, reflecting the accuracy of the burette, which is stated in the question. Two issues were seen:</td></tr>
</table>

			Readings recorded to accuracy of burette All readings recorded to **two decimal places** with the last figure either **0** or **5** **AND** Final and initial readings in correct rows ✓ **Correct titres** All 3 titres correct to 2 DP: ✓✓ 2 titres correct to 2 DP: ✓		• Some candidates ignored the terminal 0 in their readings, e.g. 1.9 for 1.90 cm^3. • A small number of candidates recorded the initial and final readings the wrong way round despite these terms being used above each burette diagram. Titres were usually correct.
		iii	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF % error = 0.46, award 1 mark** -- $\frac{2 \times 0.05}{21.65} \times 100 = 0.46\ (\%)$ ✓ 2 DP minimum *Calculator value*: 0.46189...	1	**Check Titres from 3b(ii) at top of response** -- **ALLOW** % error from **ANY** of the 3 titres from **3b(ii)** **OR** from the mean titre **DO NOT ALLOW** 0.50% **<u>Examiner's Comments</u>** Candidates are much better at calculating percentage uncertainties than in previous series. Almost all candidates realised that the uncertainty in the titre resulted from two readings and that the overall uncertainty in the titre would be 2 × 0.05 = 0.1 cm^3, resulting in a percentage uncertainty of 0.46%. Comparatively few candidates ignored the '2' and gave 0.23% as their answer. Some candidates worked out the percentage uncertainty from the mean titre but this was still given marks.
		iv	**Level 3 (5-6 marks)** Analyses the results to calculate the **correct** amount of MnO_4^- using the **correct** mean titre from the candidate's titres **AND**	6	***For mean titre, Check Titres from 3b(ii) at top of response*** **Indicative scientific points may include:**

			Obtains **correct** value of **x as 2** *There is a well-developed line of reasoning which is clear and logically structured.* *The information presented is relevant and substantiated.* **Level 2 (3-4 marks)** Analyses titration results to determine an amount of MnO_4^- from a mean titre of the candidate's titres **AND** amount of FeC_2O_4 in 25.0 cm^3 OR 250 cm^3 **OR** uses a mass of FeC_2O_4 to obtain a value of **x** with few errors *There is a line of reasoning presented with some structure.* *The information presented is relevant and supported by some evidence.* **Level 1 (1-2 marks)** Analyses results to determine an amount of MnO_4^- from the candidate's titres **OR** Analyses the information to obtain values of $n(MnO_4^-)$ and $n(FeC_2O_4)$ with some errors. *There is an attempt at a logical structure with a line of reasoning.* *The information is in the most part relevant.* **0 marks -** No response or no response worthy of credit.		**Mean titre and $n(MnO_4^-)$** $\text{Mean titre} = \frac{(21.65 + 21.55)}{2} = 21.6(0)\ (cm^3)$ $n(MnO_4^-) = 0.0200 \times \frac{21.6(0)}{1000} = 4.32 \times 10^{-4}\ (mol)$ **Amount of FeC_2O_4 in mol** $n(FeC_2O_4)$ in 25.0 cm^3 $= 5/3 \times n(MnO_4^-)$ $= 7.2(0) \times 10^{-4}$ (mol) $n(FeC_2O_4)$ in 250 cm^3 $= 7.2(0) \times 10^{-3}$ (mol) **Value of x (final answer)** Molar mass $FeC_2O_4 \cdot xH_2O = \frac{1.295}{7.2(0) \times 10^{-3}}$ $= 179.9$ Molar mass of $\mathbf{x}H_2O = 179.9 - 143.8 = 36.(....)$ $\mathbf{x} = 36/18 = 2$ **Credit other correct methods,** e.g. For value of **x** Mass of $FeC_2O_4 = 7.2(0) \times 10^{-3} \times 143.8 = 1.03536$ g Mass of $H_2O = 1.295 - 1.035 = 0.25964$ g $n(H_2O) = \frac{0.25964}{18} = 0.0144$ mol $\mathbf{x} = \frac{0.0144}{7.2 \times 10^{-3}} = \mathbf{2}$ Responses using 25.0 cm^3 rather than the titres are limited to **Level 1** For communication, a typical 'logical structure' would label most calculation steps in response e.g. *Communication strand met*  $KMnO_4$ mean titre: $\frac{21.65 + 21.55}{2} = 21.6\ cm^3$ $n(KMnO_4) = 21.6 \times 10^{-3} \times 0.02 = 4.32 \times 10^{-4}$ $n(FeC_2O_4 \cdot xH_2O) = \frac{4.32 \times 10^{-4}}{3} \times 5 = 7.2 \times 10^{-4}$ in 25 cm^3 $n = 7.2 \times 10^{-3}$ in 250 cm^3 $n = \frac{mass}{Mr}$ $Mr = \frac{mass}{n} = \frac{1.295}{7.2 \times 10^{-3}} = 179.86$ *Communication strand **not** met*

					 $\frac{21.60}{1000} \times 0.02 = 4.32 \times 10^{-4}$ mol $\left(\frac{4.32 \times 10^{-4}}{3}\right) \times 5 = 7.2 \times 10^{-4}$ mol in $25 cm^3$ $(7.2 \times 10^{-4}) \times 10 = 7.2 \times 10^{-3}$ mol in $250 cm^3$ $\frac{1.295}{7.2 \times 10^{-3}} = 179.86$ **Examiner's Comments** This unstructured titration problem was assessed by Level of Response (LOR). Candidates answered this stock titration calculation well. The key stages are listed below: 1. Determination of the mean titre from the two closest titres in the candidate's response to Question 3 (b) (ii). If the titres were correct, this would be 21.60 cm^3, the mean of 21.55 cm^3 and 21.65 cm^3. 2. Calculation of the number of moles of MnO_4^- as 4.32×10^{-4} mol. 3. Calculation of the number of moles of FeC_2O_4 in 25 cm^3 as 5/3 × $4.32 \times 10^{-4} = 7.20 \times 10^{-4}$ mol. Scaling up this number of moles by 10 for the moles in 250 cm^3 as 7.20×10^{-3} mol. 4. Determination of the number of waters of crystallisation. Most candidates completed Stages 1 and 2 correctly, securing a minimum of a Level 1 response. A significant number of candidates then completed Stage 3, with most including scaling by 10 to secure a minimum of Level 2. Many of these candidates compared the moles of FeC2O4 to the mass of $FeC_2O_4 \cdot \mathbf{x}H_2O$ used to determine the value of **x** as 2. Such candidates would have reached Level 3. The communication strand of the LOR mark was determined by the

					clarity of the response, particularly whether the numbers in the calculation had been labelled. Unfortunately, many 'correct' responses had not done this. Over half the candidates were given 5 or 6 marks for this stock calculation. Exemplar 2  Analyse the student's results to find the number of waters of crystallisation, x, in the hydrated iron(II) ethanedioate, $FeC_2O_4 \cdot xH_2O$. [6] Mean titre: $\frac{21.65 + 21.55}{2} = 21.60\ cm^3$ $\frac{21.60}{1000} \times 0.02 = 4.32 \times 10^{-4}$ mol $4.32 \times 10^{-4} \times \frac{5}{3} = 7.20 \times 10^{-4}$ mol $\times \frac{250}{25} = 0.0072$ $\frac{1.295}{0.0072} = 179.86$ $179.86 - 143.8 = 36.06$ $\frac{36}{18} = 2$ $\therefore x = 2 \therefore FeC_2O_4 \cdot 2H_2O$ This exemplar demonstrates the hazards of not communicating well. The candidate has followed the four stages described above and the chemistry behind the titration analysis is correct. However, the response is mostly a page of numbers, with no explanation about what the numbers mean. The response is clearly at Level 3 but it is impossible to credit the communication strand, receiving a total of 5 marks.
			Total	**12**	
2		i	$4PH_3 + 8O_2 \rightarrow P_4O_{10} + 6H_2O$ ✓	1	**ALLOW** multiples **ALLOW** $2PH_3 + 4O_2 \rightarrow P_2O_5 + 3H_2O$ **IGNORE** state symbols, even if wrong **<u>Examiner's Comments</u>** Candidates found this question quite challenging, with only about one-third writing a correct equation. The question gave the reactants and products with only the formula of phosphorus(V) oxide having to be worked out.

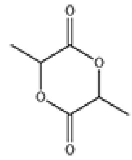
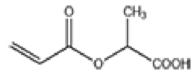
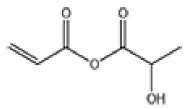
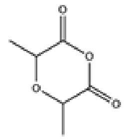
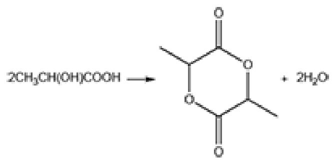
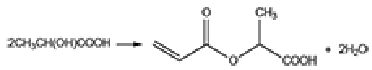
					The actual reaction does produce P_4O_{10} but P_2O_5 was shown in almost all equations, and this was acceptable. Various incorrect formulae were seen for phosphorus(V) oxide including PO, PO_2, P_5O, HPO, etc. Unfortunately a significant number of candidates could not balance the equation, despite using correct formulae.
		ii	$6AgNO_3 + (1)PH_3 + 3H_2O \rightarrow 6Ag + (1)H_3PO_3 + 6HNO_3$ ✓ Ag is reduced from +1 to 0 ✓ P is oxidised from -3 to +3 ✓ **IGNORE** oxidation numbers written around equation *Treat as rough working* **IGNORE** reference to electrons *Question states oxidation numbers*	3	**ALLOW** equation with '1' omitted, i.e. $6AgNO_3 + PH_3 + 3H_2O \rightarrow 6Ag + H_3PO_3 + 6HNO_3$ ✓ **BUT DO NOT ALLOW** '0' **ALLOW** 1 mark for **BOTH** correct oxidation number changes with 'reduced' and 'oxidised' omitted **OR** 'oxidised and reduced the wrong way round + signs required for +1 and +3 For oxidation numbers, **ALLOW** 1+, 3- and 3+ **<u>Examiner's Comments</u>** This question generated a wide range of responses, testing many important chemical skills. Candidates often used oxidation numbers correctly to show that silver is reduced and phosphorus oxidised, with silver being the easier. Hydrogen was sometimes incorrectly chosen for oxidation. The oxidation number change of +1 to 0 for silver was usually correct although +9 and +11 were common errors for silver in $AgNO_3$, presumably by choosing the oxidation number of nitrogen as -3 or -5. Candidates usually recognised that phosphorus started with an oxidation

					number of -3 but the oxidation number of +5 was a common error in H_3PO_3. Balancing the equation was the most difficult part of this question with numbers being added almost at random. It is easier to balance equations for redox reactions by balancing the oxidation number changes first. **Assessment for learning** Ag^+ and NO_3^- are among the common ions that students should know (see also Question 4 (c) (i)). For a NO_3^- ion to have a charge of 1–, the oxidation number of nitrogen must be +5. By choosing –5, the charge on NO_3 would be –11 and silver would have an oxidation number of +11. This is completely unrealistic and should be rejected as it points to a serious error. The specification states the following: *2.1.5 (a) rules for assigning and calculating oxidation number for atoms in elements, compounds and ions.* This section will have been studied at the start of the two-year course and forms part of the backbone of chemical literacy. For success in chemistry, the ions should be learnt and the rules for assigning oxidation numbers need to be mastered.
			Total	**4**	
3	a		Complete circuit **AND** voltmeter **AND** labelled salt bridge linking two half-cells ✓ Pt **AND** Fe^{2+} **AND** Fe^{3+} ✓ Pt **AND** H_2 **AND** H^+ **AND** delivery system for H_2 gas ✓	4	Electrodes / salt bridge must at least touch the surface of solutions **ALLOW** small gaps in circuit wires **ALLOW** half-cells drawn on either side **ALLOW** a formula of a strong acid for

			Standard conditions 1 mol dm^{-3} **AND** Temperature: 298 K / 25 °C **AND** Pressure: 1 atm / 100 kPa/101 kPa ✓		H^+ **<u>For standard conditions:</u>** Can be awarded if all quoted on standard condition line or in labelled diagram. **ALLOW** 1M **ALLOW** equimolar solutions for Fe^{2+} **AND** Fe^{3+} only. i.e. need 1 mol dm^{-3} for $[H^+]$ **IGNORE** H_2SO_4 in diagram unless concentration is stated with a value other than 0.5 $moldm^{-3}$ **DO NOT ALLOW** if any concentration is incorrect **<u>Examiner's Comments</u>** Successful candidates drew a complete circuit and voltmeter with the labelled salt bridge dipped into the two solutions. Both cells had Pt as the electrodes. One cell contained 1 $moldm^{-3}$ Fe^{2+} and Fe^{3+} where the other had a delivery mechanism for H_2 (at 1 atm) and H^+ (at 1 mol dm-3). Standard temperature of 298K (or 25°C) was stated. Common errors included: not have solutions in the beakers, used Fe or Fe^{2+} electrodes, the hydrogen cell was missing and/or the H_2 with a device for adding it. A few candidates suggested two cells with only Fe^{2+} one side and only Fe^{3+} on the other.
	b	i	$Li + CoO_2 \rightarrow LiCoO_2$ ✓	1	**ALLOW** ⇌ **DO NOT ALLOW** uncancelled species **<u>Examiner's Comments</u>** Most candidates were successful in constructing this equation. Common errors included the backwards reaction and some with unbalanced Li^+. Candidates should also check

					their equations, as a few included an erroneous C in the formula e.g. $LiCoCO_2$.
		ii	***Cell potentials***: ($E^{\ominus}$) = 1.23 - 0.00 **OR** 1.23 (V) **OR** (redox system 6 – redox system 3) = 1.23 (V) **AND** ($E^{\ominus}$) = 0.40 − (−0.83) = 1.23 (V) **OR** (redox system 4 – redox system 2) = 1.23 (V) ✓ **Acidic** *Cell equation* (2×) $H_2 \rightleftharpoons 2H^+ + 2e^-$ **AND** $O_2 + 4H^+ + 4e^- \rightleftharpoons 2H_2O$ **AND** $2 H_2 + O_2 \rightarrow 2H_2O$ ✓ **Alkaline** *Cell equation* (2×) $H_2 + 2OH^- \rightleftharpoons 2H_2O + 2e^-$ **AND** $O_2 + 2H_2O + 4e^- \rightleftharpoons 4OH^-$ **AND** $2 H_2 + O_2 \rightarrow 2 H_2O$ ✓	3	**IGNORE** state symbols throughout **ALLOW** multiples **ALLOW** $\rightleftharpoons$ Overall equation **AND** with evidence of working: e.g. half-equations written out / combined but not cancelled / with crossings out **OR** <u>System 6</u> goes forward / reduced **OR** <u>system 3</u> goes backwards / oxidised **ALLOW** multiples Overall equation **AND** with evidence of working: e.g. half-equations written out / combined but not cancelled / with crossings out **OR** <u>System 4</u> goes forward / reduced **OR** <u>system 2</u> goes backwards oxidised **ALLOW 1** mark for both equations with uncancelled species. **ALLOW 1** mark for <u>System 6</u> / reduced goes forward and <u>system 3</u> goes backwards oxidised **AND** <u>System 4</u> / goes forward / reduced and <u>system 2</u> / goes backwards / oxidised **<u>Examiner's Comments</u>** Most candidates were able to successfully show the overall equations were the same. Most combined the two half equations and then cancelled down to give the overall equations. A few candidates chose to describe the redox nature or use the equilibrium shifts scoring the first 2 marks. Some candidates, incorrectly, deduced the equation as $H^+ + OH^- \rightarrow H_2O$. Some candidates gave the 1.23V value without showing

					any calculation or did not refer to this part of the question at all. This was one of the most common questions where candidates omitted to provide a response on the paper.
			Total	**8**	
4	a	i	Au + 4 HC*l* → 4 H^+ + AuCl_4^- + 3 e^- ✓	1 (AO 1.2)	**Examiner's Comments** Most candidates added '4' before HC*l* and H^+, and 3 before e^- to gain this mark. Where an error was made, it invariably was with the number of electrons, usually $4e^-$.
		ii	**Formulae** **X** = NO ✓ **Z** = H2O ✓ **Equation Independent from ID of X and Z** HNO_3 + 3 H^+ + 3 e^- → NO + 2 H_2O **OR** NO_3^- + 4 H^+ + 3 e^- → NO + 2 H_2O ✓ **CHECK BELOW ANSWER SPACE FOR RESPONSE**	3 (AO 3.1 ×3)	If **X** and **Z** in wrong order award 1 out of 2 formula marks i.e. **X** = H_2O and **Z** = NO 1 mark **ALLOW** multiples **Examiner's Comments** Almost all candidates identified **X** and **Y** as NO and H_2O respectively, but the equation proved to be much more testing. Some candidates were careless, showing NO and H_2O the wrong way round (credited with 1 out of these 2 marks) or with charges. For the equation, candidates needed to consider the oxidation number change of N from +5 to +2, This should have naturally led to $3e^-$ being added on the left-hand side. Many candidates omitted the electrons entirely. Some did add $3e^-$ but on the right. This suggests that candidates would benefit with practising the construction of half equations.
	b		**Level 3 (5–6 marks)** • Reaches a comprehensive conclusion to determine all **three** correct formulae of **D**, **E AND F**	6 (AO 3.1 ×3) (AO 3.2 ×3)	**Indicative scientific points may include:** **Identify of D, E and F** • **D**: $NiSO_4$•6H_2O **OR** $NiSO_4(H_2O)_6$ **OR** $NiSO_{10}H_{12}$

			• **AND** constructs most equations with few errors *There is a well-developed line of reasoning which is clear and logically structured.* *The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** • Reaches a comprehensive conclusion to determine **two** correct formulae of **D**, **E AND F** • **AND** constructs some equations with some errors *There is a line of reasoning presented with some structure.* *The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** • Determines a correct formula for **one** of **D, E AND F** • AND provides some evidence to support the formula *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 mark** *No response or no response worthy of credit.* **EQUATIONS SHOULD BE USED TO INFORM THE COMMUNICATION STRAND** *See next page for details* *CHECK TOP OF QUESTION FOR RESPONSES* *IGNORE CONNECTIVITY FOR F* **SUMMARY** **Setting the level** **For Level 3 (5–6 marks)**, • All 3 identified: **D**, **E** and **F**		• **E**: SO_2 • **F: Cyclic diester**  **OR unsaturated ester/acid**  **OR unsaturated acid anhydride**  **OR cyclic acid anhydride**  **Equations** $H_2SO_4 + Ni(OH)_2 \rightarrow NiSO_4 + 2H_2O$ **OR** $H_2SO_4 + Ni(OH)2 + 4H_2O \rightarrow$ $NiSO_4 \bullet 6H_2O$ For equation **ALLOW** $NiSO_4 \bullet 6H_2O$ **OR** $NiSO_4(H_2O)_6$ -- $H_2SO_4 + 2HBr \rightarrow Br_2 + SO_2 + 2H_2O$  **OR** 

- Most equations

For Level 2 (3–4 marks),

- 2 identified from **D**, **E** and **F**
- 2 equations

For Level 1 (1–2 marks),

- 1 identified from **D**, **E** and **F**
- Evidence

Evidence to support a formula for Level 1

Molar ratios of D

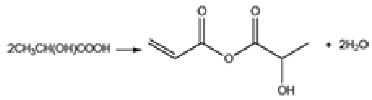
Ni	S	O	H
$\frac{22.33}{58.7}$	$\frac{12.20}{32.1}$	$\frac{60.87}{16.0}$	$\frac{4.60}{1.0}$
0.38	0.38	3.80	4.60
1	1	10	12

OR $NiSO_{10}H_{12}$

Molar mass of E

Molar mass = 2.67 × 24 = 64(.08) g mol^{-1}

OR



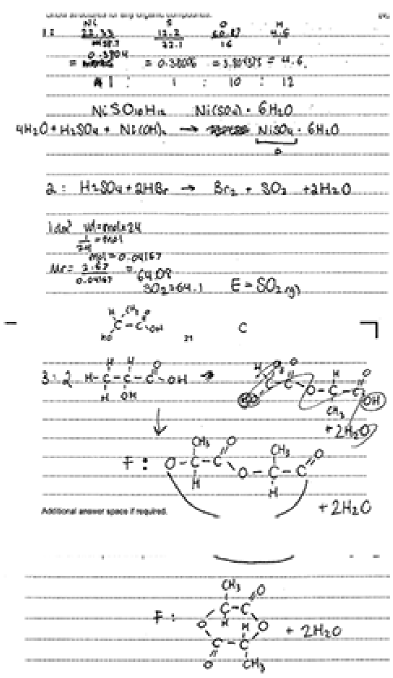
If structure of **F** is shown, **ALLOW** equation using molecular formulae, e.g. $2\ C_3H_6O_3 \rightarrow C_6H_8O_4 + 2H_2O$

<u>Examiner's Comments</u>

This level of response question required candidates to interpret three pieces of information to identify 3 unknown chemicals, linked by three reactions of sulfuric acid. Levels were assigned based on identifying the three unknowns and writing equations for the reactions. The 3 reactions were tiered in difficulty with the cyclic structure for compound **F** being the most difficult.

The question discriminated extremely well, with comparatively few candidates not scoring any marks.

Exemplar 4



					This exemplar shows an excellent response which was awarded Level 3 and 6 marks. The crossing out shows how the candidate progressively solved the problem. Despite the crossing out, working is shown throughout, and the presentation of the response is very clear. For reaction 1, the candidate initially made an error in the stock formula determination calculation. Notice that the candidate crossed out their initial values and wrote them afresh. This approach is recommended. as changing incorrect numbers can lead to ambiguous numbers. In reaction 2, the candidate comfortably identified compound **E** from its molar mass and wrote a balanced equation for this reaction. For reaction 3, you can see how the candidate's thought developed during the solve. They initially went for a straight chain structure and then worked out that there must be a cyclic structure. They finally show the cyclic diester as a conventional structural (based on glucose?), and with a balanced equation. This was an excellent response of a high-ability candidate and shows what a well-prepared candidate is capable of achieving.
			Total	**10**	
5	a	i	Colourless to (pale) pink	1 (AO 1.1)	**ALLOW** <u>**Pale**</u> purple **DO NOT ALLOW** purple <u>**Examiner's Comments**</u> Only a few candidates were given this mark. Some had the colour change inverted and most stated a variety of different colours.

		ii	12.65 12.95 12.75 ✓ $\frac{12.65+12.75}{2}$ = 12.7(0) cm^3 ✓	2 (AO 2.8 x 2)	**Examiner's Comments** Almost all candidates calculated the titres correctly. A significant number used all three titre values to derive their mean value. **OCR support** Links to the legacy coursework tasks and PAG practice question sets can be found on Teach Cambridge and can help students prepare for practical-based questions like this one. Exam hints for students is useful to share with candidates.
		iii	**FIRST CHECK THE ANSWER ON ANSWER LINE** **if answer = 6.35×10^{-3} award 3 marks** -- ***n*($MnO4^-$) in titration** = (0.00250 × $\frac{12.7}{1000}$) = 3.175×10^{-5} ✓ ***n*(Fe^{2+}) in 25.0 cm^3** = (3.175×10^{-5} × 5) = 1.5875×10^{-4} (mol) ✓ **[Fe^{2+}]** = (1.5875×10^{-4} ÷ 0.025) **OR** (1.5875×10^{-4} x 40) = 6.35×10^{-3} (mol dm^{-3}) ✓	3 (AO 2.8 × 3)	**ALLOW ECF** from incorrect titre in 21 a ii) for 3 marks e.g. Titre of 12.78 cm^3 gives 6.39 x 10^{-3} -- **ALLOW 3 SF or more throughout** **ALLOW ECF** throughout **ALLOW** *n*(Fe^{2+}) in 250 cm^3 = 1.5875×10^{-3} (mol) so [Fe^{2+}] in 25 cm^3 = 1.5875×10^{-3} ÷ 0.25 = 6.35×10^{-3} **Common errors for 2 marks** 2.46 x 10^{-2} (volumes transposed) 1.25 x 10^{-2} (same volume used twice) 1.27 x 10^{-3} (no x 5) 2.54 x 10^{-4} (÷5) **Examiner's Comments** Candidates made good progress with this calculation, many gaining 2 or 3 marks, including error carried forward from incorrect titres. Common errors included, in various combinations: transposing volumes, not using the stoichiometry of the equation and using the same volume twice.
	b			4 (AO 3.1 ×	**ALLOW ORA** throughout **IGNORE** larger/smaller/greater/less

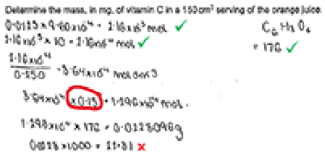
			System 1/E$^\circ$(Zn) is more negative/less positive than *system 2/ E*$^\circ$(Fe^{3+}) ✓ Eqm 2 shifts to right **AND** Eqm 1 shifts to left **OR** Zinc reduces iron(III) ions (to iron(II)) **OR** $Zn + 2Fe^{3+} \rightarrow Zn^{2+} + 2Fe^{2+}$ ✓ *System 1/E*$^\circ$(Zn) is more negative than *system 3/ E*$^\circ$(MnO_4^-) ✓ Eqm 3 shifts to right **AND** Eqm 1 shifts to left **OR** (If unfiltered), MnO_4^- oxidise zinc **OR** $2MnO_4^- + 5Zn + 16H^+ \rightarrow 2Mn^{2+} + 5Zn^{2+} + 8H_2O$ ✓	1) (AO 3.4 × 1) (AO 3.1 × 1) (AO 3.4 × 1)	throughout **ALLOW E**$^\circ$ = (+)1.53(V) **ALLOW** comparison if Fe system is identified **ALLOW E**$^\circ$ = (+) 2.27(V) **ALLOW** comparison if MnO_4^- is identified **<u>Examiner's Comments</u>** Most candidates were able to successfully explain Step 1, scoring the first 2 marks. When comparing electrode potentials, candidates should avoid the use of higher/lower as these phrases are ambiguous due to the negative signs involved. Describing them as 'more negative' or 'more positive' is clearer. Candidates are advised to read the instructions contained within the question and to use or comment on all the data presented. Very few candidates linked Step 2 to the reducing effect of zinc to manganate(VII) ions hence the need for filtration. A few candidates explained Step 2 in terms of the warming/cooling and zinc crystalising rather than explaining the redox chemistry given in the table.
			Total	**10**	
6			$\mathbf{3}V^{3+} + Cr_2O_7^{2-} + \mathbf{2}H^+ \rightarrow \mathbf{3}VO_2^+ + \mathbf{2}Cr^{3+} + H_2O$ **ALL** reactant and product species correct ✓ Correct balancing (of correct equation) **AND** cancelling of species ✓	2 (AO 2.5) (AO 2.6)	**IGNORE** Balancing and electrons for first mark **DO NOT ALLOW** electrons in final answer **<u>Examiner's Comments</u>**

					Very few candidates were able to produce the balanced overall equation; a few had the correct reactants and products but not balanced. Candidates are advised to look for the information contained within the question. The formulas were given, and it was stated that the solution was acidified, leaving only water to be identified. Some candidates approached this through two half equations whereas others used oxidation numbers to balance their equations.
			Total	**2**	
7			**C**	1 (AO 2.6)	**Examiner's Comments** Most candidates answered this question correctly with C.
			Total	**1**	
8			**B**	1 (AO 2.1)	**Examiner's Comments** This question was for the most part answered correctly with B. Errors came from not recognising the reaction is endothermic and therefore its equilibrium would shift to the left when the temperature decreases, ruling out option 2. **Assessment for learning** Practice multiple choice questions can improve the skill in solving and identifying the distractors. Exposure to this type of question style will decrease the time taken over each question. These can often form the basis of end of topic tests. Multiple choice question quizzes can be found via the resource-finder on Teach Cambridge and there are instructions on how to use the online versions of the multiple choice quizzes.
			Total	**1**	

9		i	Ca fizzes faster **AND** Ca dissolves/disappears more quickly ✓	1 (AO2.3)	**CARE** Both needed for **1 mark**. **ORA ALLOW AW** **IGNORE** finishes first **IGNORE** more bubbles (need idea of rate) **IGNORE** exothermic **Examiner's Comments** Very few candidates made two valid statements where both clearly indicated an idea of relative rate – in almost all cases one of the descriptions would be about quantity of gas rather than rate of gas production. Some candidates identified a precipitate being formed, colour change, or gave a general answer of the reaction happening quicker.
9		ii	Oxidation $Mg \rightarrow Mg^{2+} + 2e^-$ ✓ Reduction $2H^+ + 2e^- \rightarrow H_2$ **OR** $H^+ + e^- \rightarrow \frac{1}{2}H_2$ ✓	2 (AO2.6×2)	In half equations, **ALLOW** the use of e for e^- **ALLOW** $Mg - 2e^- \rightarrow Mg^{2+}$ **IGNORE** state symbols even is wrong BUT half equations **MUST** only have species that change. For charges on half equations, **ALLOW** Mg^{+2} for Mg^{2+} **OR** H^{+1} for H^+ If **BOTH** half equations are correct but shown with oxidation and reduction the wrong way around, award 1 mark from the 2 marks for half equations **Examiner's Comments** Some candidates coped well with this question which was based on the AS part of the specification and gained both marks. More candidates gained 1 mark through writing one half equation, usually the oxidation of

					magnesium. Common errors were for chlorine to featuring in the reduction half equation and the lack of electrons in their answers. Very few candidates mixed up the oxidation and reduction equations.
			Total	**3**	
10		i	$Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2$ ✓	1(AO2.6)	**IGNORE** state symbols, even if wrong **ALLOW** $[Fe(H_2O)_6]^{2+} + 2OH^- \rightarrow Fe(OH)_2(H_2O)_4 + 2H_2O$ **OR** $[Fe(H_2O)_6]^{2+} + 2OH^- \rightarrow Fe(OH)_2 + 6H_2O$ **<u>Examiner's Comments</u>** Most students scored this mark, although several gave no response.
		ii	**Explanation of the brown precipitate** The brown ppt is $Fe(OH)_3$ **OR** $Fe(OH)_2$ loses electrons/ $Fe(OH)_2$ oxidised ✓ **Comparison of *E* values** (*E* of) Fe/Redox system 1 is more negative/less positive (than *E* of O_2/redox system 2) **OR** (*E* of) O_2/Redox system 2 is more positive/less negative (than *E* of Fe/redox system 1) ✓ **Equilibrium shift**	4(AO3.1×4)	**ORA** **ALLOW** Fe^{2+} is oxidised to Fe^{3+} **ALLOW** Fe **ALLOW** E_{cell} is (+) 0.96V **IGNORE** 'lower/higher' **For equilibrium shift** **ALLOW** E_{cell} is +ve therefore the reaction is feasible. **OR** Direction of half equation correctly written. **ALLOW** multiples **ALLOW** equilibrium **IGNORE** state symbols, even if wrong **DO NOT ALLOW** uncancelled

			More negative/less positive **OR** Fe system **OR** Redox system 1 shifts left **OR** More Positive/less negative **OR** O_2 system **OR** Redox system 2 shifts right ✓ **Equation** $4Fe(OH)_2(s) + O_2(g) + 2H_2O(l) \rightarrow 4Fe(OH)_3(s)$ ✓		species **Examiner's Comments** Although a spread of marks across the full available range was seen, a good proportion of candidates gained 3 or 4 marks. Most candidates were able to produce a balanced equation, but candidates should take care cancelling out any species present on both side of the equation, e.g. the hydroxide ions. A common error within the formula of iron (III) hydroxide was to place the number of hydroxide ions within the brackets, e.g. $Fe(OH_3)$. Candidates are advised to read the instructions contained within the equation and to use or comment on all the data presented. When commenting on electrode potentials, candidates should avoid the use of higher/lower as these phrases are meaningless due to the negative signs involved.
			Total	**5**	
11			C	1(AO2.8)	**Examiner's Comments** The correct answer C required candidates to calculate the moles of manganate (VII) ions and then to use the stoichiometry of the equation to calculate the moles of H_2O_2 before calculating the concentration. Option A provided a distractor with the incorrect ratio. Option B was obtained without the reference to the molar ratio.
			Total	**1**	
12			**FIRST CHECK ANSWER ON THE ANSWER LINE** **If answer = 38 (mg) award 4 marks** -- $n(I_2) = 22.50 \times \frac{9.60 \times 10^{-4}}{1000} = 2.16 \times 10^{-5}$ (mol) ✓ *n*(vitamin C) in 250 cm^3 volumetric flask = $10 \times 2.16 \times 10^{-5} = 2.16 \times 10^{-4}$ (mol) ✓	4 (4 ×AO2.8)	**Use ECF throughout** Intermediate values for working to **at least 3 SF.** **TAKE CARE** as value written down may be truncated value stored in calculator. Depending on rounding, either can be credited. -- **COMMON ERRORS:** **22.81 mg scaling by 150/250 → 3**

			M(Vitamin C: $C_6H_8O_6$) = 176 **OR** (12 × 6) + (1 × 8) + (16 × 6) *Seen anywhere* Mass vitamin C in 150 cm^3 of orange = 2.16 × 10^{-4} × 176.0 = 0.038016 g = 38 (**mg**) ✓ ***2 SF or more***		**marks** **FINAL MARK LOST BY SCALING**  **42.24 mg** using 25.0 cm^3 instead of 22.50 → 3 marks **25.34 mg** using 25.0 cm^3 **AND** scaling by 150/250 instead of 22.50 → 2 marks **63.36 mg** scaling by 250/150 → 3 marks **<u>Examiner's Comments</u>** This question was a standard titration calculation, set in a practical context. As with Question 6 (c) (i), this assessed one of the important principles encountered in A Level Chemistry. Success required three main stages: • Calculation of the amount, in mol, of I_2 used in the titration of 25.0 cm^3 of the diluted orange juice. • Determination of the amount in mol of vitamin C in the 250 cm^3 solution (effectively scaling by ×10) • Use of this value with the molar mass of vitamin C to determination of the mass of vitamin C, in mg, in the 150 cm^3 serving of the orange juice. Most candidates calculated the amount of I2 (and vitamin C) in the titre as 2.16 × 10^{-5} mol. The next scaling stage by ×10 to 2.16 × 10^{-4} mol introduced a problem. Many candidates were distracted by the '150 cm^3' serving of orange juice and they scaled further by a factor of 150/250 to give 1.296 × 10^{-4} mol. Candidates scaling corrected by ×10 usually used the vitamin C molar mass of 176 g mol^{-1} to determine the

					correct mass of 38 mg in the orange juice serving. The common incorrect mass of 22.8 mg resulted from the extra scaling by 150/250 described above. This could still be given 3 of the available 4 marks as only one error had been made. Some candidates worked out an incorrect molar mass for vitamin C, with 174 often seen. Provided that this value was used with a correct method, ECF could still be applied for the final mass.
			Total	**4**	
13	a		**6 marking points → 5 MAX** --- **ALLOW** labels **1**, **2** and **3**; **A**, **B** and **C**, etc, provided that meaning is clear --- ***Oxidising agent AND equation*** $Cr_2O_7^{2-}$ is oxidising agent with C_2H_5OH /oxidises C_2H_5OH ✓ $Cr_2O_7^{2-} + 8H^+ + 3C_2H_5OH \rightarrow 2Cr^{3+} + 7H_2O + 3CH_3CHO$ ✓ **Explanation for $Cr_2O_7^{2-}/Cr^{3+}$ and CH_3CHO/C_2H_5OH** *E* for $Cr_2O_7^{2-}/Cr^{3+}$ is **more** +ve /higher /greater **OR** *E*cell = (+)1.527 V + *sign not required* **OR** $Cr_2O_7^{2-}/Cr^{3+}$ equilibrium shifts right ✓ ***Reducing agent AND equation*** Cr^{3+} is reducing agent with $FeO4^{2-}$ /reduces $FeO4^{2-}$ ✓ $2Cr^{3+} + 2H^+ + 2FeO_4^{2-} \rightarrow C_2O_7^{2}- + H_2O + 2Fe^{3+}$ ✓ **Explanation for $Cr_2O_7^{2-}/Cr^{3+}$ and FeO_4^{2-}/Fe^{3+}**	5 (AO2.5) (AO2.6) (AO2.6) (AO2.5) (AO2.6) (AO2.6)	**ALLOW** reverse argument **(ORA)** throughout For equations, **ALLOW** multiples In equations, **ALLOW** ⇌ for → **ALLOW** $Cr_2O_7^{2-}$ is oxidising agent if linked to C_2H_5OH as reactant in equation **ALLOW** Cr^{6+} for $Cr_2O_7^{2-}$ **ALLOW** $Cr_2O_7^{2-}$ is reduced by C_2H_5OH In explanation, look for **CON**s between '**OR**' statements **ALLOW** Cr^{3+} is reducing agent if clearly linked to FeO_4^{2-} as reactant in equation **ALLOW** Fe^{6+} for FeO_4^{2-} **ALLOW** Cr^{3+} is oxidised by FeO_4^{2-} In explanation, look for **CON**s between '**OR**' statements --- **Note on equations** There are 2 marks for the equations

			E for $Cr_2O_7^{2-}/Cr^{3+}$ is **less** +ve (*E*) / lower /smaller **OR** *E*cell = (+)0.87 V + *sign not required* **OR** $Cr_2O_7^{2-}/Cr^{3+}$ equilibrium shifts left ✓		with H^+, H_2O and e^- cancelled down **ALLOW** 1 mark for 2 'correct' equations where H^+, H_2O and e^- have **NOT** all been cancelled down. *e.g. 1 mark from 2 uncancelled equations* $Cr_2O_7^{2-} + 14H^+ + 3C_2H_5OH \rightarrow 2Cr^{3+} + 6H^+ + 7H_2O + 3CH_3CHO$ $2Cr^{3+} + 2H^+ + 2FeO_4^{2-} + 6e^- \rightarrow Cr_2O_7^{2-} + H_2O + 2Fe^{3+} + 6e^-$ **<u>Examiner's Comments</u>** Most candidates were able to obtain some credit for this problem. The equations proved to be among the easier marks, and it was encouraging to see how many candidates were able to use the E data to help them combine the half equations correctly. Most then cancelled down the common species present on both sides of the equation: H+, H2O and e-. Explanations were generally sound, either by comparing the E values, stating the direction of equilibrium shift, or by using cell potentials. The hardest marks proved to be the identification of the chromium ions that were the oxidising and reduction agents. Many candidates just referred to 'chromium' despite the chromium half equation containing two chromium ions, Cr2O72- and Cr3+. Candidates who had written correct equations sometimes assigned the wrong chromium ion as the oxidising or reducing agent. Mores successful responses constructed correct equations and stated that Cr2O72- was the oxidising agent as it oxidised C_2H_5OH and that Cr^{3+} was the reducing agent as it reduced FeO_4^{2-}.
	b		$5\ H_2S + 2\ MnO_4^- + 6\ H^+ \rightarrow 2\ Mn^{2+} + 5\ S + 8\ H_2O$	2 (AO3.2)	**ALLOW** multiples e.g. $2½\ H_2S + MnO_4^- + 3\ H^+$

			OR $40\ H_2S + 16\ MnO_4^- + 48\ H^+ \rightarrow 16\ Mn^{2+} + 5\ S_8 + 64\ H_2O$ Any **FIVE** correct species ✓ Correct balanced equation ✓		$\rightarrow Mn^{2+} + 2½\ S + 4\ H_2O$ $20\ H_2S + 8\ MnO_4^- + 24\ H^+ \rightarrow 8\ Mn^{2+} + 2½\ S_8 + 32\ H_2O$ **IGNORE** extra species containing: Mn, H, S and O **ONLY** **BUT ALLOW** $KMnO_4$ on LHS, forming K^+ on RHS **IGNORE** electrons **IGNORE** state symbols **<u>Examiner's Comments</u>** Candidates needed to interpret the information provided and to use this as the basis for their redox equation. The clue of a yellow product proved to be very difficult to interpret as being sulphur. The equation then required H^+ to be added as a reactant ('acidified' in the information) and H_2O as the other product. Balancing required use of oxidation numbers. Candidates found this equation very difficult and relatively few correct equations were seen. The mark scheme did allow 1 mark for any correct five species but the correct equation proved to be challenging in demand.
			Total	**7**	