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>
Readings recorded to accuracy of burette</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:

• 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</td></tr>
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			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: ✓		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% **Examiner's Comments** 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** 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	6	***For mean titre, Check Titres from 3b(ii) at top of response*** **Indicative scientific points may include:** **Mean titre and *n*(MnO_4^-)** 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**

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.

$n(FeC_2O_4)$ in 25.0 cm^3 = 5/3 × $n(MnO_4^-)$
= 7.2(0) × 10^{-4} (mol)
$n(FeC_2O_4)$ in 250 cm^3 = 7.2(0) × 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 xH_2O = 179.9 – 143.8 = 36.(….)

x = 36/18 = 2

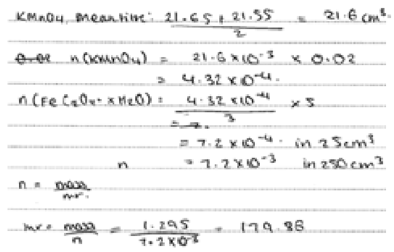
Credit other correct methods,

e.g. For value of **x**
Mass of FeC_2O_4 = 7.2(0) × 10^{-3} × 143.8 = 1.03536 g
Mass of H_2O = 1.295 - 1.035 = 0.25964 g

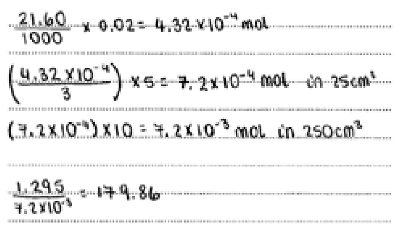
$$n(H_2O) = \frac{0.25964}{18} = 0.0144 \text{ mol}$$
$$x = \frac{0.0144}{7.2 \times 10^{-3}} = 2$$

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


KMnO4 mean titre: (21.65 + 21.55)/2 = 21.6 cm³.
n(KMnO4) = 21.6 × 10⁻³ × 0.02
= 4.32 × 10⁻⁴.
n(FeC2O4·xH2O) = (4.32 × 10⁻⁴ / 3) × 5
= 7.2 × 10⁻⁴ in 25cm³
n = 7.2 × 10⁻³ in 250 cm³
n = mass / mr
mr = mass / n = 1.295 / 7.2 × 10⁻³ = 179.86

*Communication strand **not** met*


21.60/1000 × 0.02 = 4.32 × 10⁻⁴ mol
(4.32 × 10⁻⁴ / 3) × 5 = 7.2 × 10⁻⁴ mol in 25cm³
(7.2 × 10⁻⁴) × 10 = 7.2 × 10⁻³ mol in 250cm³
1.295 / 7.2 × 10⁻³ = 179.86

<u>Examiner's Comments</u>

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 $5/3 \times 4.32 \times 10^{-4} = 7.20 \times 10^{-4}$ 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.

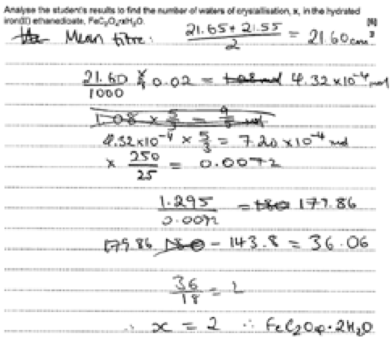
Most candidates completed Stages 1 and 2 correctly, securing a minimum of a Level 1 response.

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

$\times \frac{250}{25} = 0.0072$

$\frac{1.295}{0.0072} = 179.86$

$179.86 - 143.8 = 36.06$

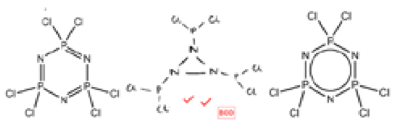
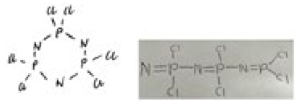
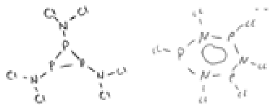
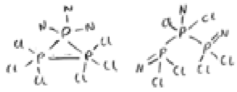
$\frac{36}{18} = 2$

$\therefore x = 2 \quad \therefore FeC_2O_4 \cdot 2H_2O$

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	$3PCl_5 + 3NH_4Cl \rightarrow P_3N_3Cl_6 + 12HCl$ ✓	1	**ALLOW** multiples **IGNORE** state symbols, even if wrong **<u>Examiner's Comments</u>** This question again required candidates to construct an equation. Candidates were provided with the formula of all species reactants and products except for that of ammonium chloride. Candidates are expected to know that the ammonium ion is NH_4^+ but many incorrect equations showed NH_3Cl. About half the candidates were able to construct a correctly balanced equation with the '12' balancing number for HCl being the hardest part. This links back to the 'assessment for learning' callout added to Question 4 (b) (ii) in this report. As with other questions requiring equations to be written, this question differentiated very well. Writing formulae and balancing equations are fundamentals for mastering chemistry and candidates are advised to practise these skills throughout the course. **Assessment for learning** The specification states the following. ***Formulae and equations*** ***2.1.2(a)*** *the writing of formulae of ionic compounds from ionic charges, including:*

					i. *prediction of ionic charge from the position of an element in the periodic table* ii. *recall of the names and formulae for the following ions: NO_3^-, CO_3^{2-}, SO_4^{2-}, OH^-, NH_4^+, Zn^{2+} and Ag^+* This section will be studied at the start of the two-year course and form the backbone for chemical literacy. For success in chemistry, the common ions should be learnt.
		ii	**FIRST, CHECK THE ANSWER ON ANSWER LINE IF % by mass = 26.72, award 2 marks IF % by mass = 26.7, award 1 mark ---** M_r of $P_3N_3Cl_6$ = 348(.0) ✓ % by mass of P = $\frac{31.0 \times 3}{348} \times 100 = 26.72$ ✓ **2 DP required**	2	**ALLOW** 1 mark total for 26.7 *Question asks for 2 DP* **ALLOW** ECF from incorrect M_r **ALLOW** 1 mark for 8.91 (omission of ×3): $\frac{31.0}{348} \times 100 = 8.91$ **Examiner's Comments** In contrast to equation writing, candidates found this simple calculation far easier with the majority obtaining both marks for 26.72. Common incorrect percentages were 26.7 (wrong number of decimal places) and 8.91 (using 31 rather than 3 × 31 for the numerator).
		iii	(P-N) bond lengths are different ✓ **OR** enthalpy change of hydrogenation is more exothermic (than delocalised structure) **OR** reacts with bromine/electrophiles/by addition	1	**Throughout, ORA** for delocalised structure **IGNORE** C-C bond lengths are different **IGNORE** hydration **ALLOW** decolourises bromine (without a catalyst/halogen carrier) **IGNORE** more reactive without example **IGNORE** alternating single and double bonds **Examiner's Comments** About half the candidates suggested a range of creditworthy responses with 'different bond lengths' and 'decolorises bromine' being the most common.

		iv	Structure shown with molecular formula $P_3N_3Cl_6$ **1st mark** • Each P bonded to 2 Cl atoms • Each P bonded to N **AND** Cl • Each N has *at least* 2 bonds • Each Cl has 1 bond ✓ **2nd mark (dependent on 1st mark)** • Each N has 3 bonds • Each P has 3 **OR** 5 bonds ✓ **IGNORE** charges Examples for 2 marks 	2	1st mark *Meets criteria for 1st mark*  **ZERO** marks  *N bonded to Cl*  *N atom(s) with 1 bond only* **<u>Examiner's Comments</u>** This was another question where valuable information: *'all N and Cl atoms are bonded to P atoms'* had been provided. Many of the structures seen ignored this information with chlorine often been shown bonded to a nitrogen atom. Nitrogen atoms were often shown with 1 bond only and chlorine atoms in the ring structure with 2 or more bonds. Most structures contained 6 or 3-membered rings. This was a difficult question, requiring candidates to use the supplied information to come up with realistic structures that met chemical bonding rules. Only about a quarter of candidates could be given any mark. The Kekulé theme in Questions 4 (c) (i) - (iv) should have prompted candidates that a Kekulé structure was likely here. Several other structures were allowed providing that they met normal chemistry bonding rules
			Total	**6**	
3	a		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF pH = 1.12, award 1 mark**	1	**<u>Examiner's Comments</u>** This question was answered well although nearly a half of candidates made errors. The initial solution

			-- pH = −log 0.075 = **1.12** ✓ ***2 DP required***		had been diluted by 10 times and its concentration had been reduced from 0.750 to 0.0750 mol dm^{-3}. From here pH = $-\log[H^+]$ gives the correct answer of 1.12 to 2 decimal places, required by the question. Candidates found Question 1 (b) more difficult than 1 (a) or 1 (c). There seemed to be little pattern in candidate errors, the dilution being the difficult part of the question. Some did not dilute the initial concentration of 0.750 mol dm^{-3}, giving 2.12. Others divided 0.750 by 2 instead of 10 or introduced 90 into the calculation as 90 cm3 of water would have been added. The most disappointing error was for a correct calculation to be displayed using the wrong number of decimal places. Two decimal places should be the norm for pH, reflecting the accuracy of most pH meters.
	b		**Calculation** ***2 marks*** $n(Cu(NO_3)_2•3H_2O) = 0.200 \times \frac{100}{1000}$ **OR** 2(.00) × 10^{-2} (mol) **OR** 0.02(00) ✓ Mass $Cu(NO_3)_2·3H_2O$ = 2.00 × 10^{-2} × 241.5 = **4.83** (g) ✓ **2 or more DP to match balances** **Method** ***3 marks*** **Dissolve** solid in (distilled) **water** (less than 100 cm^3) (in beaker) ✓ Transfer (solution) to **volumetric** flask **AND** Wash/rinse (from beaker to flask) ✓ Make up to mark/up to 100 cm^3 with (distilled water) **AND**	5	**FULL ANNOTATIONS MUST BE USED** **ALLOW ECF throughout** -- **ALLOW ECF** from incorrect $n(Cu(NO_3)_2•3H_2O)$ 4.83 g subsumes 1st mark **ALLOW** small amount/some **DO NOT ALLOW** 100 cm^3 or more of water **IGNORE** solvent **ALLOW** graduated flask **ASSUME** that wash/rinse is to a volumetric flask **ALLOW** swirl/shake -- **ALLOW** preparation of solutions > 100 cm^3 **4 marks** e.g. for 250 cm^3 $n(Cu(NO_3)_2•3H_2O) = 0.200 \times \frac{250}{1000}$ **OR** 0.05 (mol) ✓ Mass $Cu(NO_3)_2•3H_2O$ = 0.05 × 241.5 = **12.075** (g) ✓ Then method adapted for 250 cm^3 volumetric flask e.g. Make up to 250 cm^3 with water **<u>Examiner's Comments</u>**

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<td>Invert flask (several times to ensure mixing) ✓</td>
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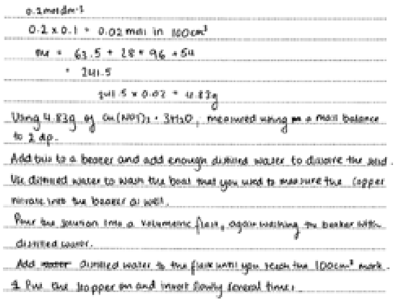
This question differentiated between candidates extremely well. See Exemplar 1 below.

Exemplar 1



0.1 mol dm-3
0.2 x 0.1 = 0.02 mol in 100cm3
Mr = 63.5 + 28 + 96 + 54
= 241.5
241.5 x 0.02 = 4.83g
Using 4.83g of Cu(NO3)2 · 3H2O, measured using a mass balance to 2 dp.
Add this to a beaker and add enough distilled water to dissolve the solid.
Use distilled water to wash the boat that you used to measure the copper nitrate into the beaker as well.
Pour the solution into a volumetric flask, again washing the beaker with distilled water.
Add ~~water~~ distilled water to the flask until you reach the 100cm3 mark.
Put the stopper on and invert slowly several times.

Exemplar 1 has been included to demonstrate a superb response. The comments that follow highlight some of the issues encountered in the responses. Unfortunately, nearly a quarter of candidates could not be given any marks at all for their responses. To improve, it is worth studying Exemplar 1.

The candidate has communicated the key steps required to prepare the standard solution:

• Calculation of the mass of hydrated copper(II) nitrate required.
• Dissolving the hydrated copper(II) nitrate in water in a suitable container (a beaker).
• Transferring the solid to a 100 cm^3 volumetric flask, washing the beaker with water and transferring the washings also to the volumetric flask.
• Making the solution up to the 100 cm^3 mark in the volumetric flask and inverting the flask to mix the contents thoroughly.

Issues with responses which arose by not reading the question closely enough:

• Omitting to calculate the mass of hydrated copper(II) nitrate required.
• Calculating the mass of anhydrous copper(II) nitrate instead of the hydrated salt.
• Dissolving in 100 cm^3 of water and then adding more water for rinsing.
• Not rinsing out the original container at all.
• Making the solution up in the volumetric flask.
• Using of a 250 cm^3 volumetric flask for preparing 100 cm^3 of solution.
• Omitting the inversion stage.
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					• Answering a different question, e.g. how to carry out a titration, how to determine an enthalpy change, how to work out the number of waters of crystallisation by heating in a crucible.
			Total	**6**	
4	a	i	Bonds are breaking **AND** endothermic **OR** energy is required/needed ✓ **IGNORE** 'overcome' for 'break'	1	**IGNORE** 'more energy needed to break bonds than released in making bonds' *Unclear whether response refers to bond breaking or overall enthalpy change* **<u>Examiner's Comments</u>** Most candidates were aware that a bond enthalpy is a measure of the energy to break bonds. Most went on to link the positive sign to an endothermic reaction which requires energy. Some candidates linked bond enthalpies to bond formation instead. A significant number of responses described an endothermic reaction, instead of bond enthalpy, in terms of the energy required to break bonds being greater than the energy to make bonds. This was the answer to a different question and could not be given marks.
		ii	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF bond enthalpy = (+)413 (kJ mol^{-1}) award 3 marks** --- *Energy for bonds made (3 × H−H + 1 × C=O)* **1 mark** 3 × 436 + 1 × 1077 **OR** 1308 + 1077 **OR 2385** (kJ)✓ **IGNORE** sign *4C−H bond enthalpy correctly calculated* **1 mark**	3	**COMMON ERRORS** **ECF for other numbers** **315.5 OR 316** → 2 marks *Wrong sign for 195* Bonds made = 2385 ✓ -195 + 2385 - 928 = 1262 × 1262/4 = **315.5 OR 316** ✓ **ECF** **877** → 2 marks *Wrong sign for 928* Bonds made = 2385 ✓ 195 + 2385 + 928 = 3508 × 3508/4 = **877** ✓ **ECF**

4 × C-H bond enthalpy = 195 + 2385 - (2 × O-H)
= 195 + 2385 - 2 × 464
= 195 + 2385 - 928
1652 (kJ mol^{-1}) ✓
IGNORE sign

C-H bond enthalpy correctly calculated **1 mark**

This mark is **NOT available from **TWO** previous errors
OR from ΔH = 195 **not** being used **

$$\text{C–H bond enthalpy} = \frac{1652}{4} = (+)\mathbf{413}\ \text{kJ mol}^{-1}\ ✓$$

For the final answer,
DO NOT ALLOW value with a negative sign

-- **COMMON ERRORS**

−413 → 2 marks *Wrong sign for answer*

304 → 2 marks *2 mol of H_2 instead of 3 mol:*

2 × 436 + 1 × 1077 = 872 + 1077 = 1949	×
195 + 1949 − 928 = 1216	ECF ✓
1216/4 = **304**	ECF ✓

364 → 1 mark *Missing ΔH, (195)*

Potentially 2 errors: missing 195 and sign for 195

Bonds made = 2385	✓	
2385 - 928 = 1457	×	
1457/4 = 364/ 364.3 /364.25	×	**NO ECF**

779.5 OR 780 → 1 mark *Wrong sign for 928* ***AND*** *195*

Bonds made = 2385	✓	
-195 + 2385 + 928 = 3118	×	
3118/4 = **779.5**	×	**NO ECF**

529 → 2 marks *1 O-H instead of 2 O-H:*

Bonds made = 2385	✓	
195 + 2385 - 464 = 2116	×	
2116/4 = **529**	✓	**ECF**

181 → 2 marks *4 O-H instead of 2 O-H:*

Bonds made = 2385	✓	
195 + 2385 - 1856 = 724	×	
724/4 = **181**	✓	**ECF**

Examiner's Comments

This question differentiated well, with about half the candidates obtaining the correct bond enthalpy of +413 kJ mol^{-1}. With ECF, few candidates scored 0 marks.

Most candidates calculated the energy involved in

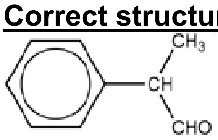
					making 3 H-H bonds and 1 C≡O bond as 2385 kJ mol^{-1}. This value had to be incorporated with the energy associated with breaking bonds and the enthalpy change of -195 kJ mol^{-1}. It was this step where problems arose. There were many errors with signs and the lowest attaining candidates sometimes omitted the enthalpy change completely in their calculation. The commonest error of 315.5 kJ mol^{-1} was the result of using the wrong sign for the enthalpy change. With ECF, this was still given 2 of the 3 available marks.
		iii	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF energy released = 7.15×10^5 kJ, award 2 marks** --- $n(H_2) = \frac{60.0 \times 10^3}{24.0} = \mathbf{2500}$ (mol) ✓ Energy released = 2500 × 285.8 = **7.15×10^5** kJ ✓ **3SF AND standard form** required **IGNORE** sign i.e. **ALLOW + OR - OR** no sign	2	**ALLOW ECF ONLY** from incorrect $n(H_2)$ based on with incorrect unit conversion from m^3 e.g. $n(H_2) = \frac{60.0 \times 10^2}{24.0} = 250$ (mol) ✗ 250 × 285.8 = 7.15×10^4 kJ ECF ✓ So **ALLOW** 1 mark for: $\pm 7.15 \times 10^x$ (unit conversion) 7.145×10^5 *(not 3SF)* 715000 *(not standard form)* --- **ALLOW** use of ideal gas equation with a sensible temperature (290-298K) and pressure (100/101/101325 kPa) e.g. e.g. At 293K and 100 kPa, $n(H_2) = \frac{100 \times 10^3 \times 60.0}{8.314 \times 293} = 2463...$ (mol) → 2463 × 285.8 = **7.04×10^5** kJ e.g. At 298K and 100 kPa, $n(H_2) = \frac{100 \times 10^3 \times 60.0}{8.314 \times 298} = 2421.7...$ (mol) → 2421.7 × 285.8 = **6.92×10^5** kJ **ALLOW** use of 8.31 for *R* (same answers) 293K → 2464.24 × 285.8 = **7.04×10^5** kJ 298K → 2422.89 × 285.8 = **6.92×10^5 kJ**

					Examiner's Comments Unlike the standard bond enthalpy calculation in Question 2 (a) (ii), this question required candidates to apply their understanding of enthalpy changes to a new context relevant to energy. Candidates also had to interconvert units and provide an answer to 3 significant figures in standard form. Apart from the chemistry, there were various mathematical skills to use. Candidates found this question much more demanding than Question 2 (a) (ii), with only just over a half gaining marks. The first step involved working out that the number of moles of hydrogen gas in 60 m^3 at RTP is 2500 mol. Candidates then had to apply their understanding of $\Delta_f H$ to calculate the energy as 7.15×10^5 kJ. Common mistakes included: • multiplying 60 m^3 by the enthalpy change of 285.8 kJ mol^{-1} (omitting to calculate the moles of H_2 - a lack of understanding) • using more than 3 significant figures, e.g. 7.145 instead of 7.15 • making an error with powers of 10 in the mole calculation (usuallysually by not converting 60 m^3 into 60,000 dm^3, leading to 2.5 moles). This type of question looks simple but makes for an excellent way of developing application and mathematical skills.
	b	i	$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$ ✓	1	***ALL*** *3 state symbols required* **Examiner's Comments** Candidates were required to write a straightforward ionic equation that they would have encountered many times during the A Level Chemistry course. It was surprising that only just over half the candidates produced an equation that could be given. Common errors included the following. • Omission of state symbols or incorrect state symbols, especially (aq) in AgC*l*(s).

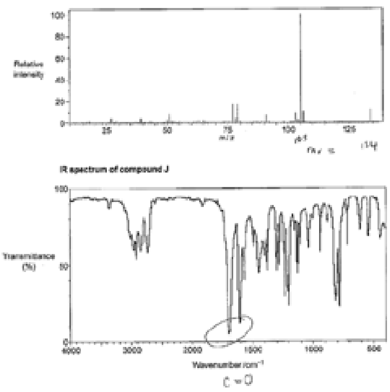
					• Inclusion of nitrate ions or use of $AgNO_3$ instead of Ag^+. • An equation using Cl_2 and forming $AgCl_2$. Some candidates used the ideal gas equation to determine the moles of hydrogen, choosing suitable values for temperature and pressure. This approach was allowed, although the exercise would have wasted candidate time compared to the much simpler division by 24 for using RTP, which is stated in the question.
		ii	***n*($AgNO_3$) 1 mark** $= 2.50 \times 10^{-2} \times 60.0/1000 = 1.5(0) \times 10^{-3}$ (mol) ✓ **Essential mark** **Formula 2 marks** **Ratio** 5.00×10^{-4} mol **A** contains $1.5(0) \times 10^{-3}$ mol Cl **OR** ratio A : Cl = $1.5(0) \times 10^{-3} \div 5.00 \times 10^{-4}$ = 1 : 3 ✓ **Formula** = $AlCl_3$ ✓ Automatically subsumes 1:3 ratio mark ✓ **ALLOW** Al_2Cl_6 **ALLOW** PCl_3	3	**Check equation from 2b(i) at top of response** -- **ALLOW** 1:3 or 3:1 ratio seen anywhere, e.g. XCl_3 **ALLOW ECF** from formula of silver chloride in **2b(i)** e.g. From $AgCl_2$ *n*(Cl) = **2** × $1.5(0) \times 10^{-3} = 3.(00) \times 10^{-3}$ (mol) ratio = 1 : 6 Formula = SCl_6 **<u>Examiner's Comments</u>** Most candidates determined the moles of $AgNO_3$ and hence Ag^+ as 1.50×10^{-3} mol. This was given 1 mark, but candidates then needed to use this amount to predict the identity of compound **A**. Most candidates could not see the way forward and many received only 1 mark. Many candidates had worked out 'something' from the supplied data, without knowing where this initial step would take them. Candidates needed to spot that the ratio of the element : C*l* in compound **A** was 5×10^{-4} : 1.50×10^{-3} or 1 : 3. The correct formula of A*l*C*l*$_3$ then follows. MgC*l*$_2$ was a common error obtained by subtracting 5×10^{-4} from 1.50×10^{-3} to obtain a 1 : 2 ratio. This question would be a good exercise for improving the application skills of candidates.
	c	i	$C_{13}H_{19}N_3O_7$ ✓	1	**ALLOW** elements in formula in any order e.g. $C_{13}H_{19}O_7N_3$ **<u>Examiner's Comments</u>** Most candidates made a good attempt at working

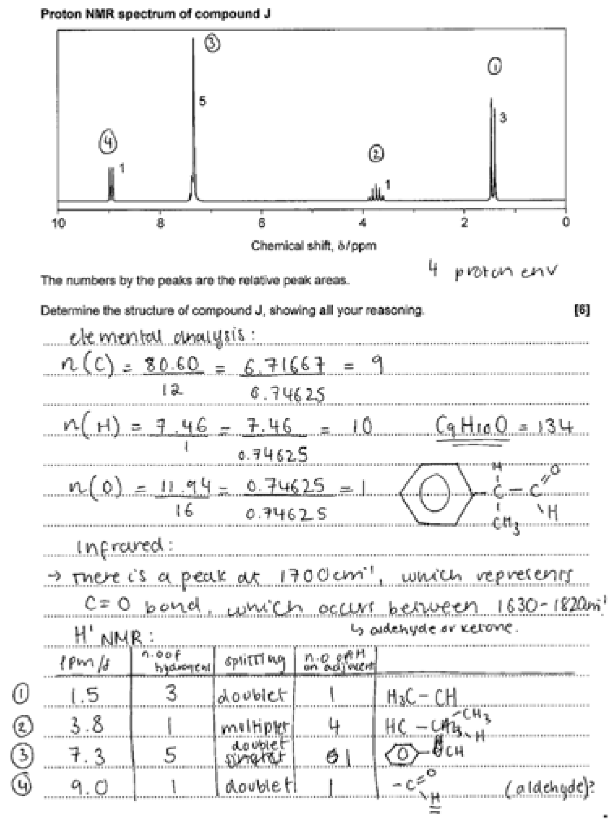
					out the molecular formula of the structure as being $C_{13}H_{19}N_3O_7$. N and O were usually correct with mistakes most common with carbon (especially 12) and hydrogen (especially 17-20).
		ii	4 ✓	1	**Examiner's Comments** This question was answered well with the correct answer of 4 being seen on most scripts, reflecting good understanding of chiral carbon centres. The commonest incorrect response was 5, presumably by including the C atom on the bottom right of the structure within the -**C**H(CH_3)$_2$ group.
		iii	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF difference = 61.7, award 2 marks** --- M_r of **C** = 380 **OR** M_r of **D** = 441.7 ✓ Correct difference = 441.7 - 380 = **61.7** ✓ **AWARD** mark for **correct answer of 61.7 only**	2	**ALLOW** other approaches based on different atoms in **C** and **D**, e.g. Difference = 7 × (32.1 - 16) - 3 × (31 - 14) = 112.7 - 51 = **61.7** ✓ **Check answer from 2c(i) at top of response for ECF** **ALLOW ECF** from incorrect formula from **2c(i)** e.g. From $C_{12}H_{16}N_3O_6$ M_r of **C** = 349 **OR** M_r of **D** = 394.6 ✓ **ECF** difference = 394.6 - 349 = **45.6** ✓ **ECF** **Examiner's Comments** This question was answered extremely well with about three-quarters of candidates securing both marks. Most candidates calculated the molecular masses of compounds **C** and **D** as 380 and 441.7 respectively, to obtain a difference of 61.7. Some candidates adopted a simpler different approach which gives the same correct answer, working out the difference between the masses of nitrogen and phosphorus (for **C**) and oxygen and sulfur (for **D**). ECF was applied to any incorrect molecular formulae from Question 2 (c) (i) from which both marks could be obtained
			Total	**14**	
5			**FIRST CHECK ANSWER ON ANSWER LINE** **If answer = 53.8 (%) award 3 marks** --	3	**ALLOW ECF** for each step **TAKE CARE** as value written down may be truncated but with value stored in calculator, depending on rounding, either can be credited. **IGNORE** trailing zeroes e.g. 0.065 for 0.0650

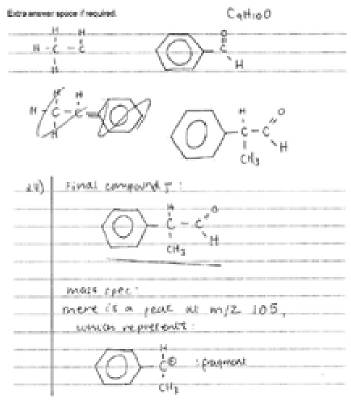
			Theoretical moles *n*(**H**) **OR** *n*(**G**) $\frac{8.97}{138.0}$ **OR** 0.065(0) (mol) ✓ **Actual moles** *n*(methyl salicylate) = $\frac{5.32}{152.0}$ **OR** 0.035(0) (mol) ✓ % yield = $\frac{0.035}{0.065} \times 100$ = 53.8% to 3 **SF** ✓		**DO NOT ALLOW ECF** for final mark if value is ≥100% **DO NOT ALLOW** 59.3% **IF** no moles have been calculated for final mark e.g. masses used 5.32/8.97 x 100 = 59.3% Calculator = 53.84615385 **BUT** 3 SF required for % yield **Alternative method using mass** 1. Theoretical moles = 0.065(0) mol ✓ 2. Theoretical mass = 0.065 × 152.0 **OR** 9.88 g ✓ 3. % yield = $\frac{5.32}{9.88} \times 100$ = 53.8% ✓ **<u>Examiner's Comments</u>** Many candidates were well prepared for this question and secured all 3 marks. Some however were unable to calculate thecorrect M_r of either **G** or **H** or both. A small proportion gained credit from error carried forward. A significant number of lower attaining candidates used both masses directly or found the mass lost as a percentage. A few tried to use density information, provided earlier in the question, in their calculation. Very few lost marks due to the wrong number ofsignificant figures, however some initially rounded the answer to 4 sf i.e. 53.85 then rounded this value to 3 sf giving 53.9.
			Total	**3**	
6			*Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.* **Level 3 (5-6 marks)** Structure is $C_6H_5CHCH_3CHO$ **AND** Analyses data from **all 3** scientific points *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)**	6	**LOOK ON THE SPECTRA** for labelled peaks and mark as **SEEN** **Indicative scientific points:** **<u>1. Empirical (and Molecular) Formulae</u>** • C : H : O = $\frac{80.60}{12.0}$: $\frac{7.46}{1.0}$: $\frac{11.94}{16.0}$ = 6.72 : 7.46 : 0.746 = 9 : 10 : 1 • Empirical formula = $C_9H_{10}O$ **<u>2. Mass spectrum and IR</u>** **Mass spectrum** • uses *m*/*z* = 134 to give molecular formula: $C_9H_{10}O$

			Structure with **most** key features including O atom(s) **AND** Analyses data from **at least 2** of the scientific points *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)** Attempts analysis from **at least 2** of the scientific points *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.*		• Any possible fragments: - m/z = 105 $C_6H_5CHCH_3^+$ - m/z = 77 $C_6H_5^+$ - m/z = 29 CHO^+ **IR** • C=O from ~1700 cm^{-1} • Likely to be aldehyde or ketone • C=C (arenes) ~1500 cm^{-1} **ALLOW** *Data Sheet ranges* **<u>3. ¹H NMR</u>** • δ = 1.4 ppm, doublet, 3H $\mathbf{CH_3}$CH− • δ = 3.8 ppm, quintet, 1H next to 4 adjacent H • δ = 7.3 ppm, singlet, 5H $\mathbf{C_6H_5}^-$ • δ = 9.0 ppm, doublet, 1H -CH**CHO** **ALLOW** approximate values for chemical shifts **Structure** **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** correct Kekulé representation of benzene **Key features** • Benzene ring • C=O • CH_3 **Correct structure**  • ($C_6H_5CHCH_3CHO$) Aspects of the **communication statement** being met might typically include:

					• Structures given are feasible and unambiguous • Easy to follow layout on empirical formula calculation • Empirical formula is shown to be same as molecular • IR peaks linked clearly to bond it refers to not just functional groups • Positive charge given on MS fragments • MS fragments plausible for the molecular formula determined • Clear information for each NMR peak • No additional irrelevant/incorrect information given **Examiner's Comments** This question was well-attempted by most candidates, with the majority of candidates gaining full marks or gaining 4 marks for a top Level 2 response. Many candidates showed excellent recall of how to determine the correct empirical formula from the percentage composition data. Most then went on to use the m/z peak on the mass spectrum to confirm that the M_r was 134, and therefore the molecular formula was identical to the empirical formula. A few also made use of the mass spectrum to identify possible fragment ions including a correct positive charge. Most candidates used the IR spectrum to identify a C=O bond and many also mentioned the absence of O-H or spotted C=C for arenes. Lower attaining candidates sometimes incorrectly mentioned the presence of a carboxylic acid O-H despite the molecular formula only having 1 oxygen atom. Many candidates annotated the NMR spectrum and/or presented their analysis clearly in a table format and were able to identify aldehyde and arene hydrogen environments. The best candidates hadfragments built up alongside their NMR analysis clearly building them using chemical shift, integratio ratios and splitting patterns. Those that struggled to interpret the splitting patterns correctly suggested incorrect structures but often with correct features so were still able to score Level 2, 4 marks. Some initially identified the multiplet peak at3.8ppm as being **H**C-O

					environment but many realised this did not fit the IR data. However, some changed other evidence to fit this, e.g. the peak at 9.0 ppm being an O-**H** rather than C**H**O and the IR having C=C only without C=O as well. A large proportion of candidates were able to correctly determine the structure of compound **J**, recognising that the peak at 3.8 ppm was shifted up-field as adjacent to both the benzene ring and the aldehyde group. The data sheet refers to this: 'C**H** bonded to 'shifting groups' on either side, e.g. O−CH_2−C=O, may be shifted more than indicated above'. Several candidates who did not get the correct structure gave structures which were chemically unfeasible, e.g. with pentavalent carbons. Many candidates had several structures as part of working but did not always ensure their final structure was clearly highlighted. A very small number of candidates received no credit for this question, as the majority were able to show analysis of 2 aspects, e.g. the calculation of empirical formula and labelling of IR or NMR spectra. Exemplar 3 





Level 3, 6 marks

There is clear and detailed analysis throughout this response to determine the correct final structure for **J**. The empirical formula calculation shows how the empirical formula was determined. On the mass spectrum the annotation links to the M_r of 134 and at the end of the response they have identified the fragment responsible for the parent ion. The C=O IR peak is labelled and described in the response. The NMR analysis is clear, with each peak being numbered and linked to a table which shows how the candidate has identified the hydrogens responsible for each peak as well as linking to neighbouring hydrogens from splitting patterns.

					The final compound is labelled as such to distinguish it clearly from other structures given, which were part of their problem solving to find a structure that fits all of the analysis they had completed.
			Total	**6**	
7			A **AND** D only ✓	1	**ALLOW** letters in any order **<u>Examiner's Comments</u>** This question was also challenging and just under half of candidates gave the correct response. Many wrote molecular formulae underneath each structure, but less successful responses often struggled to convert from the skeletal formulae correctly. Common errors included: • just giving Structure D, and omitting Structure A • including Structure E as they miscounted the number of hydrogens in the presence of a triple C-C bond • including Structure B, on the basis that it had a double C-C bond • some less successful responses just wrote "alkene" and did not apply their responses to the hydrocarbon structures given.
			Total	**1**	
8			**C**	1	**ALLOW** 1.5(0) **<u>Examiner's Comments</u>** Around two thirds of candidates gave the correct answer C, 1.50 mol dm^{-3} . Those that showed working were more likely to have the correct answer. Some only found the moles of ethylamine from the mass and M_r give so gave 0.03, A. Some candidates struggled to figure out that HCl was in excess, so used 0.04 moles of HCl to give a concentration of 2.0 mol dm^{-3}, D.
			Total	**1**	
9			**FIRST CHECK ANSWER ON THE ANSWER LINE** **IF answer = 1.8(0) (dm^3) award 3 marks** --	3	**ALLOW ECF throughout** **ALLOW** no trailing zeroes (e.g. 0.02 for 0.0200) *Only award **ECF** using moles for NO_2, O_2,* $NO_2 + O_2$

<table>
<tr>
<td></td><td></td><td></td>
<td>$n(Fe(NO_3)_3) = \frac{4.836}{241.8} = 0.02(00)$ (mol) ✓

$n(NO_2 + O_2) = 0.06 + 0.015$
OR 15/4 × 0.0200
OR 0.0750 (mol) ✓

Total volume = 0.0750 × 24 = 1.8(0) (dm^3) ✓

DO NOT ALLOW 0.02 × 24 = 0.48 dm^3
0.48 dm^3 is 1 mark only for whole question</td>
<td></td>
<td>e.g. NO_2: 0.06 × 24 = 1.44 (dm^3)
O_2: 0.015 × 24 = 0.36 (dm^3)

ALLOW use of ideal gas equation using sensible p and T for final mark. e.g.
from 100 kPa and 293 K
$\rightarrow V = \frac{nRT}{p} = \frac{0.075 \times 8.314 \times 293}{1000} = 1.83\ dm^3$
ALLOW 1 DP: 1.8 dm^3

from 100 kPa and 298 K
$\rightarrow V = \frac{nRT}{p} = \frac{0.075 \times 8.314 \times 298}{1000} = 1.86\ dm^3$
ALLOW 1 DP: 1.9 dm^3

from 100 kPa and 273 K
$\rightarrow V = \frac{nRT}{p} = \frac{0.075 \times 8.314 \times 273}{1000} = 1.7(0)\ dm^3$

Examples of ‘sensible’ p and T:
p = 100 kPa, 101 kPa, 101,325 Pa
T = 273 − 298 K

<u>Examiner’s Comments</u>

Most candidates were given at least one of the three available marks for calculating the amount of $Fe(NO_3)_2$ as 0.0200 mol. Candidates then needed to determine the moles of gas ($NO_2 + O_2$) as 0.0750 mol, which has a volume at RTP of 0.0750 × 24.0 = 1.80 dm^3.

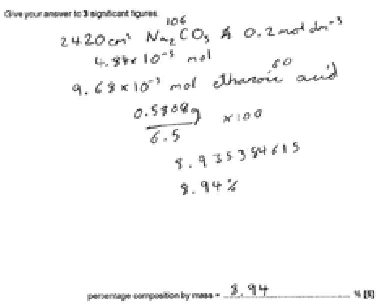
The most common error was omission of ÷4 from the equation when working out the moles of gas and obtaining a total volume of 1.80 × 4 = 7.20 dm^3. Such a response could still be given 2 marks by error carried forwards.</td>
</tr>
<tr>
<td></td><td></td><td></td><td>Total</td><td>3</td><td></td>
</tr>
<tr>
<td>10</td><td></td><td>i</td>
<td><table><tr><td>Titre/cm^3</td><td>24.40</td><td>24.15</td><td>24.25</td><td>✓</td></tr></table>
Correct subtractions to obtain titres to 2 DP</td>
<td>1</td>
<td>DO NOT ALLOW 24.4

<u>Examiner’s Comments</u>

Most candidates were able to work out these simple subtractions. Candidates were told that the titration readings were read to the nearest 0.05 cm^3, requiring volumes to be recorded to two decimal places, which may include a ‘0’. The right-hand initial reading is therefore 24.10cm^3 and not 24.1 cm^3, which continues to be the commonest error seen.</td>
</tr>
</table>

		ii	mean titre = $\frac{24.15 + 24.25}{2}$ = 24.20 (cm^3) ✓ *i.e. using concordant (consistent) titres*	1	**ALLOW** 24.2 *DP already assessed in b(i)* **DO NOT ALLOW** mean of all three titres, i.e. $\frac{24.40 + 24.15 + 24.25}{3}$ = 24.26/24.27 **ALLOW ECF** from incorrect concordant titres from **22b(i)** **<u>Examiner's Comments</u>** Candidates are expected to use only concordant titres when working out the mean titre and the left-hand titre of 24.40cm^3 should be rejected. Most candidates did this to produce 24.20 cm^3 as their mean titre. Use of 24.2 was allowed because rounding of a '0' as the second decimal place had already been penalised in Question 21 (b) (i). Predictably, the most common error was to use all three titres to produce the incorrect mean of 20.27cm^3.
		iii	**FIRST CHECK ANSWER ON ANSWER LINE** **IF answer = 89.4 (%) award 5 marks** **CHECK** mean titre from **22b(ii)** first. **THEN** apply **ECF** throughout using THIS mean titre **First 3 mark must come from the titration** ***n*(Na_2CO_3)** = 0.200 × $\frac{24.20}{1000}$ = 4.84 × 10^{-3} (mol) ✓ ***n*(CH_3COOH) in 25.0 cm^3** = 2 × 4.84 × 10^{-3} = 9.68 × 10^{-3} (mol) ✓ ***n*(CH_3COOH) in 250 cm^3**	5	**ALLOW** 3**SF** or more throughout **IGNORE** trailing zeroes, e.g. **ALLOW** 24.2 for 24.20 **ALLOW ECF** from incorrect mean titre in **b(ii)** **ALLOW ECF** from 2 × incorrect *n*(Na_2CO_3) **ALLOW ECF** from incorrect *n*(CH_3COOH), **OR** from *n*(Na_2CO_3) if *n*(CH_3COOH) stage omitted <u>**ALLOW** 5.81 (3 SF)</u> **IF** mass is rounded to 5.81, Answer is still 89.4% *Calculator = 89.38461538* *8.94% is 4 marks (omission of × 10 stage)* **IF** incorrect mean titre of 24.26/24.27 cm^3 used: *(mean of all 3 titres in **b(ii)**)*, % composition = 89.6% to 3 SF for **ALL** 5 marks by **ECF** -- **NOTE**: Some candidates are calculating *n*(CH_3COOH) based on the 6.50 g sample being pure

			$= 10 \times 9.68 \times 10^{-3}$ = 9.68×10^{-2} (mol) ✓ **mass of CH_3COOH in 250 cm^3** $= 60 \times 9.68 \times 10^{-2}$ = 5.808 (g) ✓ **% composition to 3 SF** $= \frac{5.808}{6.50} \times 100$ = 89.4 (%) ✓ **3 SF** *Calculator: 89.35384615* **COMMON ERRORS** **Omitting ÷ 1000 for *n*(Na_2CO_3)** *Up to 3 marks are possible* ***n*(Na_2CO_3)** $= 0.200 \times 24.20$ = 4.84 (mol) × ***n*(CH_3COOH) in 25.0 cm^3** $= 2 \times 4.84$ = 9.68 (mol) ✓ ***n*(CH_3COOH) in 250 cm^3** $= 10 \times 9.68$ = 96.8 (mol) ✓ **mass of CH_3COOH in 250 cm^3** $= 60 \times 96.8$ = 5808 (g) ✓		**DO NOT ALLOW 0.108(3……** $n(CH_3COOH) = \frac{6.50}{60} = 0.108(3……$ **COMMON ERRORS** **Using 25.0 cm^3 (pipette volume) instead of 24.20 cm^3** *Up to 4 marks are possible* ***n*(Na_2CO_3)** $= 0.200 \times \frac{25.00}{1000}$ = 5.00×10^{-3} (mol) × ***n*(CH_3COOH) in 25.0 cm^3** $= 2 \times 5.00 \times 10^{-3}$ = 1×10^{-2} (mol) ✓ ***n*(CH_3COOH) in 250 cm^3** $= 10 \times 1 \times 10^{-2}$ = 1×10^{-1} (mol) ✓ **mass of CH_3COOH in 250 cm^3** $= 60 \times 1 \times 10^{-2}$ = 6.00 (g) ✓ **% composition to 3 SF** $= \frac{6.00}{6.50} \times 100 = 92.3$ (%) ✓ *Calculator: 92.30769231* **Examiner's Comments** Many candidates followed a well drilled method to analyse their titration results: • Moles of Na_2CO_3 in the mean titre • Moles of CH_3COOH in 25 cm^3 • Scaling ×10 for moles of CH_3COOH in 250 cm^3 Candidates then needed to process their titration results further to determine the percentage composition:

			% composition to 3 SF $= \frac{5808}{6.50} \times 100$ = 89400 (%) × *Impossible value*		• Mass of CH_3COOH in 250 cm^3 • Percentage composition of CH_3COOH to 3 significant figures. Most candidates were able to make some progress through the analysis. Common errors included: • Not ×2 to obtain the moles of CH_3COOH • Omission of the scaling stage. Some candidates ignored the titration results entirely, instead calculating the number of moles of CH_3COOH in 6.5 g of the descaler as 0.1083 mol by assuming that all of the descaler was CH_3COOH. This approach was flawed and could not be given any marks. A final comment must be made about the presentation of many of the responses. Numbers had often been sprayed across the page and it could be difficult to see how these related to a cohesive solution. It was often impossible to give marks for such responses. The question discriminated extremely well with some candidates given all 5 marks. Less successful responses demonstrated problems with approaching this type of question and some were given no marks at all. Exemplar 1  Give your answer to 3 significant figures. 106 24.20 cm³ Na₂CO₃ 0.2 mol dm⁻³ 4.84×10⁻³ mol 60 9.68×10⁻³ mol ethanoic acid 0.5808g / 6.5 ×100 8.935384615 8.94% percentage composition by mass = 8.94 % [5] Exemplar 1 shows a well-presented response, with the only error being not scaling the moles of CH_3COOH from 25 to 250 cm^3. The result is a percentage composition of 8.94 % instead of 89.4%. The clear presentation allowed the examiner to follow how the incorrect response had been obtained. Error carried forward allowed

					marks can be given for a correct method, giving a total of 4 out of 5 marks.
			Total	**7**	
11			**D**	1	**Examiner's Comments** Most candidates selected D as the correct formula. They usually showed their working alongside the options which is good practice. B was the main distractor and working suggested that such candidates had over-rounded their ratio of 1:1.5 to 1:2.
			Total	**1**	
12			**C**	1	**Examiner's Comments** Candidates found this question very difficult. Scripts showed a general lack of working, suggesting that candidates did not know how to approach the problem. Candidates had to first work out which reactant was in excess and to use the limiting reagent to determine the volumes of CO_2 formed. The question did not discriminate very well, suggesting that many candidates guessed. C was the correct response with A and D being the main distractors, presumably because these contained the largest volumes of O_2 (in A) and of CO (in D). This would be a good question to use with high-attaining candidates.
			Total	**1**	
13			**B**	1	**Examiner's Comments** Overall, candidates had little difficulty with this question and most selected B. Options C and D were the main distractors, with few choosing option A. The question did not discriminate well across the ability range, suggesting that many candidates guessed.
			Total	**1**	

14		i	(**A** =) $[Co(H_2O)_6]^{2+}$ ✓ (**B** =) $Co(OH)_2$ ✓ (**C** =) $[CoCl_4]^{2-}$ **OR** $CoCl_4^{2-}$ ✓	3	**IGNORE** state symbols even if incorrect [ ] essential **ALLOW** $[Co(OH)_2(H_2O)_4]$ **OR** $Co(OH)_2(H_2O)_4$ **ALLOW** -2 for 2- i.e. $[CoCl_4]^{-2}$ **<u>Examiner's Comments</u>** Most candidates scored three marks. Some used other transition metal ions such as Cu^{2+} or Mn^{2+} and candidates should be mindful of the information given in the question. Charges were sometimes incorrect, and some responses lacked the square brackets to show the complex.
		ii	Complex : $[Co(NH_3)_4Cl_2]$ ✓ Charge +1 / + / 1+ ✓	2	**IGNORE** Any charges for 1st mark **ALLOW** $[CoCl_2(NH_3)_4]$ **ALLOW** $[Co(Cl)_2(NH_3)_4]$ **DO NOT ALLOW** $[Co(Cl_2)(NH_3)_4]$ **DO NOT ALLOW** if charges shown in formula within brackets for 2nd mark **<u>Examiner's Comments</u>** Most candidates identified the formula and the charge as 1+. A few candidates stated no charge or 3+. Candidates should consider the use of brackets in the formula, e.g. square brackets to show the complex and curly brackets to show the number of ligands attached. A few candidates used NH_4 rather than NH_3 for the ammonia ligand.
			Total	**5**	
15		i	Smooth s-shaped curve using a best fit line that goes through the majority of points. ✓ Reading off x-axis at 12.5 cm^3 ✓ $n(Ba(OH)_2) =)\ 0.0560 \times \frac{12.5}{1000}$ = 7.00×10^{-4} ✓ $n(CH_3COOH =)$ 2 × (moles $Ba(OH)_2$) = 1.40×10^{-3} ✓ (concentration =) $\frac{1.4 \times 10^{-3}}{(10/1000)}$ = 0.14(0) (mol dm^{-3}) ✓ <u>Alternative method based on</u>	5	**DO NOT ALLOW** point to point **DO NOT ALLOW** tram/feather lines. **ALLOW** Reading off x-axis from 12.4 − 12.6 cm^3 **ALLOW** ECF throughout **ALLOW** 3SF or more unless there is a trailing zero <u>Alternative answers:</u> 0.139 (mol dm^{-3}) (from reading off x-axis at 12.4 cm^3) 0.141 (mol dm^{-3}) (from reading off x-axis at 12.6 cm^3)

calculating pK_a from the half neutralisation point.

pH and $[H^+]$ reading will come from the candidates graph and the data points provided.

e.g.

pH at half neutralisation
6.25 cm^3 = pH 4.7 = pK_a ✓

$K_a = 10^{-4.7}$
$= 1.995 \times 10^{-5}$ ✓

$[H^+]$ at pH 3.3 (obtained from data on the graph provided)

$10^{-3.3} = 5.012 \times 10^{-4}$ ($mol\ dm^{-3}$) ✓

$[HA] = \frac{[H^+]^2}{[K_a]}$

$= \frac{(5.012 \times 10^{-4})^2}{(1.995 \times 10^{-5})}$

$= 0.0126$ ($mol\ dm^{-3}$) ✓

Common errors:
3 Marks

0.134 (Use of 12 cm^3)
0.202 (use of 18 cm^3)

ALLOW MP2 for $K_a = 1.7 \times 10^{-5}$ to 1.8×10^{-5} (knowledge of actual K_a value)

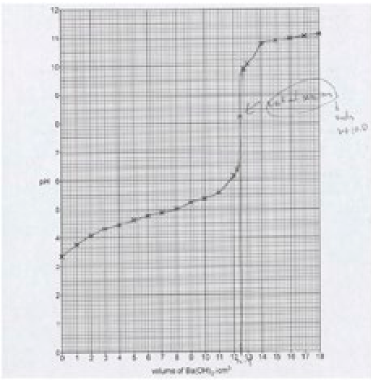
ALLOW ECF from any quoted K_a

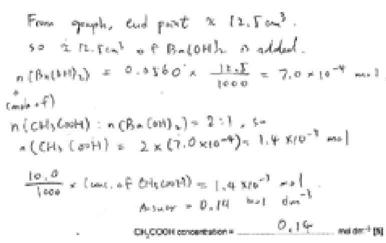
Examiner's Comments

Nearly all candidates were able to draw the line of best fit and linked the sharp vertical section of the graph with the volume of $Ba(OH)_2$ needed to neutralise the ethanoic acid. Candidates should aim to produce a smooth line of best fit and avoid 'tram' lines when the pencil is taken off the paper and the curve started again. The line should go through most points.

Some candidates misinterpreted the graph and used values of 8, 12, 12.2, 12.25 and 18. However, the remainder of the calculation was accessible, and most candidates scored well with ECF marks from this point. There was occasional division of 2 for the moles of ethanoic acid and dividing by the original volume of $Ba(OH)_2$ rather than the $10cm^3$ of ethanoic acid.

Exemplar 3





					This candidate scored all available marks. This is a very good example of a candidate displaying their working. The response was well communicated indicating the end point, links were made to what was being calculated and how the next number was obtained.
		ii	Phenol red **OR** Phenolphthalein ✓	1	Both indicators can change colour on the sharp vertical section of the candidates curve. **Examiner's Comments** Nearly all candidates scored this marking point. Phenol red and Phenolphthalein were good choices of indicator as their colour changed on the sharp vertical section of the graph, depending on how the top end of the line of best fit was drawn. Occasionally malachite green and bromophenol blue were seen.
			Total	**6**	
16			**FIRST CHECK ANSWER ON ANSWER LINE** **If answer = 84 award 4 marks** --- $n(\text{I}^-) = \frac{26.2 \times 0.150}{1000} = 3.93 \times 10^{-3}$ ✓ $n(\text{IO}_3^-) = \frac{3.93 \times 10^{-3}}{5} = 7.86 \times 10^{-4}$ ✓ mass KIO_3 in 2 tablets = $7.86 \times 10^{-4} \times 214$ = 0.168204 g ✓ mass KIO_3 in 1 tablet = 0.084102 g = 84 mg (**nearest whole number**)✓	4	**ALLOW** 3 SF or more throughout **ALLOW** ECF throughout Care – other sequence of calculations can be valid. Alternative route M3 mol (IO_3^-) in one tablet = $\frac{7.86 \times 10^{-4}}{2} = 3.93 \times 10^{-4}$ M4 Mass (KIO_3) in one tablet = $3.93 \times 10^{-4} \times 214$ = 84 **Final answer must be a whole number** **Common Errors** 3 marks: 69 mg (using M_r of IO_3^-) 421mg (not divided by 5) **Examiner's Comments** Although lots of candidates got the correct final answer, almost all achieved some credit from this calculation through error carried forward with marks spread across the available range. Almost all candidates were able to find the number of moles of iodide. A few candidates did not get the molar ratio and/or used the mass of just IO_3^- rather than KIO_3. Some then did not realise the need to half this number to find the mass in 1 tablet, and multiplied by either 10 or 100 in order to convert g to mg.

<table>
<tr><td></td><td></td><td></td><td></td><td></td><td>Assessment for learning

Candidates need to develop their ability to perform calculations that require them to convert between different units, e.g. mg to g. Each step of a calculation should be shown.</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>4</td><td></td></tr>
<tr><td>17</td><td></td><td></td><td>A</td><td>1</td><td>ALLOW −56 (correct numerical answer)

<u>Examiner’s Comments</u>

The correct answer was A. Some candidates showed full working in the space provided. B and C were common errors. Those who selected C did not take into account the need to half the reaction’s enthalpy change to meet the definition requirements of one mole of water.</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>1</td><td></td></tr>
<tr><td>18</td><td></td><td></td><td>C</td><td>1</td><td><u>Examiner’s Comments</u>

The correct answer was C. Candidates should be encouraged to use the space around the question to jot down the equation and perform any calculations. There was evidence of some confusion about atom economy leading to B or D being selected.</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>1</td><td></td></tr>
<tr><td>19</td><td></td><td></td><td>Level 3 (5-6 marks)
A comprehensive description including most of the evidence to justify the correct structure of X.

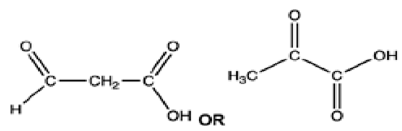
There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated

Level 2 (3-4 marks)
Explains two scientific points with few omissions OR some aspects from all three
AND
an attempt at a feasible structure</td><td>6</td><td>LOOK ON THE SPECTRA for labelled peaks.
Indicative scientific points may include:

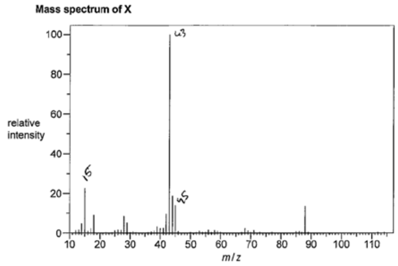
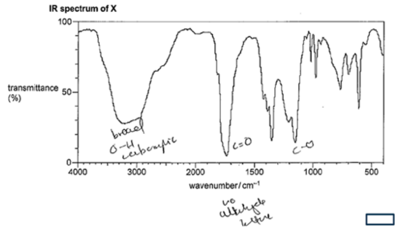
<u>1. Empirical formula</u>

<table>
<tr><th>Element</th><th>%mass</th><th>Ar</th><th>moles</th><th>ratio</th></tr>
<tr><td>C</td><td>40.91</td><td>12</td><td>3.41</td><td>3</td></tr>
<tr><td>H</td><td>4.54</td><td>1</td><td>4.54</td><td>4</td></tr>
<tr><td>O</td><td>54.55</td><td>16</td><td>3.41</td><td>3</td></tr>
</table>

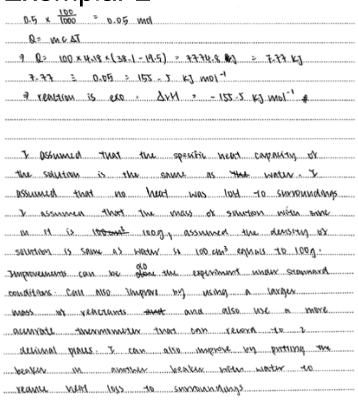
Empirical formula = $C_3H_4O_3$
ALLOW Alternative method using M_r of 88 i.e.</td></tr>
</table>

			with either a C=O **OR** COOH *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 the correct empirical/molecular formula **OR** Some aspects from two scientific points are given *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 worthy of credit.		C = 88 x (40.91/100) x 12 = 3 etc. **<u>2. Spectra and Molecular formula</u>** **Mass spectrum** • molecular ion peak m/z or M_r = 88 • molecular formula = $C_3H_4O_3$ **IR** • peak at 2500 to 3500 cm^{-1} is O-H • peak at 1630 to1820 cm^{-1} is C=O **<u>3. Functional groups and structure of X</u>** • **X** contains a carboxylic acid • **X** doesn't decolourise Br_2 so no C=C bond • Mass spectrum fragment peak(s) identified e.g. - m/z = 43 for CH_3CO^+ - m/z = 29 CHO^+ - m/z =15 due to CH_3^+ • ***Structure of X***  Aspects of the communication statement might typically have been met when evidence is presented in a logical and clear order making good use of all the evidence given. Some points which may be seen where communication is good include: • Easy to follow layout on empirical formula calculation • Empirical formula is same as molecular formula i.e. not given as $CH_{1.33}O$ • IR peaks linked clearly to bond it refers to not just functional groups • Positive charge given on MS fragments • MS fragments plausible for the molecular formula determined. • No additional irrelevant/incorrect information given

					Examiner's Comments Over a third of candidates achieved Level 3, gaining 5 or 6 marks. A correct structure (either aldehyde or ketone) alone was not enough to award Level 3 and candidates were expected to give a comprehensive description of how the evidence helped them determine the structure. The biggest challenge for many candidates was finding the correct empirical formula. The ratio worked out to 1:1.33:1 so many incorrectly rounded this to either 1:1:1 or 1:2:1, which meant they struggled to find a molecular formula that worked and added up to 88. Incorrect molecular formulas seen included $C_3H_3O_3$, which adds to 87 (often the extra H was just added to make it fit), or $C_4H_8O_2$, which does add to 88. Most candidates could analyse the IR spectrum, identifying peaks corresponding to C=O or O-H. Candidates should identify bonds present before making conclusions about the functional groups. Many were able to use mass spectra to determine the M_r value from the M+ peak. Some did go on to make use of other peaks, identifying fragments and confirming whether the structure was an aldehyde or ketone depending on analysis. For example, CHO^+ at m/z = 29 suggests an aldehyde, or conversely CH_3^+ at m/z = 15 suggests a ketone. Candidates should always be encouraged to comment on all the data provided. This can be through good annotation of the spectra and notes added to the first page of the question. Many candidates didn't mention the evidence from the bromine test. If candidates pieced together information to give a structure that is chemically feasible containing either a C=O or COOH group then they could achieve Level 2. Without a structure they were limited to Level 1. The most common incorrect structures seen included butanoic acid, 2-hydroxypropenoic acid or structures with 2 × C=O and an alcohol OH.

					   This response achieved Level 2 - 4 marks. Despite a correct calculation for empirical formula, they rounded incorrectly to CHO. They then state that molecular formula is C4H8O2 which matches the M_r value determined from the mass spectrum but not their empirical formula. They demonstrated good analysis of the IR spectrum and have even looked at potential fragments from the mass spectrum. The response meets the Level 2 descriptor as they have a feasible structure with a COOH group and have some analysis of all three scientific points. The communication is good with a clearly laid out calculation and bonds identified from IR and MS fragments have a positive charge.
			Total	**6**	
2 0	a		**Level 3 (5-6 marks)** Calculates **CORRECT** enthalpy change	1	**Indicative Scientific Points** **<u>Energy change from *mc*Δ*T*</u>** Energy in J **OR** kJ

			AND states **multiple** assumptions **AND** improvements *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)** Calculates **CORRECT** enthalpy change **OR** Correctly calculates the moles **AND** attempts the calculation of q **AND** states **multiple** assumptions **OR** improvements. *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)** Attempts any part of the calculation **AND** states **an** assumption **OR an** improvement. **OR** Correctly calculates the moles **AND** attempts calculation of q **OR** States **multiple** assumptions **OR** improvements *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.*		q = 100.0 × 4.18 × 18.6 = 7774.8(J) **OR** 7.7748 (kJ) **<u>Δ*H* in kJ mol^{-1}</u>** $n(Cu(NO_3)_2)$ = 0.05 (mol) Δ*H* = –*q*/*n* = 7.7748/0.05 = –155 kJ mol^{-1} (3 SF) **ALLOW** -156 kJ mol^{-1} (use of 7.775 kJ) **ALLOW** answer in J mol^{-1} if units are given **ALLOW** a single slip/rounding errors **<u>Assumptions and Improvements</u> (NOT INCLUSIVE)** ***Assumptions*** • density of solution is 1 g cm^{-3}/same as water • *c* of solution is same as water • ignore the mass and *c* of zinc • no heat escapes the system/lost to surroundings • mass of solution remains constant • no water lost/evaporated • reaction goes to completion • reaction completed under standard conditions • measurements recorded are accurate ***Improvements*** • polystyrene cup /thermos flask • use a lid • more precise thermometer • more precise balance • measure mass of solution • use burette to measure volume • use a cooling curve • use standard conditions Aspects of the communication statement might typically have been met when calculations have been completed in a logical order, and for L3 or L2 (where level awarded for calculation only) the use of the correct sign with the final answer given to 3 or 4 significant figures. **<u>Examiner's Comments</u>** The calculation of enthalpy change was generally well-answered and the majority of candidates were able to recall the equation q = *mc*ΔT. Many candidates forgot the minus sign or gave a positive sign for final enthalpy change.

					Errors in calculation were most commonly for using an incorrect mass, usually by finding the mass of copper(II) nitrate (from moles and M_r). Some also used the wrong value for the heat capacity, selecting the value for R from the data sheet instead. Many gave the final answer to an inappropriate six significant figures. Candidates often found it challenging to give appropriate assumptions and improvements, limiting the level achieved to Level 2. However, many candidates did correctly give the assumptions that the specific heat capacity and density of the solution was the same as water. This is usually stated for the candidates with these types of questions. The most common improvements suggested were use of a polystyrene cup, adding a lid or using a thermometer with a higher resolution. Quite a few candidates suggested using a larger volume of solution which would indeed reduce the % uncertainty in the volume measurement. However, it would lead to a smaller temperature change, increasing the % uncertainty in the temperature measurement. Some confused the question with a calculation of enthalpy change of combustion and gave improvements accordingly, e.g. 'use a copper or bomb calorimeter', 'draft shields', 'heat for longer', 'position of flame and supplies of oxygen'. Exemplar 2  0.5 × 100/1000 = 0.05 mol Q = mcΔT Q = 100 × 4.18 × (38.1 − 19.5) = 7774.8 J = 7.77 kJ 7.77 ÷ 0.05 = 155.5 kJ mol⁻¹ reaction is exo ∴ ΔrH = −155.5 kJ mol⁻¹ I assumed that the specific heat capacity of the solution is the same as the water. I assumed that no heat was lost to surroundings. I assumed that the mass of solution with zinc in it is 100 g, I assumed the density of solution is same as water so 100 cm³ equals to 100 g. Improvements can be do the experiment under standard conditions. Can also improve by using a larger mass of reactants and also use a more accurate thermometer that can record to 2 decimal places. I can also improve by putting the beaker in another beaker with water to reduce heat loss to surroundings This response achieved Level 3 - 6 marks. There is a correct calculation for ΔH, the final value has a correct negative sign and is given to 4 significant figures. Lots of valid assumptions and improvements are given.
	b		Half the energy/q **OR** volume/mass of solution	2	**ALLOW** response that links the same proportionality/ratio of energy/volume/mass of

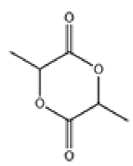
			AND half the moles ✓ Temperature change would be same✓		solution to number of moles **ALLOW** same amount of energy (released) per mole **ALLOW both marks** if seen by a calculation i.e. q = 50.0 x 4.18 x 18.6 = 3887.4(J) **OR** 3.8874(kJ) $n(Cu(NO_3)_2)$= 0.025 (mol) ΔH = (–) q/n = 3.8874/0.025 = (–)155 kJ mol^{-1}✓ Use of same temperature✓ May need to check answer in 3b to compare **IGNORE** Sign **<u>Examiner's Comments</u>** There was a lot of misunderstanding associated with this question, with many candidates failing to score any marks. Many said that nothing would change as the concentration was still the same or because the same bonds were being broken and formed. Under a quarter of students scored 1 mark, usually for making the link between the drop in volume to a change in the q and n values. A few did state that the temperature didn't change. Only a small proportion scored both marks, usually by showing by calculation that the temperature change was the same, moles was half and energy was half. Some did believe that the temperature changed, either that it decreased as less reacted or increased as there was less volume to heat. A wide variety of alternative responses were given including: 'Enthalpy change the same regardless of mass used' 'Number of moles doesn't impact energy required as it is the same bonds breaking' 'Energy to break and form bonds will still be the same with any volume' 'Amount of energy required to make the new bond would be the same' 'Only concentration has an effect on bond enthalpy values not volume' 'Decrease in volume increases concentration' '$Cu(NO_3)_2$ would still run out first so enthalpy

					change is the same' 'Zn is in excess so it doesn't matter how much volume we use because Zn and $Cu(NO_3)_2$ still 1:1 ratio.' 'Mole ratio is still the same' or 'same molar ratio' wasn't enough.
			Total	**8**	
21		i	**Line** Smooth curve using all points **EXCEPT** point at 100 s. ✓ **Anomaly** Point at 100 s circled ✓	2	**ALLOW** flexibility around point at 120 s Graph should be seen to level off on or very near to 90 cm^3 **<u>Examiner's Comments</u>** Most scored both marks here. Some didn't circle the anomalous result and some lost a mark for a poorly drawn curve. Candidates must ensure they have a sharp pencil and draw a single line through all the points (except the anomalous point). Some didn't start at the origin or didn't level off at around 90 cm^3.
		ii	**Tangent on graph** drawn at = 50 s (± 10 s)✓ **Calculation of rate** **=** gradient (y/x) of tangent drawn = 0.67 ± 0.2 cm^3 s^{-1} ✓	2	**DO NOT ALLOW** interpolation (taking a direct reading from graph), Answer must be derived from taking a gradient **ALLOW ECF** from incorrectly drawn tangent or a straight line of best fit **<u>Examiner's Comments</u>** More candidates were able to correctly draw a tangent than seen in previous years with similar questions. A generous range was given for both tangent and gradient so many scored both marks. The most common reasons for losing marks was for having a gap between the curve and the tangent or calculating the gradient incorrectly, e.g. misreading scales, dx/dy, or by using interpolation rather than a tangent.
		iii	FIRST CHECK ANSWER ON THE ANSWER LINE If answer = 0.15 (mol dm^{-3}) award 3 marks $n(O_2)$ = 90/24000 **OR** 0.09/24 **OR** 0.00375 (mol) ✓ $n(H_2O_2)$ = 2 x 0.00375 **OR** 0.0075 (mol) ✓	3	**ALLOW ECF** **COMMON ERRORS** For 2 marks: 0.075 missing x 2 150 missing a cm^3 to dm^3 conversion -- ALLOW use of ideal gas equation using sensible p and T for first mark. e.g.

			$c(H_2O_2)$ = 0.0075 x 1000/50.0 = 0.15 mol dm^{-3} ✓		from 100 kPa and 293 K $n = \frac{pV}{RT}$ $\rightarrow n = \frac{pV}{RT} = \frac{(100 \times 10^3) \times (90 \times 10^{-6})}{8.314 \times 293} = 0.00369\ldots$ (mol) Examples of 'sensible' p and T: p = 100 kPa, 101 kPa, 101,325 Pa T = 273 - 298 K **<u>Examiner's Comments</u>** Over half of candidates scored all 3 marks here. However, around a quarter did not gain any credit at all. Some confused the volume of H_2O_2 for a volume for a gas and attempted to find moles using molar gas volume (i.e. used $50cm^3$ rather than $90cm^3$). This often lost all 3 marks as they then divided by 2 and to find concentration divided by 90/1000 instead. A few attempted to use the ideal gas equation but this rarely yielded a correct value. Candidates must be encouraged to set out working clearly, showing logical steps and preferably labelling each step with what is being calculated and giving units. Many wrote the calculation as series of steps which all equalled the previous. e.g. 90 ÷ 24000 = 3.75×10^{-3} x 2 = 7.5×10^{-3} ÷ 0.05 = 0.15 **Misconception** Encourage students to assign information in the question to the correct chemical. One way to do this is to write out the equation and then underneath each species put correct volumes as given. It also helps to highlight ratios shown in the equation. It is important here to pay close attention to state symbols as it helps identify correct calculations to use. For example; $2H_2O_2$ (aq) → $2H_2O$ (l) + O_2(g) $50.0cm^3$ $90\ cm^3$ Solution Gas at RTP Conc?

			Total	**7**	
22			**FIRST CHECK ANSWER ON THE ANSWER LINE** **If answer = 6.46 (g) or 6.5 (g) award 3 marks** -- Molar mass $ZnSO_4 \cdot 7H_2O$ = 287.5 ✓ *n*($ZnSO_4 \cdot 7H_2O$) = 11.5/287.5 **OR** 0.04 (mol) ✓ *m*($ZnSO_4$) = 0.04 × 161.5 = 6.46 (g) ✓	3	**ALLOW** final answer to at least 2SF **ALLOW ECF** from incorrect molar mass but not if 161.5 is used (as this is the molar mass of anhydrous) **ALLOW ECF** from incorrect number of moles; either multiplied by 161.5 or using alternative approach below **Alternative approach, finding mass of water, for final mark:** n(H_2O) = 0.04 × 7 = 0.28 (mol) m(H_2O) = 0.28 × 18 = 5.04 (g) m($ZnSO_4$) = 11.50 − 5.04 = 6.46 (g) ✓ **<u>Examiner's Comments</u>** Just under half of the candidates scored all 3 marks. A range of responses were seen for this question but the most common error was to use the incorrect M_r for the hydrated which included either using the M_r for the anhydrous salt or the M_r for $ZnSO_4.H_2O$ (179.5). It was evident that candidates struggle to understand what is meant by water of crystallisation. Some scored 2 marks for the correct M_r and finding moles but then were unsure how to proceed with the calculation. For example, some divided moles by 7 before multiplying by 161.5. Many candidates took the more complicated alternative route to find the mass of water before subtracting from mass of hydrated compound. Low-scoring candidates often struggled to correctly work out M_r values. Their working was set out so that individual steps were unclear, often with contradictory calculations.
			Total	**3**	
23		i	Ca loses **2** electrons **AND** Oxidised✓ H gains 1 electron (per atom) **AND** Reduced✓	2	**ALLOW** H gains an electron **OR** gains electrons **OR** gains 2 electrons **ALLOW** 1 mark for Ca is oxidised **AND** H is reduced

					ALLOW 1 mark for Ca loses electron(s) **AND** H gains electron(s) **IGNORE** oxidation numbers even if incorrect **<u>Examiner's Comments</u>** Explaining redox reactions is a common question in exam papers, however here candidates needed to do it 'in terms of electron transfer'. Subsequently, many lost a mark as they identified oxidation and reduction in terms of oxidation numbers only. However, many gave responses both in terms of oxidation numbers and electrons. It was necessary to be specific here and say Ca had lost 2 electrons, so a few lost the mark by only referring to 'Ca losing electrons'. Some lost marks for only describing oxidation of Ca and not reduction of H. There was some evidence that candidates were not sure of Cl's role in the reaction (i.e. as a spectator ion) with some stating it was reduced and/or accepted electrons from Ca but then gave them to H.
		ii	*n*(HC*l*) = 0.012 (mol)✓ *n*(Ca) required to react with HC*l* = 0.006 (mol) **OR** 0.0100 mol Ca would need 0.02 mol HCl to completely react ✓ Ca reacts with water ✓	3	Second mark must show recognition of the 2:1 ratio e.g. **ALLOW** ratio is 1:2 but here only 1:1.2 so Ca is in excess **<u>Examiner's Comments</u>** Most candidates correctly calculated the amount of HCl as 0.012 mol. However, many struggled with demonstrating that Ca is in excess. Responses often highlighted misconceptions here in terms of candidates' understanding about excess and limiting reagents. For example, 'Ca has a lower concentration than HCl so becomes the limiting reagent' and 'Not all the HCl had reacted' Many compared moles of HCl calculated (i.e. 0.012) directly to moles of Ca (i.e. 0.01) saying that HCl was in excess, despite being told otherwise in the question. Some had the 2:1 ratio of HCl to Ca the wrong way around. Some attempted to calculate mass of Ca and HCl to use for comparison. Only a small proportion of candidates were able to

					access the third mark and correctly suggest that Ca was also reacting with water. Some other suggestions that were seen included: • 'Ca reacted with oxygen or was impure'. In both cases this would mean that we would expect solid to remain • 'Higher concentration of HCl added', or 'HCl is a strong acid', or 'acid acts as a catalyst'. • 'H_2 evolved' or 'Ca reacts with hydrogen formed'. • 'Human error', 'didn't weigh Ca correctly', 'measured volume of HCl incorrectly'. **Misconception** Candidates often struggle to understand the concepts around limiting reagents and those in excess. Using a simple baking analogy can help to relate this to everyday life. For example: To make 10 pancakes you need 100 g flour, 2 eggs and 300 ml milk How many pancakes can I make if I have only 50 g flour, 2 eggs and 300 ml milk? Which is the limiting ingredient and which are in excess? The number of pancakes we can make is the theoretical yield.
			Total	**5**	
2 4			**Level 3 (5–6 marks)** • Reaches a comprehensive conclusion to determine all **three** correct formulae of **D**, **E AND F** • **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)**	6 (AO 3.1 ×3) (AO 3.2 ×3)	**Indicative scientific points may include:** **<u>Identify of D, E and F</u>** • **D**: $NiSO_4 \cdot 6H_2O$ **OR** $NiSO_4(H_2O)_6$ **OR** $NiSO_{10}H_{12}$ • **E**: SO_2 • **F: Cyclic diester**  **OR unsaturated ester/acid**

- 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

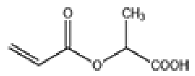
Setting the level
For Level 3 (5–6 marks),

- All 3 identified: **D**, **E** and **F**
- Most equations

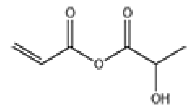
For Level 2 (3–4 marks),

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

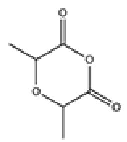
For Level 1 (1–2 marks),



OR unsaturated acid anhydride



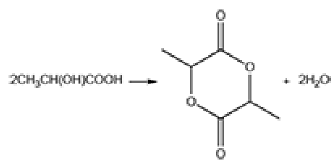
OR cyclic acid anhydride



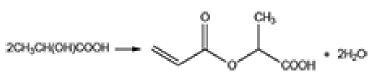
Equations
$H_2SO_4 + Ni(OH)_2 \rightarrow NiSO_4 + 2H_2O$
OR
$H_2SO_4 + Ni(OH)2 + 4H_2O \rightarrow NiSO_4{\bullet}6H_2O$

For equation
ALLOW $NiSO_4{\bullet}6H_2O$ **OR** $NiSO_4(H_2O)_6$

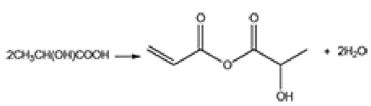
$H_2SO_4 + 2HBr \rightarrow Br_2 + SO_2 + 2H_2O$



OR

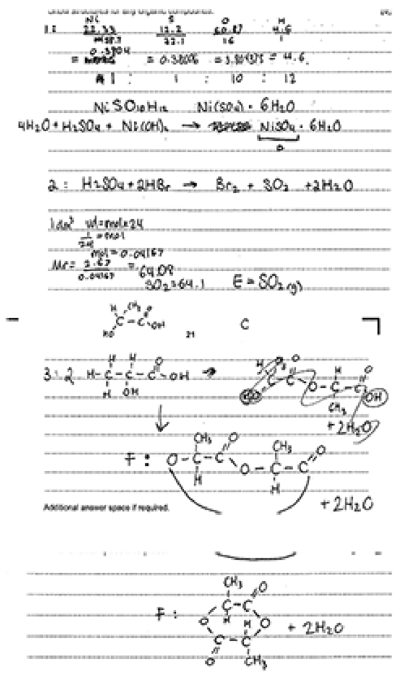


OR

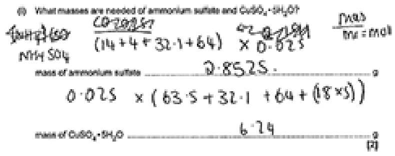


If structure of **F** is shown, **ALLOW** equation using molecular formulae,
e.g. $2\ C_3H_6O_3 \rightarrow C_6H_8O_4 + 2H_2O$

Examiner's Comments

			• 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}		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	**6**	
25			As ✓	1 (AO 2.2)	**<u>Examiner's Comments</u>** This question was a good discriminator. Candidates who scored the mark usually showed their mathematical working which led to As being chosen as the correct element. Other elements were seen randomly. More candidates omitted this part of Question 1 than other parts. With questions such as this, it is always better to guess as there is no penalty for an incorrect response.
			Total	**1**	
26	a	i	Mass $(NH_4)_2SO_4$ = 3.3025 g ✓ Mass $CuSO_4•5H_2O$ = 6.24 g ✓	2 (AO 1.2 ×2)	**ALLOW** 3.3, 3.30. 3.303 **ALLOW** 6.2 **<u>Examiner's Comments</u>** This question required candidates to calculate the masses of two reactants that could be used to prepare a sample of the Tutton's salt. Candidates were supplied with the formula of hydrated copper(II) sulfate but not the formula of ammonium sulfate, so candidates needed to work out its formula from ions that candidates are expected to be able to recall from the specification. Just over half the candidates obtained both correct masses but many obtained just one correct mass, usually that of $CuSO_4•6H_2O$. Exemplar 3

					 This exemplar shows a typical response with the incorrect formula of ammonium sulfate clear shown by the candidate, resulting in the incorrect mass of 2.8525 g. This incorrect formula and mass were seen in many responses and, from the initial crossings out, this candidate is clearly confused about how to tackle this simple mole calculation. The incorrect answer of 2.85 g was seen on almost as many scripts as the correct answer of 3.30 g. The moral is that candidates need to learn the formula and charges of the common ions encountered in chemistry. The comments here apply also to Question 6 (b) (i), where formulae need to be written using ions listed in the specification.
		ii	• Prevents water of crystallisation from being removed • Anhydrous salt would form • Prevents dehydration ✓	1 (AO 3.4)	**IGNORE** all the water would be removed *water is the solvent* **IGNORE** prevents decomposition **IGNORE** increases the size of crystals **<u>Examiner's Comments</u>** The majority of candidates did not answer this question correctly. Candidates were expected to refer back to the formula of the Tutton's salt, spot that there was water of crystallisation present, and that this would be lost if all the solvent was boiled off. Many responded vaguely in terms of decomposition or formation of larger crystals but a mark was only awarded if there was a definite link to the water contained within the crystals. **Assessment for learning** In the specification, Section 2.1.2a states the following: (a) the writing of formulae of ionic compounds from ionic charges, including:

					i. prediction of ionic charge from the position of an element in the periodic table ii. recall of the names and formulae for the following ions: NO_3^-, CO_3^{2-}, SO_4^{2-}, OH^-, NH_4^+, Zn^{2+} and Ag^{+u}. This section will be studied at the start of the 2 year course. Candidates need to be confident with using these common formulae. For success in chemistry, these ions must be learnt.
	b	i	$[Cu(NH_3)4(H_2O)_2]^{2+}$ ✓ **TAKE CARE** with correct brackets, numbers and 2+ charge	1 (AO 2.4)	**ALLOW** +2 for charge **IGNORE** $[Cu(NH_3)_4]^{2+}$ H_2O and NH3 can be in either order, i.e. $[Cu(H_2O)_2(NH_3)_4]^{2+}$ **<u>Examiner's Comments</u>** This reaction of copper(II) ions with aqueous ammonia and the formula of the complex ion formed are part of the specification. Within this novel context, the molar mass had been provided as a clue. Less than half the candidates correctly gave the correct formula and it was noticeable how well this part discriminated across abilities. This was another example of many candidates being unable to apply their knowledge and understanding to a novel context.
		ii	**Formula of precipitate** $Cu(OH)_2$ ✓ **IGNORE** name: copper(II) hydroxide --- **Formula of gas** ;NH_3 ✓ **IGNORE** name: ammonia --- **Test for ammonia** Available only from a reasonable attempt for identifying the gas as NH_3, e.g. NH_4, NH_4+, NH_2, ammonia, ammonium (Moist/damp) indicator/litmus (paper) turns blue ✓	3 (AO 2.3 ×3)	ALLOW $Cu(OH)_2(H_2O)_4$ **ALLOW** charges on Cu **AND** OH e.g. $Cu^{2+}(OH^-)_2$ ✓ **DO NOT ALLOW** unbalanced charges. e.g. $Cu(OH^-)_2$ ✗ --- **DO NOT ALLOW** correct test for NH_3 based on incorrect ID of the gas **NO ECF** for a test on the wrong gas (has to be test for NH_3) **DO NOT ALLOW** bleaches indicator **CON** **<u>Examiner's Comments</u>** Addition of NaOH(aq) to the Tutton's salt results in two reactions: precipitation of copper(II) hydroxide and a reaction of an ammonium ion, used to show

			Moist/damp **NOT** required. Initial colour of litmus **NOT** required but *blue* is **CON**		its presence as a qualitative test. As with Question 4 (c) (i), this part discriminated very well with many candidates able to be rewarded with some of the marks. The formula of copper(II) hydroxide, as $Cu(OH)_2$ or $Cu(OH)_2(H_2O)_2$ were both acceptable. This was correct more often than the responses related to the ammonium ion. The formula of the gas formed in the reaction of NaOH(aq) with the ammonium ion caused problems, with NH_3 and its subsequent test with moist indicator turning blue seen much less than the reaction of Cu^{2+}(aq) ions. Hydrogen (the 'squeaky pop test) and oxygen (relighting a glowing split) were common incorrect responses. This was another question in which referring back to the formula of the Tutton's salt would have revealed important clues.
		iii	**Reagent** $BaCl_2$ / barium chloride (solution) **OR** $Ba(NO_3)_2$ / barium nitrate (solution) **OR** Ba^{2+} (solution/aq) / barium ions ✓ **Observation** **white** precipitate/ppt ✓ Only available from soluble Ba^{2+} reagent **ALLOW** minor slips in formula of Ba^{2+} reagent, e.g. BaCl, $BaNO_3$	2 (AO 2.3 ×2)	**ALLOW** $Ba(OH)_2$ or other **soluble** Ba^{2+} compounds -- **IGNORE** test for other anions provided they do **NOT** interfere with SO_4^{2-} test **e.g.** **IGNORE** addition of $HCl/HNO_3/H^+$ **BUT DO NOT ALLOW** H_2SO_4 *Interferes with SO_4^{2-} test* **IGNORE** $Ag^+/AgNO_3$ **after** SO_4^{2-} test **DO NOT ALLOW before** SO_4^{2-} test **IGNORE** bubbling any gas through limewater **IGNORE** responses linked to CrO_4^{2-} *Not in Tutton's salt that student prepares* __**Examiner's Comments**__ Th final part of Question 4 required candidates to identify the anion in the Tutton's salt as sulfate, and to recall that Ba^{2+} ions is used for the sulfate test to form a white precipitate. Any soluble barium compound was credited with barium chloride and nitrate being the commonest seen. As with earlier parts, this part discriminated very well. Most candidates who knew that barium ions were needed also collected the mark for the white

					precipitate observation. Over half the candidates did not score here, the most common errors being to repeat the test for the ammonium ion, or to use silver nitrate, clear confusion with the halide test.
			Total	**9**	
27			**FIRST CHECK THE ANSWER ON ANSWER LINE** **If Mass = 318 (mg) award 6 marks** --- **Mean titre 1 mark** $= \frac{(22.30 + 22.40)}{2}$ = 22.35(0) (cm^3) ✓ **Analysis of results 5 marks** *n*(HCl) = 0.200 × $\frac{22.35}{1000}$ = 4.47 × 10^{-3} (mol) ✓ *n*(NaOH) remaining in 25.0 cm^3 = *n*(HCl) *n*(NaOH) remaining in 250 cm^3 = 4.47 × 10^{-3} × 10 = 4.47 × 10^{-2} **OR** 0.0447 (mol) ✓ *n*(NaOH) that reacted with **aspirin** = 0.0500 – 4.47 × 10^{-2} = 5.30 × 10^{-3} (mol) ✓ mass in 3 tablets = 5.30 × 10^{-3} × 180 = 0.954 g ✓ Mass in 1 tablet = 318 mg ✓	6 (AO 2.8 ×6)	***FULL ANNOTATIONS MUST BE USED*** --- **Common error:** Incorrect mean from all 3 titres = 22.6 cm^3 **CHECK BELOW TITRATION TABLE** **Use ECF throughout** Intermediate values for working to **at least 3 SF.** **ALLOW** scaling for 1 aspirin tablet early in calc, e.g. for final 2 marks: *n*(aspirin) in 1 tablet = $\frac{5.30 \times 10^{-3}}{3}$ = 1.77..... × 10^{-3} (mol) ✓ Mass in 1 tablet = 1.77..... ✓ 10^{-3} × 180 = 0.318 g = 318 mg ✓ **COMMON ERRORS:** *No scaling × 10* 0.05 – 4.47 × 10^{-3} → 4.553 × 10^{-2} ✓ 4.553 × 10^{-2} × 180 → 8.1954 g in 3 tablets ✓ → **2731.8/2732/2730 mg** in 1 tablet ✓ *5 marks* --- *No scaling × 10 before subtraction but scaling after 4 marks* 0.05 – 4.47 × 10^{-3} → 4.553 × 10^{-2} ✓ 4.553 × 10^{-2} × 10 × 180 → 81954 g in 3 tablets ✗ → **27318 / 27320 / 27300 mg** in 1 tablet ✓ --- *No subtraction from 0.05 5 marks* → 4.47 × 10^{-2} × 180 → 8.046 → **2682/2680 mg** in 1 tablet

					--- *Omitting initial titration calculation* *2 marks* 0.05 × 180 → 9 g in 3 tablets ✓ → **3000 mg** in 1 tablet ✓ --- Mean of 22.60 (use of all 3 titres) *5 marks* Mean = 67.8/3 = 22.60 ✗→ 4.52 × 10^{-3} ✓×10 → 4.52 × 10^{-2} ✓ 0.05 – 4.52 × 10^{-2} → 4.80 × 10^{-3} ✓ 4.80 × 10^{-3} × 180 → 0.864 g in 3 tablets ✓ → **288 mg** in 1 tablet ✓ **Examiner's Comments** Compared with the application based Question 4, candidates answered this stock titration calculation well. Almost all candidates determined that the mean titre was 22.35 cm^3 and went on to calculate the number of moles of HC*l* as 4.47 × 10^{-3} mol. Most scaled this value by 10 to determine the moles in 250 cm^3. Most candidates then used the initial moles of HCl to determine the moles of aspirin in the 3 tablets as 5.30 × 10^{-3} moles. A significant number omitted this stage but they were able to be credited for the next stage of calculation using a correct method. Consequently over half the candidates were awarded 5 or 6 marks for this stock calculation.
			Total	**6**	
28	a	i	$(K_p) = \frac{p(N_2O_4(g))}{p(NO_2(g))^2}$ ✓ **Units** atm^{-1} ✓ **CHECK THE ANSWER ON ANSWER LINE** **if answer = 1.17 × 10^{-2} OR 1.18 × 10^{-2} award 3 calculation marks** --- -	5 (AO 1.2 × 1) (AO 1.2 × 1) (AO 2.6 × 3)	**ALLOW** species without state symbols and without brackets. e.g., pSO_3^2 , $ppSO_3^2$, PSO_3^2, $p(SO_3)^2$ $(pSO_3)^2$ etc. **DO NOT ALLOW** square brackets **ALLOW** atm as **ECF** if K_p is upside down **ALLOW ECF** throughout **ALLOW** 3 SF up to the calculated value. **IGNORE** RE after 3SF

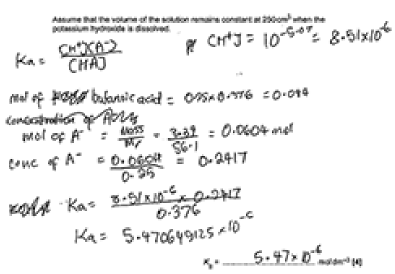
			Calculation • nN_2O_4 = 0.3(00) (mol) **AND** $n$total = 5.7(0) (mol) ✓ • pNO_2 = ($\frac{5.4(0)}{5.7(0)}$ × 5.00 =) 4.74 (atm) **AND** pN_2O_4 = ($\frac{0.3(00)}{5.7(0)}$ × 5.00 =) 0.263 (atm) ✓ • **K_p to 3 SF** (Kp = $\frac{0.263}{4.74^2}$ =) 1.17 × 10^{-2} ✓		*Calculator value* pNO_2 = 4.7368…… pN_2O_4 = 0.26315…. Mark use of 2SF in working as incorrect **once** and then allow ECF Answer MUST be 3 SF **Common error for 2 calculation marks:** 2.47 x 10^{-2} (using 0.6 mol N_2O_4) **<u>Examiner's Comments</u>** Candidates tend to find K_p calculations difficult and so a strategy to work their way through them could include: • write the K_p expression, with units, ensuring square brackets are not used. Common mistakes with units included atm^{-1} mol^{-1}, mol^{-1} dm^3, kPa^{-1} • calculation of initial moles present, with careful consideration of the use of appropriate significant figures • calculation of the change in moles present • deduction of the number of moles present at equilibrium • determination of total moles present at equilibrium. These steps are often best completed as RICE tables (Ratio, Initial, Change, Equilibrium) and should look to use the appropriate amount of significant figures: • calculation of mole fractions at equilibrium • calculation of partial pressures at equilibrium • inserting partial pressure vales into the K_p expression and avoiding any unnecessary unit conversions • writing an answer to the required number of significant figures.
		ii	**Higher temperature** Δ*H* is negative / exothermic (for forward reaction) **AND** equilibrium shifts to left/to LHS/decreases yield ✓	3 (AO 2.1 × 2) (AO 3.1 × 1)	**ORA** **ALLOW** correct equilibrium shifts without explanations for 1 mark

			Higher pressure 2 (gaseous) moles form 1 (gaseous) mole/ to side with fewer moles **AND** Equilibrium shifts to right /RHS/increases yield ✓ **Comparison** Difficult to predict relative contributions of two opposing factors ✓		**ALLOW** opposing effects may not be the same size **ALLOW** effects could cancel each other out **ALLOW** effects oppose one another **DO NOT ALLOW** if both equilibrium shifts are in the same direction **DO NOT ALLOW** just 'it is difficult to predict equilibrium position' (in question) For the **3rd mark**, we are assessing the idea that we don't know which factor is dominant **<u>Examiner's Comments</u>** This question was answered for the most part correctly with many candidates scoring 2 marks for the explanations of the effect on the equilibrium position by the changing of the temperature and pressure. Most candidates were able to recognise the changes had opposite effects but could not score the final mark, as their response needed the concept of opposing factors, or 'we don't know which factor is dominant'. Some did not write anything about equilibrium and attempted answers based on rate, or loss of energy/chemicals to the surroundings.
	b		***Rearranging ideal gas equation*** $n = \frac{pV}{RT}$ ✓ ***Unit conversion AND substitution into*** $n = \frac{pV}{RT}$: • *R = 8.314* ***OR*** *8.31* • *V* in m^3 = 74 × 10^{-6} • *T in K = 348* • *P in Pa = 101 x 10^3* *e.g.* $\frac{101 \times 10^3 \times 74.0 \times 10^{-6}}{8.314 \times 348}$ ✓ ***Calculation of n*** *n = 2.58........... × 10^{-3} (mol)* ✓ ***Calculation of M*** *M* = (0.28 ÷ 2.58…. x 10^{-3}) = 108(............) ✓	5 (AO 2.1 × 1) (AO 2.6 × 3) (AO 3.2 × 1)	**FULL ANNOTATIONS MUST BE USED** -- **ALLOW ECF** throughout if all values have been used to calculate n **IF** $n = \frac{pV}{RT}$ is omitted, **ALLOW** when values are substituted into rearranged ideal gas equation **CARE:** Correct n value subsumes first marking point **only** as two incorrect unit conversions can lead to correct n Calculator value: from 8.314 *n* = 2.583234483 × 10^{-3} from 8.31 *n* = 2.584477917 × 10^{-3} Calculator value: *M* from 8.314 = 108.3912443 *M from 8.31 = 108.3390955* M from 0.28 ÷ 2.58 x 10^{-3} = 108.5 **OR** 109

			Molecular formula that is the closest to the calculated M_r value. e.g. M_r 108 = N_2O_5 ✓		**ALLOW ECF** from calculation of *n provided formula of oxide contains at least one N i.e. NO (Mr = 30)* --- **Use of 24 dm³**: Final 2 marks possible by **ECF** e.g. $n = \frac{74.0}{24000} = 3.08 \times 10^{-3}$ **No mark** (*calculation much simpler*) $M = \frac{0.28}{3.08 \times 10^{-3}} = 90(.8)$ **ECF** N_3O_3 **ECF** **DO NOT ALLOW** N_2O_4 (in question) **ALLOW ECF** matching calculated *M* **<u>Examiner's Comments</u>** This question was well answered by nearly all candidates and many scored all 5 marks. A number used the wrong units for the pressure and the volume so used both kPa and dm³. This resulted in the correct number of moles and scored 4 marks as error carried forward. Most candidates were able to find the formula from the molar mass and very few used the incorrect molar volume route.
			Total	**13**	
29	a	i	**FIRST CHECK THE ANSWER ON ANSWER LINE** **if answer = 6.77 award 2 marks** --- $K_w = [H^+][OH^-]$ **OR** $K_w = [H^+]^2$ **OR** $[H^+] = \sqrt{K_w}$ ✓ ($[H^+] = \sqrt{(2.92 \times 10^{-14})}$) pH = $-\log(1.71 \times 10^{-7}) = 6.77$ ✓	2 (AO 1.1 × 1) (AO 2.2 × 1)	**DO NOT ALLOW** use of A^- or X^- **<u>Examiner's Comments</u>** Most candidates were given the first mark from a correct or rearranged equation. Many candidates then answered this question correctly and were given both marks. Those who didn't, either used 1.00×10^{-7} as $[OH^-]$ when calculating $[H^+]=K_w/[OH^-]$ or calculated pH as $-\log(2.92 \times 10^{-14})$.
		ii	(In pure water), $[H^+]$ (always) equals $[OH^-]$	1 (AO 3.2 × 1)	**ALLOW** moles/number of H^+ is (always) equal to moles/number of OH^-. **DO NOT ALLOW** ratio $[H^+]$: $[OH^-]$ doesn't change **<u>Examiner's Comments</u>** This question proved difficult with only a few candidates able to state that in neutral water, $[H^+]$ =

					$[OH^-]$. Many candidates said that as the pH is close to 7, water is therefore neutral.
	b		• **Equation** $Sr + 2H_2O \rightarrow Sr(OH)_2 + H_2$ ✓ **CHECK THE ANSWER ON ANSWER LINE** **if answer = 11.51 award 4 calculation marks** --- • **n($Sr(OH)_2$)** $= \frac{0.145}{121.6} = 1.1924... \times 10^{-3}$ ✓ • **$[OH^-]$** $= 2 \times (1.1924 \times 10^{-3} \div 0.25) = 9.539... \times 10^{-3}$ ✓ • **[H+]** = $K_w \div [OH^-]$ $= \frac{0.145}{121.6} = 3.061... \times 10^{-12}$ ✓ • **pH** = $-\log(3.061... \times 10^{-12})$ = 11.51 ✓ **2 DP** required	5 (AO 2.6) (AO 2.4 × 3) (AO 1.2 × 1)	**IGNORE** state symbols (even if wrong) **ALLOW** multiples **ALLOW** $Sr^{2+} + 2OH^-$ for $Sr(OH)_2$ **ALLOW** 3 SF up to the calculated value. Ignore RE after 3SF. **ALLOW** ECF throughout but final answer must be pH>7 **Final answer must be from calculated values.** **Common errors for 3 calculation marks** 11.98 *(Use of $K_w = 1 \times 10^{-14}$)* 11.21 *(no × 2)* 10.91 *(÷ by 2)* **Common error for 2 calculation marks** pH = 11.67 *(no × 2 and wrong K_w)* --- **Alternative method for:-** **pH = pKw – pOH** ○ ***n*($Sr(OH)_2$)** $= \frac{0.145}{121.6} = 1.1924... \times 10^{-3}$ ○ **$[OH^-]$** $= 2 \times (1.1924 \times 10^{-3} \div 0.25) = 9.539... \times 10^{-3}$ ○ ***pH*** *= pKw - pOH*

					= (-log 2.92 x 10^{-14}) - (-log 9.539..x 10^{-3}) • ***pH** = 13.53(46) - 2.02(05)* **= 11.51** **Examiner's Comments** Most candidates wrote the correct equation. Common errors were using Sr^{2+} as reactant, not balancing the H_2O and not having the H_2 as second product. Most candidates calculated the moles of $Sr(OH)_2$ correctly but fewer recognised that $[OH^-]$ = twice the $[Sr(OH)_2]$. As a result, most candidates scored 3 calculation marks. A few candidates chose the incorrect K_w value.
	c	i	One **mole** of (butanoic) acid donates/dissociates to form one **mole** of protons/H^+ ✓	1 (AO 1.1)	**ALLOW** One **molecule** of (butanoic) acid donates/dissociates to form one proton/H^+ **ALLOW** only one hydrogen ion in the acid can be replaced per molecule (in an acid-base reaction) **Examiner's Comments** Very few candidates wrote the complete definition of a monobasic acid. Most wrote "donates one proton" only, omitting mole or molecule. Some candidates described donating electrons or OH^-.
		ii	**FIRST CHECK THE ANSWER ON ANSWER LINE** **IF ANSWER = 1.5(3) x 10^{-5} award 4 marks** --- - • $[H^+] = 10^{-pH}$ **OR** $10^{-5.07}$ **OR** 8.51×10^{-6} ✓ • $(\frac{3.39}{56.1})$ **OR** 0.0604 (0.06042781) (nA⁻ in buffer) = (n(KOH)) **OR** 0.0604 x 4 **OR** 0.242	4 (AO 1.2 × 1) (AO 2.6 × 3)	**FULL ANNOTATIONS MUST BE USED** --- **ALLOW ECF** throughout **ALLOW 2 SF** for $[H^+]$ (use of pH) **ALLOW** 3 SF up to the calculated value. Ignore RE after 3SF for moles and concentration values Mark use of 2SF in working as incorrect **once** and then allow ECF

			✓ ($[A^-]$ in buffer) • *n*HA in buffer = (0.376 x 0.25) – 0.0604 = (0.094) – 0.0604 **OR** 0.0336 (0.03357219...) **OR** [HA] in buffer = (0.376 – 0.242) **OR** 0.0336 x 4 **OR** 0.134 (0.13428877) ✓ • $K_a = [H^+][A^-] \div [HA]$ $= \frac{8.51 \times 10^{-6} \times 0.242}{0.134}$ $= 1.5..... \times 10^{-5}$ (1.5319942×10^{-5})✓		**ALLOW** full marks for use of moles (volumes cancel) $K_a = \frac{8.51 \times 10^{-6} \times 0.0604}{0.0336}$ $=1.53 \times 10^{-5}$ **ALLOW** final answer to 2SF **Common errors for 3 marks** $5.47(1731026) \times 10^{-6}$ (not subtracting moles of KOH from HA) **<u>Examiner's Comments</u>** This calculation proved difficult with many figures and sums appearing with little indication as to their relevance. Candidates should remember to provide written indications of what it is they're working out – presenting the calculations without any annotations can make it harder for error carried forward marks to be given if there is an error in their calculation. Few candidates scored all 4 marks. Most found the concentration of H^+ from the pH and the moles of KOH correctly but did not recognise they had to take away the moles of KOH from those of HA to find the remaining concentration of HA. Some candidates then used the [H+] as the [HA]. A few candidates tried a $[H^+]$ squared expression of a weak acid. Exemplar 2  The candidate has clearly set out the calculation so each numerical value can be linked and the steps understood. The only error is not calculating the excess acid (i.e. not subtracting moles OH- from initial moles acid) so 3 marks were given.

			Total	13	
30	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)	**<u>Examiner's Comments</u>** 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. <u>Exam hints for students</u> 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) **<u>Examiner's Comments</u>** 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		*System 1*/$E^{\ominus}$(Zn) is more negative/less positive than *system 2*/ $E^{\ominus}$(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*/$E^{\ominus}$(Zn) is more negative than *system 3*/ $E^{\ominus}$(MnO_4^-) ✓ Eqm 3 shifts to right **AND** Eqm 1 shifts to left **OR** (If unfiltered), MnO_4^- oxidise zinc **OR** $2MnO_4^- + 5Zn + 16H^+ \rightarrow 2Mn^{2+} + 5Zn^{2+} + 8H_2O$ ✓	4 (AO 3.1 × 1) (AO 3.4 × 1) (AO 3.1 × 1) (AO 3.4 × 1)	**ALLOW ORA** throughout **IGNORE** larger/smaller/greater/less throughout **ALLOW** $E^{\ominus}$ = (+)1.53(V) **ALLOW** comparison if Fe system is identified **ALLOW** $E^{\ominus}$ = (+) 2.27(V) **ALLOW** comparison if MnO_4^- is identified **Examiner's Comments** 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**	
3 1			**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = –4950 award 3 marks** --- - ○ $q = mc\Delta T$ = 150 x 4.18 x 10.5 = 6583.5 (J) **OR** 6.5835 (kJ) ✓	3 (AO 2.4 × 1) (AO 2.8 × 2)	**ALLOW** 3 SF up to the calculated value Ignore RE after 3SF **IGNORE** sign **ALLOW** ECF from incorrect *q* and/or *n* **Common errors for 2 marks** +4950 kJ mol^{-1} (wrong sign) -5077 (use of 0.0013 and 6.6 2SF) -5064 (use of 0.0013 2SF) -4962 (use of 6.6kJ use of 2SF)

			○ $n(C_7H_{16})$ $\frac{0.133}{100} = 1.33 \times 10^{-3}$ ✓ • $\Delta_cH = q \div n$ $= \frac{6.5835}{1.33 \times 10^{-3}}$ $= -4950$ kJ mol^{-1} **– sign required** ✓		**Examiner's Comments** Many candidates calculated the correct value of q and scored all three marks. Common errors saw some candidates using the incorrect mass, of either 0.133 or that added to or subtracted from the 150. The temperature change was given but a few candidates added the 10.5 to 273 in order to, incorrectly, convert to K. The final mark required the candidate to link the temperature increase to an exothermic value and include a minus sign.
			Total	**3**	
32			**B**	1 (AO 1.2)	**Examiner's Comments** Most candidates answered this question correctly with the answer B. D was a common error based on the highest mass.
			Total	**1**	
33			**C**	1 (AO 2.2)	**Examiner's Comments** Candidates found this question challenging with the correct answer being C. A or B were the common errors selected by most candidates.
			Total	**1**	
34			**D**	1 (AO 2.2)	**Examiner's Comments** The correct answer was D. Most candidates did not recognise the number of H atoms, 5, in the compound, choosing A as their final answer.
			Total	**1**	
35			**C**	1 (AO 2.2)	**Examiner's Comments** This question was answered correctly for the most part with the answer being C.
			Total	**1**	
36		i	Volumetric flask ✓	1 (AO1.2)	**ALLOW** graduated flask **Examiner's Comments** Most candidates recognised that a volumetric flask is used to accurately prepare volumes of solutions. A common error was a conical flask, perhaps by

<table>
<tr><td></td><td></td><td></td><td></td><td></td><td>not reading the information clearly and giving the name of the flask used in the titration itself.</td></tr>
<tr><td></td><td></td><td>ii</td><td>
<table>
<tr><td>Final reading/cm^3</td><td>20.25</td><td>40.85</td><td>25.85</td></tr>
<tr><td>Initial reading/cm^3</td><td>0.00</td><td>20.25</td><td>5.50</td></tr>
<tr><td>Titre/cm^3</td><td>20.25</td><td>20.60</td><td>20.35</td></tr>
</table>
All 3 titres correct to 2 DP ✓</td><td>1
(AO1.2)</td><td>DO NOT ALLOW 1 DP, e.g. 20.6 instead of 20.60

<u>Examiner's Comments</u>

Most candidates were able to work out these simple subtractions. Candidates were told that the titration readings were read to the nearest 0.05 cm^3, requiring titres to be shown to two decimal places, which includes a '0'. The middle titre is therefore 20.60 cm^3 and not 20.6 cm^3, which continues to be the commonest error seen.</td></tr>
<tr><td></td><td></td><td>iii</td><td>mean titre = $\frac{20.25 + 20.35}{2}$ = 20.30 (cm^3) ✓
i.e. using concordant (consistent) titres</td><td>1
(AO2.8)</td><td>ALLOW 20.3
Missing '0' already penalised in c(ii)

DO NOT ALLOW mean of all three titres,

i.e. $\frac{20.25 + 20.60 + 20.35}{3}$ = 20.40

<u>Examiner's Comments</u>

Candidates are expected to use only concordant titres when working out the mean titre and the middle titre of 20.60 cm^3 should be rejected. Most candidates did this to produce 20.30 cm^3 as their mean titre. Predictably, the commonest error was to use all three titres to produce the incorrect mean of 20.40 cm^3.</td></tr>
<tr><td></td><td></td><td>iv</td><td>$n(H_2SO_4) = 0.165 \times \frac{20.30}{1000} = 3.5 \times 10^{-3}$ (mol) ✓
n(MOH) in 25.0 cm^3 $= 2 \times 3.35 \times 10^{-3}$
$= 6.70 \times 10^{-3}$ (mol) ✓
n(MOH) in 250.0 cm^3 $= 10 \times 6.70 \times 10^{-3}$
$= 6.70 \times 10^{-2}$ (mol) ✓
A_r of M = $\frac{2.62}{6.70 \times 10^{-2}} \times 10^{-2}$ = 39.1 AND M = potassium/K ✓</td><td>4
(AO3.1 ×3)
(AO3.2 ×1)</td><td>ALLOW ECF throughout and from incorrect concordant titres from 22c(iii)

Calculator value = 3.3495×10^{-3}

Calculator value = 6.699×10^{-3}

Calculator value = 6.699×10^{-2}

By ECF, ALLOW Group 1 metal nearest to calculated value of A_r

COMMON ERRORS

Use of 20.4 from mean of all 3 titres ALL 4 MARKS</td></tr>
</table>

$n(H_2SO_4) = 0.165 \times \frac{20.4}{1000} = 3.366 \times 10^{-3}$ (mol) ✓
from **(c)(iii)**
n(**M**OH) in 25.0 cm^3 = $2 \times 3.366 \times 10^{-3}$
$= 6.732 \times 10^{-3}$ (mol) ✓
n(**M**OH) in 250.0 cm^3 = $10 \times 6.732 \times 10^{-3}$
$= 6.732 \times 10^{-2}$ (mol) ✓

A_r of **M** = $\frac{2.62}{6.732 \times 10^{-2}}$ = 38.9…. **OR 39 AND M** = K ✓
IF ×10 is absent, A_r = 389 **AND M** = Cs **OR** Fr

Use of 25.0 (wrong volume) for $n(H_2SO_4)$

$n(H_2SO_4) = 0.165 \times \frac{25}{1000} = 4.125 \times 10^{-3}$ (mol) ✗
n(**M**OH) in 25.0 cm^3 = $2 \times 4.125 \times 10^{-3}$
$= 8.25 \times 10^{-3}$ (mol) ✓
n(**M**OH) in 250.0 cm^3 = $10 \times 8.25 \times 10^{-3}$
$= 8.25 \times 10^{-2}$ (mol) ✓

A_r of **M** = $\frac{2.62}{8.25 \times 10^{-2}}$ = 31.75.....**AND M** = K ✓
IF ×10 is absent, A_r = 317.5 **AND M** = Cs **OR** Fr

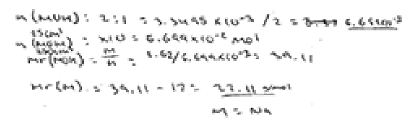
<u>Examiner's Comments</u>

Many candidates followed a well drilled method to identify the unknown metal M as potassium:

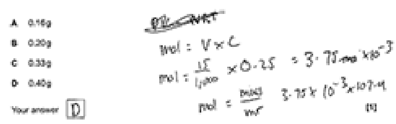
- Moles of H_2SO_4 in the mean titre
- Moles of KOH in 25 cm^3
- Scaling ×10 for moles of KOH in 250 cm^3
- Molar mass of the metal as 39.11 and identified as K.

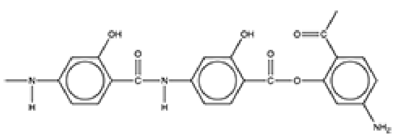
A number of candidates omitted the scaling stage to obtain a molar mass of 391.1. By ECF, the 'correct' identity would be caesium or francium. Some candidates then 'fiddled' their response, dividing by 10 to 'identify' the metal as K. This incorrect approach was not credited.

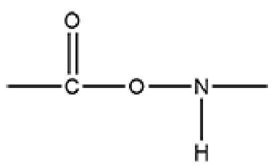
Exemplar 2

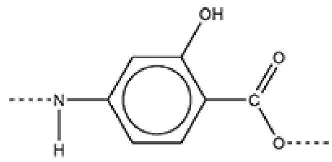


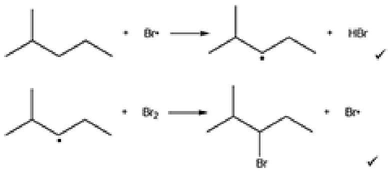
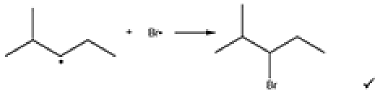
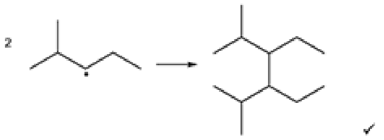
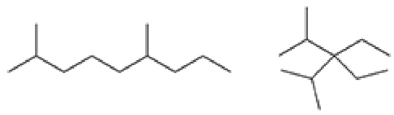
A common error, illustrated in Exemplar 2, was for candidates to calculate 39.11 but to think that this

					was the mass of MOH and not M. They then subtracted 17 (for OH) from 39.11 to obtain a response of 22.11 and identified M as sodium instead of potassium. This error probably stems from candidates either not reading the question closely enough or confusion about the mole concept.
			Total	**7**	
3 7			**D**	1 (AO 2.6)	**<u>Examiner's Comments</u>** Candidates found this question demanding. It showed very good discrimination between abilities with most able candidates choosing the correct option D. Option C was chosen by many, the result of working out the moles of NO_2(g) without adding the moles of O_2. Care is needed when reading the question which asked for 'volume of gas', rather than 'volume of NO_2(g). Despite the question stating the volume has been measured at RTP, some candidates chose to use the Ideal Gas Equation instead of the simplified molar volume of 24 $dm^3\ mol^{-1}$ at RTP. This approach could still lead to success but would have wasted significant time.
			Total	**1**	
3 8			**C**	1 (AO 2.2)	**<u>Examiner's Comments</u>** Candidates found this question very difficult with less than half successfully choosing option C. Many candidates chose option D, as shown in Exemplar 1. Exemplar 1  This candidate's working is clear and would have been correct had $AgNO_3$ have been the limiting factor. Calculating the moles of Zn shows that this is the limiting factor, producing 0.33 g of Ag for option C.
			Total	**1**	

3 9			**D**	1 (AO 2.4)	**Examiner's Comments** Most higher attaining candidates chose the correct option of D. From candidate annotations, most calculated the moles of HCl as 0.27 mol. This directly gave the common distractor of B, the result of not taking into account the volume of 250 cm^3. Successful candidates multiplied 0.27 by 4 (or divided by 0.250) to get the correct response of 1.08 mol dm^{-3} (D).
			Total	**1**	
4 0			**B**	1 (AO 1.2)	**Examiner's Comments** Most candidates are well drilled in the calculation of an empirical formula from percentage compositions and most selected the correct response of B. Option D proved to the main distractor, presumably due to confusion between the terms empirical and molecular formula.
			Total	**1**	
4 1			**C**	1 (AO 1.2)	**Examiner's Comments** Most candidates selected the correct response of C but some chose D, the result of dividing 8 (for $4H_2$) by 44 (for CO_2) instead of dividing by their sum (8 + 44 = 52). Overall, candidates showed a good understanding of the term 'atom economy'.
			Total	**1**	
4 2			**C**	1 (AO 2.6)	**Examiner's Comments** Candidates found this question more demanding than Questions 1–6 with only about half the candidates correctly choosing option C. Most candidates showed working on their scripts with B being the common distractor, the result of working out the moles of SiO_2 as 120.2/60.1 = 2, and then multiplying the Avogadro Constant by 2, rather than first doubling 2 to take into account the two O atoms in SiO_2.
			Total	**1**	
4 3		i	 Section contains	3 (AO1.2 ×2) (AO3.2)	

			A displayed amide linkage between 2 benzene rings ✓ A displayed ester linkage between 2 benzene rings ✓ Section with at least **one** 'end bond' and correct positioning of all 3 groups on **each** benzene ✓		**Marking point 3 is dependent on first 2 marks** Check bonding around **each** benzene so C=O position 1, C-O position 2 and C-NH position 4. **ALLOW** 'end bonds' (with either a solid or dashed line') **OR** terminal ends e.g. -O- or -OH **ALLOW** any combination of 'end bonds' as showing a section not a repeat unit **IGNORE** connectivity of OH and NH_2 groups to benzene __**Examiner's Comments**__ This was a demanding question with just over a third of candidates not scoring marks. However, many candidates were able to gain a mark for either showing the displayed ester or amide link between two benzene rings. Some candidates recognised that at least 3 PAS units would be needed to show both the amide and ester links appropriately. Few responses were able to show a section of polymer that contained correct amide and ester linkages, the correct substituent groups and at least one end bond. The most common reason why candidates did not secure all 3 marks was omission of the OH group on one or more benzene rings of PAS. This question was more challenging as candidates needed to show a polymer section. Many gave 2 'end bonds' as they would for a repeat unit but this was not sufficient here due to the many different possible combinations, we could not make assumptions about what would be next. A common incorrect response was:  Furthermore, many candidates just gave 1 benzene ring, like this:

					
		ii	**FIRST CHECK ANSWER ON THE ANSWER LINE** **If answer = 2.36×10^{22} award 3 marks** **Calculate moles of PAS:** 300 mg of PAS contains $\frac{300 \times 10^{-3}}{153}$ **OR** 1.96.... × 10^{-3} (mol) ✓ **Daily dose of PAS:** *n*(PAS) for 20.0 kg child = 20 × 1.96…. × 10^{-3} (mol) **OR** 0.0392....... (mol) ✓ **Use of Avogadro's constant:** Number of PAS molecules = 0.0392....... × 6.02 × 10^{23} = 2.36 × 10^{22} ✓	3 (AO3.1 ×2) (AO3.2 ×1)	**ALLOW 3SF** up to calculator value throughout **IGNORE** rounding errors past **3SF** **If there is an alternative answer, apply ECF throughout. Steps can be carried out in any order.** **Calculator values:** 1.960784314 x 10^{-3} 0.03921568627 **Common alternative method:** m(PAS) for 20.0 kg child = 0.3 x 20 **OR** 6.0 (g) ✓ n(PAS) for 20.0 kg child = 6/153 **OR** 0.0392…(mol) ✓ **<u>Examiner's Comments</u>** Nearly half the candidates were able to correctly calculate the number of PAS molecules in the maximum daily dosage. Some struggled with conversion from mg to g. Some made errors calculating the molar masses or did not calculate moles at all. Most were confident to multiply by N_A at the end. As with other calculations some lost marks for significant figures and rounding errors.
			Total	**6**	
4 4		i	**Initiation** $Br_2 \rightarrow 2Br•$ **AND** ultraviolet / UV ✓ **Propagation**	6 (AO1.1) (AO2.5) (AO2.5) (AO2.5) (AO3.1)	**DOT REQUIRED** throughout **IGNORE** temperature and pressure **ALLOW ECF** for use of Cl• (from Cl2) in subsequent propagation and termination steps **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous

			 **Termination** $2Br\bullet \rightarrow Br_2$ ✓  		**ALLOW** 1 mark for propagation for 2 'correct' equations but with dot omitted or in wrong position **DO NOT ALLOW ECF** from incorrect radical intermediate for termination steps **<u>Examiner's Comments</u>** Many candidates tackled this question confidently, especially when using skeletal formula following the format of the structure given in the question. Over half the candidates scored 5 or 6 marks. Only the highest attaining candidates were able to provide all three correct termination steps. Many lost a mark for the combination of the two alkyl radicals, typically either by simply joining the ends of the chains or by missing the connecting C-C bond.  Those that attempted to use structural formula often lost marks due to missing Hs. Other common errors included the incorrect positioning of the radical dot, most typically on the terminal carbon, addition of Br in the first propagation step or use of molecular formula. Lower attaining candidates were often able to score a mark for the initiation step and the termination step involving two Br radicals. However, for some this was not a well-known mechanism, with attempts to break up the chain or form hydrogen radicals or charged species. Errors were also seen with correct balancing of equations such as truncated C chains or extra Br atoms added.
		ii	C_6Br_{14} ✓ Correct balanced equation $C_6H_{14} + 14\ Br_2 \rightarrow C_6Br_{14} + 14\ HBr$ ✓	2 (AO2.6 ×2)	**ALLOW** 1 mark for correct balanced equation using any combination of skeletal **OR** structural **OR** displayed formula **<u>Examiner's Comments</u>** Most responses gained at least 1 mark for this question giving the correct molecular formula of C_6Br_{14}. However many hadn't assimilated that when a hydrogen atom is substituted in an alkane

					it requires one mole of a halogen and produces one mole of the hydrogen halide. So many gave this incorrect equation instead: $C_6H_{14} + 7Br_2 \rightarrow C_6Br_{14} + 7H_2$. Some lost marks for C_5H_{14} or for use of structural formulae.
		iii	$n(\mathbf{B}) = \frac{72.0}{40000}$ OR $\frac{0.072}{40}$ **OR** $1.8(0) \times 10^{-3}$ (mol) ✓ $M(\mathbf{B}) = \frac{0.8649}{1.8(0) \times 10^{-3}} = 480.5$ ✓ Molecular formula = $C_6H_9Br_5$ ✓	3 (AO2.2 ×2) (AO3.2)	**ALLOW 2SF** up to calculator value **ALLOW ECF** from incorrect *n*(**B)** **ALLOW ECF** from incorrect *M*(**B**) from *n*(**B**) --- **COMMON ERROR** $n(\mathbf{B}) = \frac{72.0}{24000} = 3 \times 10^{-3}$ (mol) ✗ $M(\mathbf{B}) = \frac{0.8649}{3 \times 10^{-3}} = 288.3$ ....✓ Molecular formula = $C_6H_{12}Br_2$ **OR** $C_6H_{11}Br_3$ ✓ **ALLOW ECF** for viable molecular formula with C_6 but must be derived from a calculated value for *M*(**B**) **<u>Examiner's Comments</u>** Overall, this question was well answered with over half of candidates gaining all 3 marks. The use of a different molar volume confused some candidates. Some attempted to use PV=nRT or different combinations of the figures given with varying degrees of success. Lower attaining candidates typically struggled with unit conversions and were unable to make use of the units to help them work out the methodology to use.
			Total	**11**	
45			**FIRST CHECK ANSWER ON ANSWER LINE** **If answer = 73.2 award 3 marks** --- **Theoretical moles** $n(C_6H_5NO_2)$ **OR** $n(C_6H_4(NO_2)_2)$	3 (AO2.8) (AO2.8) (AO1.2)	**ALLOW 3SF** up to calculator value throughout working **IGNORE** rounding errors past **3SF** **TAKE CARE** as value written down may be truncated but with value stored in calculator, depending on rounding, either can be credited. Calculator = 0.1219512195 Calculator = 0.08928571429

			$= \frac{12.5 \times 1.20}{123.0}$ **OR** 0.12195... (mol) ✓ **Actual moles** $n(C_6H_4(NO_2)_2) = \frac{15.0}{168.0}$ **OR** 0.0892857(mol) ✓ % yield = $\frac{0.0892857...}{0.12195....} \times 100$ = 73.2 % to **3SF** ✓		**ALLOW ECF** except for final mark if value is ≥100% --- **Alternative method using mass** 1. Theoretical moles = 0.12195…. mol 2. Mass = 0.12195… × 168.0 OR 20.4878... g 3. % yield = $\frac{15}{20.4878...} \times 100$ = 73.2% --- **Common errors** 87.9% → 2 marks • From $\frac{12.5}{123}$ = 0.101626…..*(no density)* **Examiner's Comments** Approximately half of the candidates scored all 3 marks and were confident calculating % yield. However, about a third did not gain any credit. A common response was 100% with both masses as 15 g. Some struggled with conversion of the volume of nitrobenzene to a mass using the density. Many candidates struggled with obtaining the correct molar mass values, especially if they were not sure on the correct structures. As with any calculation work, clear working is vital to gain error carried forward credit here. Three significant figures were required for final answer but many also lost marks as a consequence of incorrect rounding. For example, use of 0.089 moles gave a value of 73.0%. It was not uncommon to see contradictory calculations as candidates appeared to try to find a suitable value.
			Total	3	
4 6			**Level 3 (5–6 marks)** Structure is either $CH_3CH_2COOCH_2C(CH_3)_3$ **OR** $(CH_3)_3CCH_2COOCH_2CH_3$ **AND** Most of the data analysed. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and*	6 (AO1.2 × 2) (AO3.1 × 2) (AO3.2 × 2)	**Mark spectra page as SEEN** Indicative scientific points: **1. Empirical Formulae** • C : H : O = $\frac{66.63}{12.0} : \frac{11.18}{1.0} : \frac{22.19}{16.0}$ = 5.55 : 11.18 : 1.39 = 4 : 8 : 1 • Empirical formula = C_4H_8O **2. Molecular Formulae**

substantiated.

Level 2 (3–4 marks)
Structure is an ester of $C_8H_{16}O_2$ with **some** key features present
AND
Analyses some of the data from at least 3 of the scientific points.

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)
Attempts analysis from at least 2 of the scientific points.

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.

- uses *m/z* = 144.0 to determine molecular formula as $C_8H_{16}O_2$

3. Functional group
From IR,

- → C=O from ~1740 cm^{-1}

IGNORE references to C–O peaks

No reaction with 2,4-DNP

- → no carbonyl/no ketone and aldehyde
- Likely to be an ester

4. [1]H NMR analysis

- δ = 0.9 ppm, singlet, 9H –C**(CH_3)**$_3$
- δ = 1.2 ppm, triplet, 3H **CH_3**CH_2–
- δ = 2.2 ppm, quartet, 2H CH_3**CH_2**CO
- δ = 4.1 ppm, singlet, 2H **–OCH_2–**

ALLOW approximate values for chemical shifts.

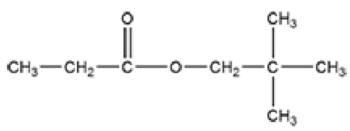
Structure
ALLOW any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous

Key features consistent with chemical shift data and relative peak areas

- O-CH_2
- $C(CH_3)_3$
- $CH_3CH_2C=O$

Correct Structure

- $CH_3CH_2COOCH_2C(CH_3)_3$



					Examiner's Comments Most candidates were able to deduce the empirical and/or molecular formula of the organic compound. Analysis of the IR spectrum was also well attempted, but some candidates assumed the unknown was a carboxylic acid, attributing the sharp peak just below 3000 cm^{-1} to an OH group. Others misidentified the C=O peak as a C=C group suggesting alkene or arene structure. They were often led to this conclusion as they believed no precipitate with 2,4-DNP suggested no C=O rather than no aldehyde or ketone. Good analysis of the NMR data was crucial for deducing the correct ester. Some candidates opted to annotate the proton NMR spectrum, some produced tables and others gave written details for each peak. It was vital that they were able to interpret all information for each peak i.e. number of proton environments, the type of environment from chemical shift, the number of protons in each environment from relative peak areas and use of splitting patterns to find information about adjacent protons. Many tried to make the data fit their proposed structure rather than the other way round. Some suggested structures that were only partially consistent with the data such as $CH_3CH_2CH_2COOC(CH_3)_3$ and were awarded Level 2. Others did not take full note of all the information provided, for example omitting the 2,4-DNP observations, giving the ketone $(CH_3)_3COCH_2COCH_2CH_3$ or not checking it matched the molecular formula $CH_3CH_2COOC(CH_3)_3$ so only achieved Level 1. Candidates need to be encouraged to draw a structure as without they can only achieve a maximum of 2 marks despite some excellent analysis of the data. Conversely, it is not sufficient to just give a structure, candidates must give analysis of the data provided. Exemplar 3

					 This is a good Level 3 6 mark response. As well as this clearly laid out analysis they also had details written on the question, e.g. no aldehyde or ketone due to no reaction with 2,4-DNP. This response has been selected due to the detailed analysis of NMR data that has been summarised in a table.
			Total	**6**	
4 7			**B**	1 (AO1.2)	**ALLOW** 24 **<u>Examiner's Comments</u>** More than a third of candidates answered this question incorrectly. They struggled interpreting the skeletal formula for this more complex substituted benzene. An effective strategy used by many candidates was to label each C with number of H atoms using sticks or dots or numbers.
			Total	**1**	
4 8			**B**	1 (AO2.2)	**<u>Examiner's Comments</u>** This was a demanding question. Candidates needed to calculate the moles of oxygen and then determine the ratio of alkane to oxygen to find the correct response. The majority of successful candidates clearly showed their working to help them to arrive at the correct answer. The most common incorrect answer was C.
			Total	**1**	

4 9			**Level 3 (5–6 marks)** A comprehensive explanation of relative reactivities of chlorine and iodine **AND** Uses an appropriate method to calculate volume of seawater allowing for **an acceptable error** *There is a well-developed line of reasoning which is clear an d logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** A comprehensive explanation of relative reactivities of chlorine and iodine **AND** Some attempt at calculation **OR** Explanation of relative reactivities of chlorine and iodine containing **most** details **AND** A reasonable attempt at calculation **OR** Explanation of relative reactivities of chlorine and iodine containing **some** details **AND** Uses an appropriate method to calculate volume of seawater allowing for **an acceptable error** *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)** Explanation of relative reactivities of chlorine and iodine containing **some** details **AND** Some attempt at the calculation **OR** Explanation of relative reactivities containing **most** details	6 (AO 1.1 × 2) (AO 1.2 × 1) (AO 2.6 × 3)	*Indicative scientific points may include:* **Explanation of relative reactivities** Comparison required throughout • Chlorine gains electron more easily **OR** forms negative ion more easily **OR** attracts an electron (to its outer shell) more easily • Because chlorine (atom) is smaller **OR** outer shell of chlorine less shielded/closer • Greater nuclear attraction (on chlorine electrons) • **ORA** **IGNORE** 'nuclear charge' for 'nuclear attraction' **Determination of volume of seawater** • $Cl_2(g) + 2I^-(aq) \rightarrow I_2(aq) + 2Cl^-(aq)$ **OR** molar ratio I^-: I_2 = 2:1 • $n(I_2) = \frac{1 \times 10^6}{253.8}$ = 3940(.11…) (mol) • n(KI) = 3940(.11…) × 2 = 7880.(22…) (mol) • n(KI) in 1 dm^3 seawater = $\frac{0.150}{166}$ = 9.036(144..) × 10^{-4} (mol) • Volume of seawater = $\frac{7880.(22..)}{9.036(...) \times 10^{-4}}$ = 8.72…… × 10^6 dm^3 **Alternative method:** • m(KI) = 7880.(22…) x 166 (mol) = 1.308(116627) x 10^6 • Volume of seawater = $\frac{1.308(116627) \times 10^6}{0.15}$ = 8.72…… × 10^6 dm^3 **Acceptable errors:** Volume of seawater obtained from: • Use of 126.9 to find $n(I_2)$ giving 1.74….x 10^7 • Missing x 2 ratio giving 4.36….x 10^6 **DO NOT ALLOW** for L3 if both errors are present, please note it gives a volume of 8.72…… × 10^6 dm^3 **ALLOW** minor slips in rounding, transcription errors, etc throughout **<u>Examiner's Comments</u>**

			OR A reasonable attempt at calculation *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* **0 mark** *No response or no response worthy of credit.*		Very few candidates managed to access the higher level on this question. They found the calculation very challenging. In addition to a typical mole calculation, they needed to use the tonnes conversion (given on the data sheet), look at the ratio of I_2 to KI and use a mass concentration. Many used the mass concentration as a molar concentration. Even if a balanced equation was given, it didn't guarantee the correct ratio in calculations and a common error was to find moles of I_2 using the relative atomic mass of iodine (126.9). As with previous calculations on this paper, it was often challenging to follow the logic in the steps of the calculation. It is important to encourage candidates to label each step of their calculation, showing them as independent steps and only using = when terms are equal. Explanations of relative reactivities of chlorine and iodine often lacked detail or had extra irrelevant information, such as reference to electronegativity, ionisation energy, bond enthalpy or intermolecular forces. Some candidates gave responses for the general trend in reactivity in the group rather than comparing Cl and I. Confusion around nuclear charge and nuclear attraction was also often seen. A key skill for longer answer questions is to plan out answers to avoid contradictions. Candidates should also be encouraged to re-read their answers to check that what they have written makes sense. Exemplar 2  2KI + Cl₂ ⟶ 2KCl + I₂ concentration = mass / volume Additional answer space if required. This exemplar demonstrates a L3 6 mark response. A comprehensive explanation of relative reactivities of chlorine and iodine is given. The steps in the calculation are logical with each step

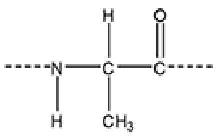
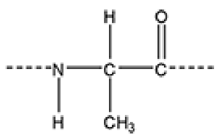
					labelled, making it easy to follow. A balanced equation is also given.
			Total	**6**	
5 0		i	Titanium (IV) oxide ✓	1 (AO2.5)	**DO NOT ALLOW** titanium dioxide **Examiner's Comments** Very few candidates gave the correct answer for this question. The most common errors included: titanium oxide, titanium(IV) **di**oxide, titanium oxide(IV), titanium(II) oxide. A few also attempted to give names like those for organic compounds: 1,1-titanium dioxide or the reverse 1,1-dioxytitanium. **How Science Works** It is important in Chemistry to have clear communication by use of systematic and unambiguous nomenclature. This includes the use of Roman numerals to indicate the magnitude of the oxidation number when an element, such as Ti, may have different oxidation numbers in different compounds. See specification statement 2.1.5(c) and HSW8.
		ii	**FIRST CHECK ANSWER ON ANSWER LINE** **If answer = 2.67 kg award 4 marks** --- *n*(Ti) = $\frac{1000}{47.9}$ **OR** 20.8768… (mol) ✓ *n*(Na) for 72% yield = 20.88 × 4 **OR** 83.5073… (mol) ✓ *n*(Na) for 100% yield = 83.51 × $\frac{100}{72}$ **OR** 115.98237… (mol) ✓ mass Na = 115.98 x 23.0 = 2667.659… (g) = 2.67 (kg) ✓ **3 SF AND kg required**	4 (AO2.2 × 4)	**ALLOW ECF** throughout **TAKE CARE: values shown may be truncated calculator values.** Steps can be calculated in any order which will change the intermediate answers**.** Marks are for the processing of the data. **ALLOW 3SF** up to calculated value throughout **IGNORE** rounding errors past **3SF** **Common Errors for 3 marks:** 1.92 (missing yield) 1.38 (yield wrong way round) 0.673 (use of Mr 189.9 for $TiCl_4$ instead 47.9 for Ti) **Examiner's Comments** Candidates found this calculation quite challenging, with less than a quarter achieving full marks. The most common errors are highlighted on the mark scheme. Many that struggled were often given credit for the x4 ratio mark but only if it was possible to see this in the working. Many gave multiple, often contradictory attempts at the calculation. It was not always clear how the final

					answer had been obtained. Clear working enables us to follow the logic and give ECF where appropriate. Many divided 1000 g by the molar mass for $TiCl_4$ and then found 72% of this. It was important here to read the question carefully to ensure complete understanding. Exemplar 1  This candidate achieved 3 out of the 4 possible marks. The steps in their calculation are logical and it is easy to follow their working and therefore spot the error in their calculation. They have divided by 4 rather than multiplying. It also shows the calculation can be performed in a different order to that on the mark scheme. All intermediate values are used in calculations as calculator values without rounding to ensure an accurate answer.
		iii	Add water **AND** filter ✓ Ti does not dissolve **OR** NaC*l* does dissolve ✓	2 (AO 3.3 × 2)	**ALLOW** dissolve **in water** **ALLOW** Ti is insoluble **OR** NaCl is soluble/aqueous **ALLOW** Ti is the residue **OR** NaCl is the filtrate **<u>Examiner's Comments</u>** Most candidates did not gain any credit here. However, the range of responses seen highlighted some misconceptions in their understanding of how different mixtures can be separated. Many assumed that sodium chloride was in solution/aqueous, not recognising that water was not present in this reaction. Responses such as "sodium chloride will evaporate" or "remove the water" were seen. Some gave a description of the purification method for an organic liquid - the use of a separating funnel and/or distillation were common. Some suggested the use of a magnet to remove Ti despite it being a non-magnetic metal.

					Misconception Understanding how to separate mixtures is covered in both KS3 and KS4 but it is important that these concepts can be applied during further study. Asking this type of problem solving question would make a good starter activity. Some useful activities for separating mixtures can be found in the [GCSE Chemistry B (Twenty First Century Science) Chemical analysis transition guide]
			Total	**7**	
5 1		i	$Ba(NO_3)_2(aq) + Na_2SO_4(aq) \rightarrow BaSO_4(s) + 2NaNO_3(aq)$ Balanced equation ✓ State symbols ✓	2 (AO 2.5 x 2)	**ALLOW** ionic equation $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$ **M2 dependent on M1** **IGNORE** NaCl balanced on both sides **<u>Examiner's Comments</u>** Less than half the candidates gained credit for this challenging question. There was lots of information to process. Many struggled to give the correct formula for the products, e.g. $NaNO_3$, Ba_2SO_4, or had issues with balancing. Some tried to involve the NaCl in the reaction, either recognising that it didn't react (acceptable on the mark scheme) or forming barium chloride or even Cl_2. Lots of candidates lost the mark for state symbols as they left $Ba(NO_3)_2$ as (s), not recognising that in step 1 the mixture was dissolved in water so should now be (aq).
		ii	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 26.6 % award 4 marks** --- $n(BaSO_4)$ = $\frac{3.28}{233.4}$ **OR** 0.014053… (mol) ✓ mass $Ba(NO_3)_2$ = 0.014053… × 261.3 **OR** 3.672.......(g) ✓	4 (AO 3.1 ×3) (AO 3.2)	**ALLOW ECF** from incorrect equation in 2(b)(i) and throughout **ALLOW 3SF** up to calculated value throughout **IGNORE** rounding errors past **3SF** *Calculator:* 0.01405312768 *Calculator:* 3.672082262 *Calculator:* 1.327917738 **ALLOW ECF** for use of calculated mass NaCl e.g. 0.014053…x 58.5 = 0.8221….

			mass NaC*l* = 5.00 – 3.672.. **OR** 1.3279… (g) ✓ % NaC*l* = $\frac{1.3279 \times 100}{5.00}$ = 26.6(%) **3 SF** ✓		to give final % 16.4 to 3SF -- **Alternative approach for last 2 marks** % $Ba(NO_3)_2$ = $\frac{3.672 \times 100}{5.00}$ = 73.44 … ✓ % NaC*l* = 100 – 73.44 = 26.6 % ✓ **<u>Examiner's Comments</u>** This was a tricky calculation, made more challenging if candidates hadn't been able to successfully complete (i). Many were able to calculate the moles of $BaSO_4$ but often rounded their answer to only 2 significant figures at this stage i.e. 0.014. Many assumed a direct ratio between $BaSO_4$ and NaCl so mass was found by multiplying moles by 58.5 (molar mass for NaCl) - if this was done then credit was given for ECF for the final marking point. **OCR support** The M1 section of the Mathematical Skills handbook contains useful information on handling data, including M1.1 use of significant figures.
		iii	Silver chloride/AgC*l* would be produced (as a precipitate) ✓ (Mass of NaC*l*) can be calculated from the mass/moles of AgC*l* ✓	2 (AO 3.4 × 2)	**ALLOW** Chlor**ide** reacts to give (white) ppt **IGNORE** incorrect formula of silver chloride **ALLOW** equation showing formation of AgCl(s) **ALLOW** Weigh AgC*l* and use to calculate %/mass/moles **<u>Examiner's Comments</u>** Another tricky question with less than half gaining credit. Many were able to recognise the addition of silver nitrate as the test for halide ions but did not realise that it could be used quantitatively. Many didn't read the question carefully and assumed Na_2SO_4 was still present, giving a mixture of two precipitates. Some, despite recognising the formation of AgCl, could not then see how to calculate the mass of NaCl i.e. "you won't have formation of $BaSO_4$". Some suggested that barium nitrate would also form a precipitate, perhaps confused by the (s) state symbol in the question.
			Total	**8**	
52			**Level 3 (5-6 marks)** Diagram showing reflux with most	6 (AO2.8 ×2)	**Indicative scientific points may include:** <u>Diagram</u>

			labels **AND** A **CORRECT** calculation of the % yield of 1-bromobutane **AND** A **detailed** description of most purification steps. *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)** Diagram showing reflux with some labels **AND** Calculates the % yield of 1-bromobutane with some errors **OR** Diagram showing reflux with most labels **AND** describes some purification steps, with some detail **OR** Calculates the % yield of 1-bromobutane with some errors **AND** describes some purification steps, with some detail *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)** Diagram showing reflux **OR** Attempts to calculate the % yield of 1-bromobutane **OR** Describes few purification steps. *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.	(AO3.3 ×4)	Diagram draw with condenser above flask Labels including • condenser • water in at bottom and out at top • pear-shaped or round-bottom flask ***<u>Calculation of % yield of 1-bromobutane</u>*** • n(butan-1-ol) = $\frac{9.25}{74.0}$ = 0.125 (mol) • mass 1-bromobutane = 6.10 × 1.268 = 7.7348 g • n(1-bromobutane) = $\frac{7.7348}{136.9}$ = 0.0565 (mol) • % yield = $\frac{0.0565}{0.125}$ × 100 = 45.2% **ALLOW** 45.2 ± 0.2 for small slip/rounding **NOTE Use of 6.1 g (omission of density)** • n(1-bromobutane) = $\frac{6.10}{136.9}$ = 0.044558… (mol) • % yield = $\frac{0.044558...}{0.125}$ × 100 = 35.6% ***<u>Purification</u>*** • In separating funnel, **organic layer is on bottom** • Drying with an **anhydrous salt by formula or name**, e.g. $MgSO_4$, Na_2SO_4, $CaCl_2$ • Redistil **at 102°C** **Examples** of detail in **bold** (**NOT INCLUSIVE**) **NOTE**: 'Use a separating funnel', dry, and 'redistil' on their own are **NOT** detailed descriptions **<u>Examiner's Comments</u>** This question was assessed by level of response (LoR). Candidates were required to describe key features in a procedure to prepare a pure organic liquid, including a labelled diagram for reflux, a calculation of the percentage yield and the procedural steps for purification. Levels were determined using these three features. Marks within a level were determined by communication. This question discriminated extremely well. Level 3 candidates would draw a clear diagram with all key items labelled and the set up being

					capable of being used safely. The percentage yield calculation would be correct, producing a percentage yield close to 45.2%. The steps for the purification: use of a separating funnel, drying and redistillation would be described in the correct order and with some detail. Level 2 candidates would have obtained some of the features required for Level 3 but there would be some key omissions or errors. The diagram may have been drawn clearly but labelling may have been incomplete or a thermometer with bung may have been inserted into the top of the condenser, a very hazardous arrangement. The calculation would be attempted but with some errors, such as omitting to use the density, or using a mixture of moles and masses. The purification steps may have been described but in the wrong order. Purification steps would be incomplete, perhaps only including distillation. Level 1 candidates often drew a diagram resembling a tube above a flask, with water often flowing in the wrong direction. The percentage yield may have been a simple mass ratio with no moles being used. A significant number of candidates described the purification steps for an organic solid, including recrystallisation. The preparation of an organic liquid is a key practical procedure that will have been experienced by students during their A Level studies (PAG 5). The overall standard of drawing diagrams was poor, an area that needs improvement.
			Total	**6**	
53	a	i	 ✓ **ONE** repeat unit **ONLY**	1 (AO2.5)	end –N– may be at either side e.g.  ✓ 'End bonds' **MUST** be shown (do not have to be dotted) **IGNORE** brackets **IGNORE** *n*
		ii	**IF** answer on answer line = 28418, **AWARD** 2 marks **IF** answer on answer line = 28400,	2 (AO2.2×2)	

			AWARD 1 mark -- M_r of 400 molecules = 400 × 89 = 35600 ✓ M_r of polymer = 35600 − (399 × 18) = 28418 ✓		**ALLOW ECF** from incorrect repeat unit in 19di **ALLOW ECF** from incorrect M_r of 400 repeat units Alternative method based on repeat unit: M_r of 400 repeat units = 400 × 71 = 28400 ✓ M_r of polymer = 28400 + 1 + 17 = 28418 ✓ **<u>Examiner's Comments</u>** Few candidates were given the mark for this question. Frequently candidates drew structures with two repeat units or the did not remove the oxygen atom from the OH group. A variety of responses were seen in this demanding question. In general candidates adopted one of two approaches. The most common was to multiply the Mr of the repeat unit by 200 and then add the mass of H and OH at each end of the polymer. The other approach used the Mr of the monomer by 200 and then subtract the mass of the 199 water molecules removed in the polymerisation. Many candidates were successful with the first step of their approach, but the best responses included the second step taking into account the Mr of water. A significant number of candidates used an incorrect value for the Mr.
	b		**Level 3 (5-6 marks)** Correct calculation of mass of $CH_3CHClCOOH$. **AND** Planned synthesis includes substitution of –Cl and formation of compound **I** (or its corresponding ammonium salt) with the correct reagents and some conditions identified and equations are mostly correct. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.*	6 (AO3.3×6)	**Indicative scientific points may include:** **<u>Calculation of mass of $CH_3CHClCOOCH_3$</u>** **Using moles** • $n(\mathbf{I}) = \frac{9.36}{117.0}$ = 0.08(00) (mol) • $n(CH_3CHClCOOC_2H_5) = 0.0800 \times \frac{100}{64}$ = 0.125 (mol)

			Level 2 (3-4 marks) Calculation of mass of $CH_3CHClCOOH$ is correct **AND** Planned synthesis includes one step of the synthesis with the correct reagent and some conditions identified and equation is mostly correct **OR** Calculation of mass of $CH_3CHClCOOH$ is partly correct **AND** Planned synthesis includes substitution of –Cl and formation of compound **I** (or its corresponding ammonium salt) with the correct reagents **OR** Attempts to calculate mass of $CH_3CHClCOOC_2H_5$ but makes little progress **AND** Planned synthesis includes substitution of –Cl and formation of compound **I** (or its corresponding ammonium salt) with the correct reagents and some conditions identified and equations are mostly correct *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)** Calculation of mass of $CH_3CHClCOOH$ is partly correct **OR** Planned synthesis includes both steps with some of the reagents and conditions identified **OR** Attempts equations for both steps but these may contain errors		• Mass of $CH_3CHClCOOH$ = 108.5 × 0.125 = 13.5625 g **Using mass** • Theoretical mass of $\mathbf{I} = 9.36 \times \frac{100}{64}$ = 14.625 (g) • Theoretical $n(CH_3CHClCOOH) = \frac{14.625}{117.0}$ = 0.125 (mol) • Mass of $CH_3CHClCOOH$ = 108.5 × 0.125 = 13.5625 g **ALLOW** slip/rounding errors such as errors in M_r, e.g. use of 107.5 instead of 108.5 for $CH_3CHClCOOH$ → 13.4375 --- ***Examples of partly correct calculations*** Mass = 5.5552 g from $0.0800 \times \frac{64}{100} \times 108.5$ (% *yield inverted*) Mass = 8.68 g from 0.0800 × 108.5 (% *yield omitted*) <u>**Synthesis: *Either order for 2 stages***</u> **Substitution of –Cl → amine:** • Reagents: (excess) NH_3

			OR Describes one step of the synthesis with reagents, conditions and equation mostly correct *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.		• Condition: ethanol • Equation: $CH_3CHClCOOH + 2NH_3 \rightarrow CH_3CHNH_2COOH + NH_4Cl$ **OR** $CH_3CHClCOOH + NH_3 \rightarrow CH_3CHNH_2COOH + HCl$ **Esterification of amine → compound I** • Reagents: CH_3CH_2OH • Conditions: acid (catalyst), e.g. H_2SO_4 (reflux/heat) • Equation: $CH_3CHNH_2COOH + CH_3CH_2OH \rightarrow CH_3CHNH_2COOCH_2CH_3 + H_2O$ **OR** --- **Esterification of carboxylic acid → ester** • Reagents: CH_3CH_2OH • Conditions: acid (catalyst), e.g. H_2SO_4 (reflux/heat) • Equation: $CH_3CHClCOOH + CH_3CH_2OH \rightarrow CH_3CHClCOOCH_2CH_3 + H_2O$ **Substitution of –Cl → amine:** • Reagents: (excess) NH_3 • Condition: ethanol • Equation: e.g $CH_3CHClCOOCH_2CH_3 + 2NH_3 \rightarrow CH_3CHNH_2COOCH_2CH_3 + NH_4Cl$ **OR** $CH_3CHClCOOCH_2CH_3 + NH_3 \rightarrow CH_3CHNH_2COOCH_2CH_3 + HCl$ **OR**

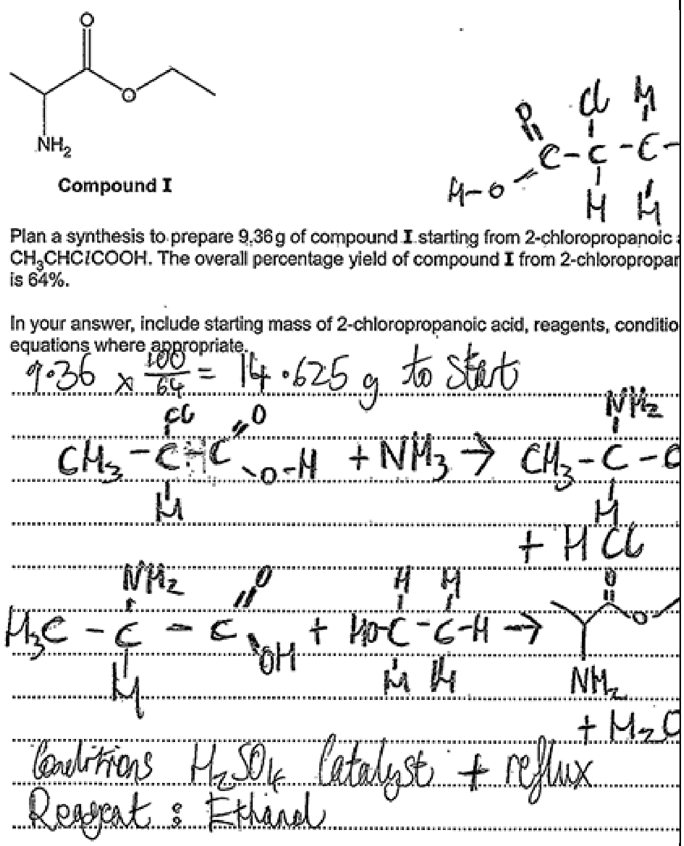
$CH_3CHClCOOCH_2CH_3 + NH_3 \rightarrow CH_3CHNH_3ClCOOCH_2CH_3$

(ammonium salt)

Examiner's Comments

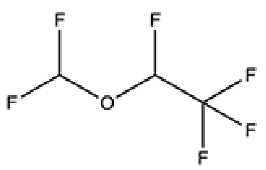
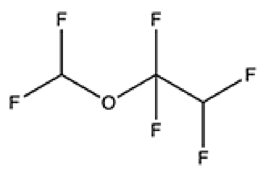
This question was marked using a level of response mark scheme. Most candidates gave an answer worth of at least Level 2 (3-4 marks) by providing the synthetic steps with reagents and equations for the synthesis of compound I. Exemplar 2, below, shows a frequent Level 2 response. The best performing candidates correctly determined the mass attempting to calculate the mass and showed the synthesis efficiently, using equations to communicate the preparation of compound I, with these responses being given Level 3 (5-6 marks). A number of responses omitted the mass calculation, such responses received Level 2 (1-2 marks).

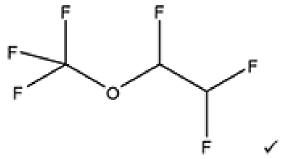
Exemplar 2



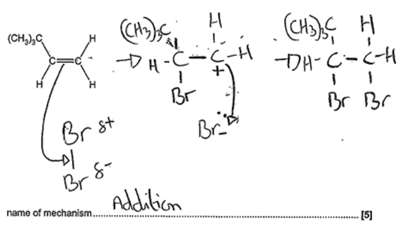
In this response the candidate has attempted to calculate the starting mass but has made little

					progress. Two stages of the synthesis have been covered with the reagents and most of the conditions identified. Both equations are complete. This is a Level 2 response and 4 marks have been given as the repones is logical and well communicated
			Total	**9**	
5 4			B	1 (AO1.2)	**<u>Examiner's Comments</u>** The majority of candidates identified B as the correct answer, with candidates frequently showing their calculations alongside each option to aid their choice.
			Total	**1**	
5 5			D	1 (AO1.2)	**<u>Examiner's Comments</u>** Most candidates correctly identified D as the correct response.
			Total	**1**	
5 6			C	1 (AO2.2)	**ALLOW** 500 (This is the correct mass) **<u>Examiner's Comments</u>** The majority of candidates correctly calculated C as the mass of paracetamol in the tablet.
			Total	**1**	
5 7			C	1 (AO2.6)	**ALLOW** 4.8 (This is the correct volume) **<u>Examiner's Comments</u>** This question discriminated well, with higher ability candidates correctly identifying C as the volume of hydrogen produced. Many candidates overlooked the hydrogenation of the CN group and incorrectly selected option A.
			Total	**1**	
5 8			**FIRST CHECK ANSWER LINES** **If M=168(.0) Award 4 marks for calculation providing unit**	6 (AO1.2×1)	**ALLOW ECF throughout** **ALLOW** calculator value of 167.968115 (using

			conversions are correct **--** ***Use of ideal gas equation*** *pV*= *nRT* ***OR*** $n = \frac{pV}{RT}$ ✓ ***SI Unit conversions AND substitution into*** $n = \frac{pV}{RT}$: • *R = 8.314* ***OR*** *8.31* • *V* = 186 × 10^{-6} • *T in K: 303 K* *e.g.* $\frac{1.07 \times 10^5 \times 186 \times 10^{-6}}{8.314 \times 303}$ ✓ ***Calculation of n*** *n* = 7.90 × 10^{-3} (mol) ✓ ***Calculation of M*** $M = \frac{1.327}{7.90 \times 10^{-3}}$ = 168(.0) ✓ ***Molecular formula*** $C_3H_2F_6O$ ✓ ***Structure*** 	(AO2.4× 3) (AO2.5× 2)	8.314) for M **ALLOW** calculator value of 167.8873033 (using 8.31) for M Calculator value of *n*: from 8.314 = 7.900308915 × 10^{-3} from 8.31 = 7.904111711 × 10^{-3} **ALLOW** ECF that matches M but the formula MUST contain F_6O **--** **Use of 24 dm^3**: e.g. $n = \frac{186.0}{24000} = 7.75 \times 10^{-3}$ **No mark** *(calculation much simpler)* $M = \frac{1.327}{7.75 \times 10^{-3}}$ = 171(.2) ✓ **ECF** $C_3H_5F_6O$ ✓ **ECF** **ALLOW** ECF for a feasibile chemical structure that matches M **AND** contains F_6O **AND** has a chiral carbon **DO NOT ALLOW** 

			OR  ✓		*no chiral carbon* **Examiner's Comments** This question proved difficult and discriminated well. Higher ability candidates correctly used SI units and showed each step of their calculation and then using this to correctly identify a structure of compound X. Candidates frequently used the wrong interconversions and gave structures that lacked a chiral centre. A small number of candidates used molar gas volume rather than PV=nRT for their calculation.
			Total	**6**	
5 9			**Molar ratios** Zn : H : N : O $= \frac{21.99}{65.4} : \frac{4.04}{1.0} : \frac{9.41}{14.0} : \frac{64.56}{16.0}$ **OR** 0.336 : 4.04 : 0.672 : 4.04 **OR** 1 : 12 : 2 : 12 ✓ **Empirical formula** $ZnH_{12}N_2O_{12}$ ✓ ***Any order*** **With water of crystallisation** ZnN_2O_6-$6H_2O$ **OR** $Zn(NO_3)_2$-$6H_2O$ **Inverse fractions>NO MARKS**	3 (AO1.2 ×2) (AO2.2 ×1)	**NOTE**: If only the correct answer of ZnN_2O6*6H_2O **OR** $Zn(NO3)_2*6H_2O$ is seen with no working, award 1 mark only **ALLOW ECF** from incorrect molar ratios of Zn : H : N : O e.g. from use of atomic number(s) **ALLOW** $Zn(NO3)_2(H_2O)_6$ **ALLOW ECF** from incorrect empirical formula e.g. $ZnNO_3$•$3H_2O$ from ZnH_6NO_6 **Examiner's Comments** Candidates processed the empirical formula data well to obtain the correct molar ratio of the elements, with many being able to convert this ratio into an empirical formula. This type of problem is common in chemistry and candidates were clearly well-versed in the method of its solution. The most common error was H:11 rather than H:12. The third mark for water of crystallisation was far harder to obtain. Many candidates identified that $6H_2O$ was present, but the O was often missing in a formula shown as ZnN_2·$6H_2O$, or 'included' with the water as ZnN_2·$6H_2O_2$. Many candidates did not seem to know how to proceed here. The mark scheme allowed credit for both the preferred answer of $Zn(NO_3)_2$·$6H_2O$ and for ZnN_2O_6·$6H_2O$, as both had extracted the waters of crystallisation from the rest of the empirical formula. A few candidates inverted the moles calculation, a strategy that could not be given marks.
			Total	**3**	
6 0			**Identification of halide** Add (aqueous) silver nitrate **OR**	5 (AO3.3×	**ANNOTATE ANSWER WITH TICKS AND CROSSES**

			$AgNO_3$ **OR** Ag^+/silver ions ✓ **Observations - mark independently** Chloride/Cl^- gives white precipitate Bromide/Br^- gives cream precipitate Iodide/I^- gives yellow precipitate ✓ **Precipitate/solid seen at least once** **Equation for at least one halide** e.g. $Ag^+ + Cl^- \rightarrow AgCl$ **ALLOW** $Ag^+ + X^- \rightarrow AgX$ ✓ ***IGNORE*** *state symbols (ppt already assessed)* **Identification of B and C** **B**: NaBr **OR** sodium bromide ✓ **C**: $CaCl_2$ **OR** calcium chloride ✓	3 AO3.2×2)	**IGNORE** addition of HNO_3 but HCl **CONs** $AgNO_3$ **IGNORE** references to solubility in NH_3 (dil or conc), even if incorrect **ALLOW** chlorine for chloride, etc **ALLOW** equation with Br^-**OR** I^- e.g. $Ag^+ + Br^- \rightarrow AgBr$ **ALLOW** full/partial equations, e.g. $AgNO_3 + Cl^- \rightarrow AgCl + NO_3^-$ **ALLOW** explanation for identification: i.e. **B (Group 1):** Subtract molar/atomic mass of halide/Br from number in range 100–115/molar mass of B ✓ **C (Group 2):** Subtract **2** × molar/atomic mass of halide/Cl from number in range 100–115/molar mass of **C** ✓ **ALLOW** displacement by addition of halogen ✓ 2 correct colours in water or organic solvent ✓ Equation, e.g. $Cl_2 + 2Br^- \rightarrow Br_2 + 2Cl^-$ ✓ **<u>Examiner's Comments</u>** Candidates generally answered the first part of this question well. Most candidates were able to identify silver nitrate (or a halogen displacement method), to describe the expected observations, supported with mainly correct ionic equations. Candidates found it much harder to identify B and C as NaBr and $CaCl_2$. They could do this in various ways by matching possible formula with the provided molar mass ranges. The mark scheme did allow marks to be given when candidates described the identification process, although this was often very muddled, so, only the most able few candidates fully identified the unknown B and C.
			Total	**5**	
6 1		i	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF $\Delta_r H$= -116 (kJ mol^{-1}) award 4 marks** **IF $\Delta_r H$= +116 (kJ mol^{-1}) award 3 marks** **Energy released in J OR kJ** = 75.0 × 4.18 × 18.5 = 5799.75 (J) **OR** 5.79975 (kJ) ✓ **Correctly calculates $n(Ba(OH)_2)$ OR $n(HNO_3)$** $n(Ba(OH)_2) = 2 \times \frac{25.0}{1000} = 0.05(00)$ (mol) **OR**	4 (AO2.4) (AO2.4) (AO2.8) (AO2.8)	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **ALLOW** 5799.8 **OR** 5800 J **OR** 5.7998 **OR** 5.8 kJ **DO NOT ALLOW** < 3 SF **EXCEPT** 5.8 *(trailing zeroes)* **IGNORE** any sign **IGNORE** units ***i.e. ALLOW*** *correctly calculated number in J* ***OR*** *kJ* ***OR*** *no units* **ALLOW** 3SF or more **OR** use of 5800 J **OR** 5.8 kJ Sign **NOT** needed 3 **SF** needed **Common errors** **3 marks** $\frac{5799.75}{0.1} \rightarrow$ **−58.0** no 2 × using 0.1

			$n(HNO_3) = 2 \times \frac{50.0}{1000} = 0.1(00)$ (mol) ✓ **Δ*H* per mole $Ba(OH)_2$ in J OR kJ** *Answer **MUST** divide energy by $n(Ba(OH)_2)$ **OR** $2 \times n(HNO_3)$)* $\pm\frac{5799.75}{0.05}$ OR $\pm 2 \times \frac{5799.75}{0.1}$ = ±115995 (J) **OR** $\pm\frac{5.79975}{0.05}$ OR $\pm 2 \times \frac{5.79975}{0.1}$ = ±115.995 (kJ) ✓ **Δ*H* in kJ mol^{-1} to 3 SF AND - sign** $\Delta_r H$ = -116 (kJ mol^{-1}) ✓		$\frac{5799.75}{0.15} \rightarrow$ **−38.7** ÷ by 0.05 + 0.10 $2 \times \frac{5799.75}{0.15} \rightarrow$ **−77.3** **2 marks** for answers above with wrong sign or not to 3 SF Other multiples by using *m* as 50 or 25: Mark using same principal Use of 50 → **-77.3 3 marks** Use of 25 → **-38.7 3 marks** **<u>Examiner's Comments</u>** More successful candidates followed a well-rehearsed method for processing experimental enthalpy results to arrive at an enthalpy change. The result was usually the correct answer of –116 kJ mol^{-1}. Most candidates combined the 2 volumes (25 cm^3 and 50 cm^3) to give 75 cm^3 with *m* = 75 g and then calculated the correct energy change of 5799.75 J using $mc\Delta T$. Some candidates did not combine the volumes and used *m* = 25 g or 50 g instead. Most candidates worked out the amount in moles of $Ba(OH)_2$ and HNO_3. Unfortunately, these calculations were often scattered across the page with no indication of what the calculated values applied to. Some candidates incorrectly combined the moles (0.10 and 0.05) and divided this value (usually 0.15) into the energy change. The mark scheme accounted for these errors and allowed error carried forward marks to be allocated appropriately. Candidates are strongly advised to organise their calculation in a coherent way and to show what each calculated value applies to so that error carried forward can be applied for mistakes. Exemplar 3  Exemplar 3 illustrates a common misconception of less successful responses when using of $mc\Delta T$: misunderstanding the meaning of m in the equation $q = mc\Delta T$, used for finding the energy change *q* from experimental results. **Misconception**

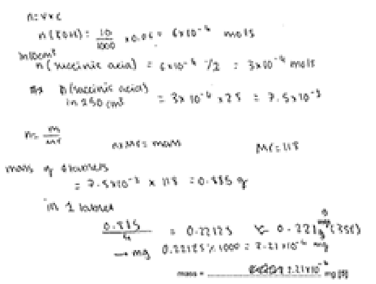
					In the equation q = $mc\Delta T$, mass m is the mass of the substance that changes temperature by ΔT. This substance has a specific heat capacity, c. Looking at the experimental results, the substance changing temperature is the mixture of the two solutions, which have volumes of 25 cm^3 and 50 cm^3. This is where the thermometer has been placed. The information states that the density of the solutions is the same as for water, 1.00 g cm^{-3}. Therefore, the mass *m* that changes temperature ΔT is 75.0 g and the energy change is 75.0 × 4.18 × 18.5 J. This candidate has correctly calculated the moles of one of the reactants, $Ba(OH)_2$, as 0.0500 but has then calculated its mass as 75.0 × 4.18 × 18.5 J = 8.565 g and has used this in $mc\Delta T$. So the key message is that m in $mc\Delta T$ is where the thermometer has been placed.
		ii	**Reason for incorrect conclusion** neutralisation forms **1 mol H_2O** **OR** $\Delta_r H$ forms 2 mol **H_2O** ✓ Value for $\Delta_{neut}H = \pm \frac{\text{answer to 25a(i)}}{2}$ (kJ mol^{-1}) ✓ 2 SF or more **2 SF or more**	2 (AO3.2 ×1)	**H_2O essential** **IGNORE** sign, even if wrong **ALLOW** 2 SF, e.g. 58 **Examiner's Comments** Many candidates correctly identified that neutralisation is the formation of 1 mole of water, whereas this equation forms 2 moles of water. Significantly fewer were then able to use their answer to the calculation in Question 25 (a) (i) to determine a value for the neutralisation enthalpy as half of that that value. This was a novel question, not used in previous examinations, and many candidates coped with the challenge admirably.
			Total	**6**	
62			**FIRST check the molar mass on answer line** **MUST be derived from *pV* = *nRT*, CROSSES** **Award 4 marks for calculation for:** **• answer = 136.9 OR 137** *Rearranging ideal gas equation to make n subject* $n = \frac{pV}{RT}$ ✓ *Substituting all values including conversion to m^3 and K* $n = \frac{(1.01 \times 10^5) \times (74.0 \times 10^{-6})}{8.314 \times 373}$ ✓ $n = 2.410095443 \times 10^{-3}$ (unrounded) → 2.41×10^{-3} (mol) (rounded to 3 SF) ✓	5(AO2.4 ×4) (AO3.2)	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **If there is an alternative answer, check to see if there is any ECF credit possible using working below** 1st mark may be implicit by direct substitution of correct values below into rearranged equation. **ALLOW** use of 8.31 for *R* → 2.411×10^{-3} **ONLY award this mark if *n* has been derived from correct rearranged ideal gas equation** **ALLOW 3 SF up to calculator value, correctly rounded** **2.41×10^{-3} OR 0.002411255537 → first 3 marks** **→ 136.868581616** → C_4H_9Br **NOTE: ALLOW** 137 (i.e. to 3 SF) **ALLOW** any unambiguous structure **ALLOW ECF** provided that formula given is a

			Calculation of molar mass, M $M = \frac{m}{n} = \frac{0.330}{2.410095443 \times 10^{-3}} = 136.9..\ (\text{g mol}^{-1})$ $\rightarrow \frac{0.330}{2.41 \times 10^{-3}} = 136.9\ (\text{g mol}^{-1})$ ✓ **ALLOW** calculated *M* in range 136.9 – 137 *Molecular formula of* **D** C_4H_9Br ✓ **IF** candidate has failed to derive suitable value of *n*, **ALLOW** value of *M* from 0.330 **AND** 24000 with haloalkane closest to calculated value for last 2 marks **See Guidance column.**		haloalkane and matches *M* calculated from 0.330 g **AND** $pV = nRT$ $M = \frac{0.330}{74.0/24000}$ **OR** $\frac{0.330}{3.0833.. \times 10^{-3}}$ = 107 to 3 SF ✓ From **107, ONLY ALLOW** = C_2H_5Br (108.9)✓ **Examiner's Comments** In contrast with the mechanism in Question 26 (a), this ideal gas calculation was answered well by most candidates. Most had obviously learnt the method for successfully processing this type of calculation. More candidates than in previous series were able to convert °C into K and cm^3 into m^3 to obtain *n* = 0.00241 mol. Many candidates were then able to achieve the correct molar mass of 136.9 g mol–1 and molecular formula of C_4H_9Br. Candidates with incorrect unit conversions could still collect method marks by error carried forwards. The most common error was to use × 10^{-3} instead of × 10^{-6} for the cm^3 conversion to m^3, unfortunately this error led to a molar mass of 0.1369 from which a molecular formula is impossible. Notwithstanding the success of obtaining the correct answers, most calculations were unclearly presented, as in Question 25 (a) (i).
			Total	**5**	
63			**C**	1(AO2.2)	**Examiner's Comments** Candidates often appear to find quantitative questions such as this one easier than questions involving interpretation of textual information. Most candidates selected the correct response and most scripts contained working including molar proportions alongside the question. This is an excellent strategy.
			Total	**1**	
64			**D**	1(AO2.6)	**Examiner's Comments** Candidates found this question very difficult. B was the main distractor, obtained by multiplying the number of moles (4) by the Avogadro constant. Only the highest-attaining candidates realised that the question asked for the number of **ions** and multiplied the answer to B by 3 to obtain option D. The lesson here is to consider carefully any bold text in the question (**ions**).
			Total	**1**	

6 5			**B**	1(AO2.4)	**Examiner's Comments** Candidates found this calculation more difficult than Question 7. From the annotations, most showed working using the relationship between moles, concentration and volume. Options A (18 × 250/1000) and C (18 × 250/1000 ÷ 0.450) were the main distractors.
			Total	**1**	
6 6			**C**	1(AO1.2)	**ALLOW** 12 **Examiner's Comments** Most candidates selected the correct response. Where an error had been made, it was usually option B, the result of ignoring the two tertiary H atoms.
			Total	**1**	
6 7			**D**	1(AO2.6)	**Examiner's Comments** This question discriminated extremely well with most candidates choosing the correct option. Most candidates showed some working. The key to success was to identify the balanced equation that produced CO_2 and H_2O in a 3 : 4 molar ratio.
			Total	**1**	
6 8		i	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF *T* = 52.4 °C OR 52.5 °C award 4 marks** **IF *T* = 32.4 (°C) award 3 marks** --- ***Correctly calculates n($AgNO_3$)*** $= 0.400 \times \frac{100.0}{1000}$ **OR** 0.04(00) (mol) ✓ ***Energy released per mole of $AgNO_3$ in J OR kJ*** $= \frac{678 \times 0.0400}{2}$ **OR** 13.56 (kJ) **OR** 13560 (J) ✓ ***Correctly calculates ΔT***	4 (AO1.2) (AO2.4) (AO2.8) (AO2.8)	***FULL ANNOTATIONS MUST BE USED*** --- **ALLOW ECF** throughout --- **ALLOW** 13.6 kJ **OR** 13600 J (to 3SF) **DO NOT ALLOW** < 3 SF **IGNORE** any sign **and** units *i.e.* ***ALLOW*** *correctly calculated value in J* ***OR*** *kJ* --- **ALLOW ECF ONLY** from calculated Δ*T* +*20* °C **Common errors** **3 marks**

			$\Delta T = \frac{13560}{100 \times 4.18}$ **OR** 32.4 (°C) ✓ ***Maximum temperature reached*** = 32.4… + 20.0 = 52.4 °C ✓ **3 SF required**		**84.9 °C (not divided $\frac{\Delta H}{2}$)** **<u>Examiner's Comments</u>** Many candidates made some attempt at this unusual twist on a Q = mcΔT calculation, but only a minority of candidates produced a fully correct answer. A temperature of 84.9 °C was seen much more often than 52.4 °C. The calculation of n($AgNO_3$) was performed well. Common errors were not dividing the moles by 2, not recognising the need to calculate the energy released per mole of $AgNO_3$, confusing the mass of water with the mass of the silver nitrate solid or of using an energy in kJ alongside a value of c based on J.
		ii	Maximum temperature is the same **AND** Half the energy/ moles **AND** half the mass/volume	1 (AO3.4)	**ALLOW** response that links the same proportionality/ratio of volume/mass and energy/moles **ALLOW** if seen by a calculation **<u>Examiner's Comments</u>** Although there were a few well explained, correct answers, this question proved challenging for most candidates. Candidates needed to link the changes as a proportion (e.g. half) to be given the mark. Candidates often only considered the change to energy or mass, but not both, e.g. dealt only with the decrease in moles reacting leading to a smaller temperature rise.
			Total	**5**	
6 9			8.3×10^{-22} (kJ) ✓ From $\frac{500}{6.02 \times 10^{23}}$ Answer **MUST** be to 2 SF **AND** in standard form.	1 (AO2.2)	**ALLOW** use of IEs close to 500 giving a range: *8.3×10^{-22} (from 500)* *to 9.1×10^{-22} (from 550)* **<u>Examiner's Comments</u>** This question proved demanding for candidates, with many simply quoting a molar value taken from the graph and converting into standard form. Of those who recognised the need to use the Avogadro constant, a few tried to multiply it by the molar ionisation enthalpy. For those who worked out the correct answer, several lost marks due to the requirement of 2 significant figures.
			Total	**1**	

70	a	i	**Titres** 22.75 | 22.45 | **22.70** | 22.55 ✓ **Mean titre** $\frac{22.45 + 22.55}{2}$ = 22.5(0) (cm^3) ✓	2 (AO1.2×2)	**2 DP essential** i.e. last 0 for 22.70 **DO NOT ALLOW** use of trial titre. **Examiner's Comments** Almost all candidates calculated the titres correctly, but a significant number were penalised for recording 22.70 as 22.7. A significant number also used this result and the trial titre to derive their mean value. There were also very small numbers of candidates who used all 4, or all of titres 1, 2 and 3, to calculate their mean. **OCR support** Links to the legacy coursework tasks and PAG practice question sets can be found on OCR Interchange. Exam hints for students can be found at: https:/www.ocr.org.uk/Images/592305-exam-hints-for-students.pdf.
		ii	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 498 mg award 5 marks --- **Number of moles of KOH in titre** $= 0.0600 \times \frac{22.50}{1000}$ **OR** 1.35×10^{-3} (mol) ✓ **Number of moles of acid in 10 cm^3** $= \frac{1.35 \times 10^{-3}}{2}$ **OR** 6.75×10^{-4} (mol) ✓ ***Number of moles of* acid in 250 cm^3** $= 6.75 \times 10^{-4} \times 25$ **OR** 0.016875 (mol) ✓ ***Mass of* acid in 4 tablets** $= 0.016875 \times 118$ **OR** 1.99125 (g) ✓ **Mass in one tablet AND mg conversion** (i.e. divide by 4 **AND** x 1000) $= \frac{1.99 \times 10^3}{4}$ =498 (mg)✓	5 (AO2.8×3) (AO3.1) (AO3.2)	**ALLOW ECF** from incorrect titre in 19 (a) (i) **ALLOW ECF** throughout **TAKE CARE: values shown may be truncated calculator values.** Steps can be calculated in any order which will change the intermediate answers. Marks are for the processing of the data. **ALLOW 3SF** up to calculated value throughout **BUT** ignore trailing zeros on intermediate values **IGNORE** rounding errors past **3SF** --- **Common errors** **5 marks** 503 mg (use of 22.725 cm^3) **4 marks** 996mg (no divided by 2) 19.9mg (no volume conversion i.e. x 25) **Examiner's Comments** Candidates made good progress with this calculation, many gaining 4 or 5 marks, including error carried forward from incorrect titres. Common errors included, in various combinations: not

			Answer must be to 3SF		converting the final answer into mg, not converting volume to dm^3, missed ratio, multiplying the moles in $10cm^3$ acid by 10 instead of 25 and/or wrong M_r. Responses to Question 19 (a) (ii) often featured rows of figures and random sums without a single word about what the figures, or sums, were set to calculate. Candidates should remember to provide written indications of what it is they are working out – presenting the calculations without any annotations can make it harder for error carried forward marks to be given if there is an error in their calculation. **Exemplar 1**  The exemplar here shows a good use of annotation. There is a clear indication of the mathematical process so that the error carried forward is easily identified and the candidate gains the method marks
	b	i	(Glycolic) acid is in **excess/partially neutralised** **AND** glycolate/potassium glycolate (ions) are present/produced ✓	1 (AO1.1)	**ALLOW** some acid remains **ALLOW** conjugate base for glycolate ions/salt of weak acid **ALLOW** $HOCH_2COO^-$ **<u>Examiner's Comments</u>** Many candidates did not answer the question and instead described what a buffer was. Very few candidates correctly explained that a weak acid was being added to a base, sometimes mentioning the formation of the salt or conjugate base. The majority also did not include the importance of there being excess acid, or some acid remaining, after the partial neutralisation.
		ii	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 3.93 award 4 marks** **---** **Initial amounts** $n(HOCH_2COOH) = 0.750 \times \frac{60.0}{1000}$ **OR** 0.045(0)	4 (AO1.2×1) (AO2.8×3)	**ALLOW ECF** throughout

			(mol) **AND** n(KOH) = $0.625 \times \frac{40.0}{1000}$ **OR** 0.025(0) ✓ **Amounts in the buffer solution** $n(HOCH_2COOH)$ = 0.0450 − 0.0250 **OR** 0.02(00) (mol) **AND** $n(HOCH_2COO^-)$ 0.025(0) (mol) ✓ **pH** $K_a = 10^{-3.83}$ **OR** 1.479 & × 10^{-4} ✓ $[H^+] = \frac{1.479... \times 10^{-4} \times 0.200}{0.250}$ **OR** 1.183 × 10^{-4} (mol dm^{-3}) pH = 3.93 (**2 DP**) ✓		**ALLOW use of moles for concentration** $[H^+] = \frac{1.479... \times 10^{-4} \times 0.0200}{0.0250}$ **Common errors** **3 marks** pH = 3.57 not using n(HA) remaining **2 marks** pH = 3.75 using HA and KOH concentrations within question **<u>Examiner's Comments</u>** Most candidates were able to derive a value for K_a from pK_a and calculate the number of moles of glyolic acid and potassium hydroxide reacting. Less were successful in determining the moles or concentrations present in the buffer solution causing many to get the common error of 3.57. Many candidates tried to calculate pH for the weak acid, without considering changes to concentrations or the buffering effect. Clarity of working is essential and in questions such as this, candidates are advised to include word descriptions of what they are calculating, even if it is abbreviations such as 'n' for number of moles.
		iii	NH_3 / OH^- reacts with H^+ / $HOCH_2COOH$ / (Glycolic) acid ✓ $HOCH_2COOH \rightleftharpoons H^+ + HOCH_2COO^-$ **AND** Equilibrium shifts to the right ✓	2 (AO1.2×2)	**ALLOW** NH_3 will act as a base (and form NH_4^+) **ALLOW** NH_3 decreases $[H^+]$ **ALLOW** $HA \rightleftharpoons H^+ + A^-$ Equilibrium equation needs to be shown. **<u>Examiner's Comments</u>** Most candidates correctly described the ammonia reacting with the glycolic acid or with hydrogen ions, although some thought that ammonia was acidic. Many of them then went on to say that "the equilibrium will move to the right" without realising that the equilibrium had not itself appeared within the question, and so they needed to write it out to gain marks. A few candidates thought that ammonia was an acid, due to the 3 × Hs in the molecule.

			Total	**14**	
7 1			**Level 3 (5–6 marks)** Uses correct method to calculate K_c **AND** explains why most operational condition is different with few omissions in the explanation. *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)** Uses correct method to calculate K_c with few errors **OR** Derives a correct expression for K_c with an attempt at the K_c calculation **AND** explains why an operational condition is different with some omissions. *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)** Derives a correct expression for K_c **AND** explains why one operational condition is different with some omissions. **OR** explains why most operational conditions are different *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.*	6(AO2.4 ×4 AO1.2×2)	**Indicative scientific points may include:** **IGNORE trailing zeroes** **Equilibrium amounts** $n(N_2)$: 1.20 − 0.08 = 1.12, $n(H_2)$: 3.60 − 0.24 = 3.36 **Equilibrium concentrations** $[N_2] = \frac{1.12}{8.00} = 0.140$ (mol dm^{-3}) $[H_2] = \frac{3.36}{8.00} = 0.420$ (mol dm^{-3}) $[NH_3] = \frac{0.160}{8.00} = 0.0200$ (mol dm^{-3}) **Equilibrium expression and K_c value wih units** $K_c = \frac{[NH_3]^2}{[N_2] \times [H_2]^3}$ $K_c = \frac{0.0200^2}{0.140 \times 0.420^3} = 0.0386$ *Calculator: 0.03856417851* **Units:** dm^6 mol^{-2} **Explanation for operational differences.** **Temperature** • Low temperature for maximum yield: (Δ*H* −ve \exothermic) • High temperature to increase rate **Pressure** • High pressure for maximum yield (fewer (gaseous) moles/molecules of products) • High pressure expensive to generate **OR** high pressure is a safety hazard **Catalyst** • Allows a lower temperature to be used for maximum yield. • Reducing fuel expense **OR** increasing rate **Examiner's Comments** This Level of Response question was generally well answered with many candidates achieving maximum marks by simply considering what was required in the question. Responses were often split between a calulation on the main paper and the conditions explanation on extra pages. The calculation errors included no shift or incorrect shift

					in the equilibrium values. Not calculating the concentration or incorrectly multiplying by 8 rather than dividing by 8. Some candidates attempted a 'hybrid' calculation of Kp by trying to calculate a mole fraction and partial pressures. There was a number of candidates who confidently worked out the value of K_c. There were also some very good analyses of the operational conditions. Many of those who had done well on the calculation treated the explanation as an afterthought, not giving it enough attention to give them an answer that would access Level 3. Exemplar 2  An example of a complete answer, showing a good level of communication in the description and the calculation layout, achieving Level 3 (6 marks) is shown above. This candidate gave a clear method using an "ICE" table to calculate the number of moles at equilibrium. The calculation of the new concentrations can be seen by the use of [ ] and division by 8. The candidate then shows the Kc expression and substitutes the numerical values before successfully calculating the value and includes the units. This is followed by a concise explanation of the conditions used by industry.
			Total	**6**	
72	a	i	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 2.53(g) award 5 marks** **--** **[H⁺]** = $10^{-13.12}$ **OR** 7.58..... × 10^{-14} (mol dm^{-3}) ✓ $[OH^-] = \frac{1 \times 10^{-14}}{7.58........ \times 10^{-14}}$ **OR** 0.1318 .... (mol dm^{-3}) ✓	5 (AO2.4×5)	**ALLOW ECF and 3SF throughout.** **ALLOW** calculation process in any order. **IGNORE** rounding errors past **3SF** **--** Calculator: 7.58577575 × 10^{-14} Calculator: 0.1318256739 **ALLOW** alternative approach using pOH for first 2

			$n(OH^-)$ in 250 cm^3 = $\frac{0.1318.....}{4}$ **OR** 0.0329...... (mol) ✓ $n(Ba(OH)_2)$ or $n(BaO)$ = $\frac{0.0329.......}{2}$ **OR** 0.0164….. (mol) ✓ **Mass of BaO** = 0.0164..... × 153.3 = 2.53 (g) **3SF** ✓		marks. $p[OH^-]$ = 14 − 13.12 = 0.88 $[OH^-]$ = $10^{-0.88}$ = 0.1318….. Calculator: 0.03295641846 0.033(0) comes from $[OH^-]$ = 0.132 Calculator: 0.01647820923 Calculator: 2.526109475 **Common errors 4 marks** 5.05g Not dividing by 2 2.82g Use of M_r for $Ba(OH)_2$ 5.06g rounds to 0.132 in M2 then not dividing by 2 **3 marks** 5.65g not dividing by 2 and using Mr for $Ba(OH)_2$ **Examiner's Comments** Although few candidates got the correct final answer, however almost all achieved some marks from this calculation through error carried forward, with marks spread across the available range. Almost all candidates were able to find the concentrations of hydrogen and hence hydroxide ions. A few candidates successfully used $p[OH^-]$ method. Most were able to calculate the moles of hydroxide ions in $250cm^3$. Many then did not realise the need to half this number to find the moles of barium, and/or used the Mr for barium hydroxide instead of barium oxide.
		ii	$Ba^{2+}(aq)$ +$2H^+(aq)$ + $SO_4^{2-}(aq)$ +$2OH^-(aq)$ → $BaSO_4(s)$ +$2H_2O(l)$✓	1 (AO3.2)	**ALLOW** multiples **ALLOW** $H^+(aq)$+ $OH^-(aq)$ → H2O(l) **OR** $Ba^{2+}(aq)$ + $SO_4^{2-}(aq)$ → $BaSO_4(s)$ **Examiner's Comments** This question was answered well, with many candidates giving one of the equations in the 'ALLOW' part of the mark scheme. Those candidates who did not gain this mark gave full equations or missed out state symbols.

	b	i	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 731(g) award 3 marks** **--** ***n*(Z)** $n(Ca_5NH_4(NO_3)_{11}\cdot 10H_2O) = \frac{1500}{1080.5}$ **OR** 1.388246… ✓ **Mass of limestone** *n*($CaCO_3$) = 1.388246.... × 5 **OR** 6.94123& **AND** mass $CaCO_3$ = 6.94123.... × 100.1 **OR** 694.8 g ✓ mass limestone = $\frac{694.8 \times 100}{95.0}$ = 731 g (**3SF**) ✓	3 (AO2.6× 3)	**ALLOW ECF throughout** **ALLOW** calculation process in any order. **IGNORE** rounding errors past **3SF** **DO NOT ALLOW** 100 for M_r of $CaCO_3$ **Common errors** **2 marks** 146g no x 5 for moles of $CaCO_3$ 660g use of 95.0/100 29.3g divide by 5 rather than x5 __**Examiner's Comments**__ This proved a difficult question for most candidates. Most were able to correctly calculate the moles of fertiliser by converting kg to g. The next step was to deduce that 5 moles of calcium carbonate would be required for each mole of Z and multiply by 5, rather than the common error of dividing by 5. Few candidates were able to multiply by 100/95, to account for the impurities in limestone, with many multiplying by 95/100.
		ii	$Mg_3Ca(CO_3)_4$ (s) + 8HC*l*(aq) → 3MgCl_2(aq) + CaCl_2(aq)+ 4H_2O(l) + 4CO_2(g) Correct formulae ✓ Balanced **AND** state symbols ✓	2 (AO2.6× 2)	**ALLOW** multiples **M2** dependent on **M1** **IGNORE** incorrect state symbol for $Mg_3Ca(CO_3)_4$ __**Examiner's Comments**__ This was another very challenging question using an unfamiliar mineral. Most candidates identified a formula of salts containing both magnesium and calcium, or carbonates of the separate elements. Only the most successful candidates were able to give the correct formula. Common errors, for those who solved the formulae, were the use of "4"HCl in balancing and the absence of state symbols.
			Total	**11**	

<table>
<tr>
<td>7
3</td>
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<td>
Level 3 (5–6 marks)
Reaches a comprehensive conclusion to determine the correct formulae of almost all of B, C, D, E, F and G.
AND
most correct equations and identifies some changes in oxidation number
AND
Calculation of M_r of the gas

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 conclusion to determine the correct formulae of at least half of B, C, D, E, F and G.
AND EITHER
some correct equations
OR
Any one correct equation and a relevant change in oxidation number
OR
any one correct equation and a correct calculation of the M_r

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)
Reaches a simple conclusion to determine the correct formulae of some of B, C, D, E, F and G
OR
The correct formulae for 1 of B, C, D, E, F and G with correct equation or calculation.

There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.

0 marks
</td>
<td>6(AO3.1 ×3
AO3.2×3)</td>
<td>
Indicative scientific points may include

<table>
<tr><th></th><th>Formula</th></tr>
<tr><td>B</td><td>$CuCl_4^{2-}$
OR
$[CuCl_4]^{2-}$</td></tr>
<tr><td>C</td><td>$[Cu(H_2O)_6]^{2+}$
OR
$CuSO_4$</td></tr>
<tr><td>D</td><td>SO_2</td></tr>
<tr><td>E</td><td>$Cu(NO_3)_2$
OR
$[Cu(H_2O)_6]^{2+}$</td></tr>
<tr><td>F</td><td>CuI</td></tr>
<tr><td>G</td><td>I_2</td></tr>
</table>

Experiment 1

Equation

$[Cu(H_2O)_6]^{2+} + 4Cl^- \rightarrow [CuCl_4]^{2-} + 6H_2O$
$[Cu(H_2O)_6]^{2+} + 4HCl \rightarrow [CuCl_4]^{2-} + 6H_2O + 4H^+$

Experiment 2

Evidence
$n(D) = \frac{45}{24000} = 1.875 \times 10^{-3}$ Molar mass (D) $= \frac{0.12}{1.875 \times 10^{-3}} = 64$
Equation
$Cu + 2H_2SO_4 \rightarrow CuSO_4 + SO_2 + 2H_2O$

Oxidation numbers
Cu 0 → Cu +2; S +6 → S +4

Experiment 3

Equation

$CuO + 2HNO_3 \rightarrow Cu(NO_3)_2 + H_2O$

$2Cu^{2+} + 4I^- \rightarrow 2CuI + I_2$
OR
$2Cu(NO_3)_2 + 4KI \rightarrow 2CuI + I_2 + 4KNO_3$

Oxidation numbers

Cu +2 → Cu +1; I −1 to 0
</td>
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</table>

			No response or no response worthy of credit.		**Examiner's Comments** Answers were distributed across all 3 levels of achievement. Most of the candidates managed to identify at least some of the substances. Of the equations, the reaction of copper (II) oxide with nitric acid was most regularly seen correct, although many students could also represent the ligand replacement in Experiment 1. Many candidates were able to calculate Mr for gas D but some of those suggesting SO_2 as a possible formula preferred to have an equation in experiment 2 producing hydrogen. A few candidates used the M_r to suggest that the gas was $2O_2$ and as such candidates found the equation between copper and sulphuric acid challenging. A good number of candidates identified F and G, recognising what they had learned from their work on redox titrations, and some were able to reproduce the equation. Incorrect formula of copper (I) iodide (CuI_2) was a common error. Many candidates made no attempt at identifying changes in oxidation states. Candidates are advised to address all parts of the question in order to access the higher levels and to allow sufficient time to attempt the LoR questions.
			Total	**6**	
74			**C**	1(AO1.2)	**Examiner's Comments** This question was quite well answered with many candidates identifying the correct response as C. Candidates had to link the volume of gas with the moles of each gas and then match to the stoichiometry of the equation. Some candidates calculated the moles of gas and then appeared to choose an answer at random.
			Total	**1**	
75			**B**	1(AO2.2)	**Examiner's Comments** This was a challenging question, the correct answer being B. The candidates would be advised to usethe space around the question to perform the calculation. A was a common error as the Al ion was seenas the obvious choice without doing any calculations due to being Al^{3+}.
			Total	**1**	
76			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	
7 7			**B**	1(AO2.2)	<u>**Examiner's Comments**</u> The correct answer B required the candidate to calculate the number of moles of the gas using Avogadro's number. Then link this numerical value to the M_r of the gas so that the formula could be deduced from calculating the M_r of the molecules suggested. Incorrect answers, often if appeared that option C had been guessed as an answer, rather than being arrived at by mistake.
			Total	1	
7 8	a	i	UV **OR** ultraviolet ✓	1 (AO1.1)	**ALLOW** Sunlight **IGNORE** Temperature <u>**Examiner's Comments**</u> Most candidates gave the correct response to this question. Incorrect responses included use of high temperatures and/or catalyst.
		ii	$CH_3CH_2CH_2CH_3 + Br\bullet \rightarrow CH_3CH_2\dot{C}HCH_3 + HBr$ ✓ $CH_3CH_2\dot{C}HCH_3 + Br_2 \rightarrow CH_3CH_2CHBrCH_3 + Br\bullet$ ✓	2 (AO 2.5 × 2)	**ALLOW** Displayed or Skeletal formulae **ALLOW 1 mark** if **BOTH** equations are 'correct' using molecular formulae, i.e. $CH_3CH_2CH_2CH_3 + Br\bullet \rightarrow C_4H_9\bullet + HBr$ $C_4H_9\bullet + Br_2 \rightarrow C_4H_9Br + Br\bullet$ ✓ **IGNORE** position of • within $CH_3CH_2CHCH_3\bullet$ **ALLOW 1 mark** if incorrect structure of intermediate radical is used, e.g. $CH_3CH_2\mathbf{CH_2CH_2}\bullet$ for $CH_3CH_2\mathbf{CHCH_3}\bullet$ ✓ <u>**Examiner's Comments**</u> Candidates always find radical mechanisms tricky and this one had the added complexity of forming 2-bromo isomer. However, a majority of students still gained marks. Many candidates formed the incorrect radical removing H from C-1 i.e. $CH_3CH_2CH_2CH_2\cdot$ therefore scoring only 1 mark.

					Some responses were a little messy making it very easy to miss off a dot or H or Br. Many candidates reacted with Br· in the first step but added Br to the radical intermediate (as well as forming HBr). Candidates should always check equations so that they balance in terms of atoms.
		iii	Further substitution **OR** formation of di/ tri / etc. bromobutanes **OR** produces different termination products **OR** more than one termination step ✓ Formation of 1-bromobutane **OR** (Br) subsitution in a different position ✓	2 (AO 3.2 × 2)	**ALLOW** multisubstitutation, including examples **ALLOW** an example of a different termination product **ALLOW** more than one hydrogen (atom) can be replaced **ALLOW** radicals react with each other to form other products **<u>Examiner's Comments</u>** Candidates found this question very challenging and few scored both marks. Many responses considered only the formation of HBr (other product) and/or general statements about other products with no indication of how they were formed. Some described losses due to the purification method or incomplete reaction (due to conditions such as T and P) or low atom economy. Some referred to the stability of the radical intermediate, showing possible confusion with electrophilic addition. Candidates who understood the mechanism were more confident in answering this question, at least recognising that further substitution was possible.
	b		% atom economy for butane and bromine (5.1) $= \frac{136.9}{217.8} \times 100 = 62.9\%$ ✓ atom economy for but-2-ene and HBr (5.2) is 100% ✓	2 (AO 2.2) (AO1.2)	Calculator: 62.85583104 **ALLOW** calculation for 5.2 **ALLOW** Calculations not expressed as a % i.e. 0.629 and 1. **<u>Examiner's Comments</u>** Despite the question asking for calculations to be included, many candidates didn't include them and so lost both marks. Some gained one mark as recognised that 5.1 has 100% atom economy but either didn't or incorrectly calculated for 5.2 (30% was seen frequently). Care needs to be taken with rounding of final values.

	c	i	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 8.07 g award 3 marks** **CARE: Intermediate rounding may give 8.06 g which is acceptable for 3 marks** --- n(2-bromobutane) $= \frac{10.0}{136.9} = 0.073(0)....$ (mol) ✓ $n(CH_3CH_2CHOHCH_3)$ $= 0.0730.... \times \frac{100}{67.0} = 0.109$ (mol) ✓ mass $CH_3CH_2CHOHCH_3$ = 0.109 × 74.0 = **8.07** g ✓ **3 SF** required	3 (AO 2.4 × 3)	**ALLOW ECF throughout** **IGNORE** trailing zeroes in intermediate working, e.g. 0.073 for 0.0730 **ALLOW** 3 SF or more, correctly rounded Calculator: 0.7304601899 Calculator: 0.1089552239 **ALLOW alternative method mass** • Theoretical mass of 2-bromobutane $= 100 \times \frac{10.0}{67.0} = 14.9.....$ (g) Calculator: 14.925373 • Theoretical $n(CH_3CH_2CHBrCH_3)$ $= \frac{14.923373}{136.9} = 0.1902$ (mol) • Mass of $CH_3CH_2CHOHCH_3$ = 0.109 × 74.0 = **8.07** g ✓ **Common Errors for 2 marks** 5.41 g (no % yield) 3.62 g (inverted yield) **<u>Examiner's Comments</u>** The most common errors were omitting the yield or inverting the yield, as given on mark scheme, resulting in 2 marks. Clear working was vital here to help marks to be given even if the final answer was incorrect. Many candidates did not gain the final mark due to incorrect significant figures. As with other multi-step calculations, rounding of intermediate values could also cause marks to be lost.
		ii	Separating funnel (to separate aqueous and organic layers) ✓ Dry organic layer with anhydrous salt ✓	3 (AO 3.3 × 3)	**ALLOW** Use a drying agent **ALLOW** appropriate example of an anhydrous salt e.g. $MgSO_4$, $CaCl_2$

<table>
<tr><td></td><td></td><td></td><td>Distil and collect fraction at 91°C ✓</td><td></td><td><u>Examiner's Comments</u>

This question was not answered well with over half the candidates failing to score any marks. While some candidates seemed familiar with the techniques required, describing the process to separate the layers, they often struggled to name the separating funnel. Common approaches were to attempt to 'filter' the layers or to use heat (via evaporation or distillation) to drive off the water. Some attempted to use Na_2CO_3 or NaOH to dry the organic layer – perhaps confusing neutralisation of any remaining acid. Although distillation appeared frequently many did not give the temperature so did not gain marks. The order of the procedure was also not always clear with distillation before using a drying agent. Some described attempts to crystallise the organic layer. The range of answers suggests students may need more practical experience with separating organic liquids.</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>13</td><td></td></tr>
<tr><td>79</td><td>a</td><td>i</td><td>
<table>
<tr><th></th><th>Titration 1</th><th>Titration 2</th><th>Titration 3</th></tr>
<tr><td>Final reading/cm³</td><td>27.35</td><td>27.65</td><td>27.85</td></tr>
<tr><td>Initial reading/cm³</td><td>0.05</td><td>0.10</td><td>0.45</td></tr>
<tr><td>Titre/cm³</td><td>27.30</td><td>27.55</td><td>27.40</td></tr>
</table>

Initial and final readings
All titration readings (×6) correct ✓

Titres
Correct subtractions to obtain final titre values ✓

Mean titre calculated from concordant results
Correct mean titre = 27.35 (cm^3) ✓

Reading recorded to accuracy of</td><td>4
(AO 1.2 × 4)</td><td>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC

ALLOW missing zeroes throughout except for last marking point

e.g. 0.1 for 0.10

ALLOW ECF from incorrect burette readings

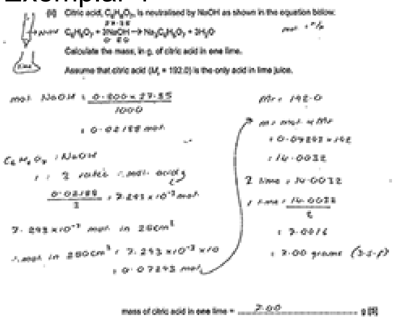
IF MEAN IS CALCULATED FROM ECF, IT MUST BE FROM CLOSEST TITRES
ALLOW any number of decimal places for mean titre for this mark

Note: Question asks for mean titre to nearest 0.05 cm^3

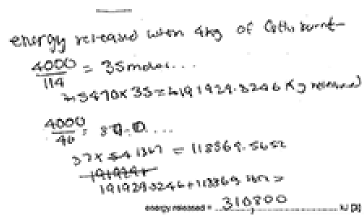
<u>Examiner's Comments</u>

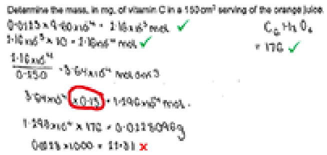
Although most candidates gained some marks here, there were a significant number who did not</td></tr>
</table>

			burette All values including mean titre recorded to **two decimal places** with the last figure either **0 or 5** ✓		gain all 4 marks. Some candidates need to practice reading burettes and recording their values – this can be checked during practical work. The most common errors included not recording values to 2 decimal places (especially if final number was 0), readings recorded the wrong way round in the table, and misreading 0.05 as 0.5. Most candidates were able to identify concordant results, but some still calculated the mean from all values. This led to an average that needed to be rounded to the nearest 0.05, as asked for in the question, resulting in them losing both the mean titre mark and mark for accuracy. Some had errors which lead to values which weren't concordant – this should be a flag to students that they have made a mistake.
		ii	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 7.(00) award 5 marks** **---** *n*(NaOH) $= \frac{27.35 \times 0.800}{1000} = 0.02188$ ✓ *n*(A) in 25.0 cm^3 $= \frac{0.02188}{3} = 0.00729(33)$ ✓ *n*(A) in 250 cm^3 = 10 × 0.00729(33) = 0.0729(33) ✓ mass citric acid in 250 cm^3 = 0.0729 × 192 = 14(.0032) (g) ✓ mass citric acid in one lime $= \frac{14.0}{2} = 7.(00)$ (g) ✓	5 (AO 2.8 ×4) (AO 2.4)	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **--** ALLOW ECF from incorrect titre calculated in 1(b)(i) Throughout: **ALLOW** 3 SF or more, correctly rounded e.g. *n*(NaOH) = 0.0219 for 0.02188 **ALLOW ECF** from incorrect *n*(NaOH) **ALLOW ECF** for all subsequent steps From *n*(NaOH) = 0.0219, *n*(A) = 0.073(0) *mass* citric acid = 14(.016) *mass* in 1 lime = 7(.008) **<u>Examiner's Comments</u>** Most candidates managed to gain at least 1 mark for this question. The most common mark lost was for not multiplying by 10, having missed that only 25cm^3 of 250 cm^3 citric acid solution was used in the titration. Another mark that was often lost was for not dividing by 2 to find mass in 1 lime rather than the 2 used in experiment. Some candidates used 25cm^3 to calculate their moles of NaOH rather than the titre value from (i). It is vital that candidates are given the opportunity to practice more complex multi-step calculations of

					this type, with modelling given for lower-attaining candidates. Identifying which information goes with each reactant is vital. All steps in the calculation should be separate and clearly labelled to help avoid confusion. Encourage candidates to keep full values in their calculators to avoid intermediate step rounding. When writing down intermediate values, ideally write down the full calculator value or where this is not possible the value must be given to at least 3 significant figures (correctly rounded). It is helpful to the examiner to know if calculator values are used and this could be indicated by using truncated answers followed by … , for example 0.00729… for n(A). Exemplar 1  The exemplar shows a response where each step of the calculation is shown clearly. The candidate has also used pictures to aid them, recognising that the NaOH is in the burette and lime juice in the conical flask. All values are identified and there is no intermediate rounding. All 5 marks are given here.
	b		**Action taken to modify method** Use half a lime **OR** Make up lime juice (solution) in 1 dm^3 volumetric flask ✓ **Dilution ratio to justify** 4 times less citric acid/lime juice **OR** NaOH is 4 times more dilute (giving same titre) **OR** 1:4 ratio for NaOH concentration ✓	2 (AO 3.4 × 2)	**ALLOW** any feasible method that would give a dilution factor of 4 **ALLOW** quartered **Examiner's Comments** A very challenging question with very few candidates scoring both marks. The response needed a clear indication of how the method would be altered and a justification for why this would work. Lots of candidates recognised the need to dilute the citric acid to obtain the correct titre but were not able to give a method of how to do this or

					any indication of quantities needed. Some candidates said to use a larger volume of NaOH – not recognising that this would be the titre value, e.g. “in order to keep the same titre but lower concentration of NaOH the student should titre more NaOH”. Some gave the method of how to dilute the NaOH or even just said to add water. A few suggested using a higher concentration of lime juice. Candidates need to be given opportunities to plan practical work to fully appreciate the impact that any changes will have (specification 1.1.1). **OCR support** Further information about practical skills assessed on written exams can be found in section 3 of the practical skills handbook - https:/www.ocr.org.uk/Images/208932-chemistry-practical-skills-handbook.pdf. If using our suggested practicals, then encourage candidates to answer the extension opportunity questions to help develop a deeper understanding in preparation for written assessments.
			Total	**11**	
80		i	$C_8H_{18} + C_2H_5OH + 15½\ O_2 \rightarrow 10\ CO_2 + 12\ H_2O$ ✓	1 (AO2.6)	**ALLOW** multiples e.g. $2\ C_8H_{18} + 2\ C_2H_5OH + 31\ O_2 \rightarrow 20\ CO_2 + 24\ H_2O$ **ALLOW** $C_{10}H_{24}O$ for $C_8H_{18} + C_2H_5OH$ *Combining ethanol and octane!* **<u>Examiner’s Comments</u>** Most candidates attempted to write an equation for the combustion of the 1:1 molar mixture of octane and ethanol. The formulae of C_8H_{18} and C_2H_5OH were usually seen although some candidates combined these as a ‘mixture formula’ of $C_{10}H_{24}O$ (which was accepted). The balancing of the equation using $15½O_2$ was the hardest part of the equation and many different balancing numbers for O2 were seen ($10CO_2$ and $12H_2O$ where usually correct). Less successful responses often attempted a combustion equation using octane OR ethanol, but not both. This is not an easy equation to construct, and the

					context was novel. Overall candidates made a good attempt at this question.
		ii	**FIRST CHECK ANSWER ON THE ANSWER LINE If answer = 341850 to 2 SF or more award 3 marks** -- *M*(C_8H_{18}) = 114 **AND** *M*(C_2H_5OH) = 46 **OR** 1 mol C_8H_{18} + 1 mol C_2H_5OH has mass of 160 g ✓ 50 mol C_8H_{18} **OR** 50 mol C_2H_5OH **OR** 50 mol (C_8H_{18} + C_2H_5OH) **OR** 8.00 kg fuel contains 50 mol C_8H_{18} + 50 mol C_2H_5OH ✓ Energy = (50 × 5470) + (50 × 1367) **OR** 50 × (5470 + 1367) **OR** 50 × 6837 **OR** 273500 + 68350 **=341850(kJ)✓**	3 (3 ×AO2.2)	**IGNORE** sign throughout **ALLOW** approach based on mass for 2nd mark *m*(C_8H_{18}) = (114/160) × 8000 = 5700 g **AND** *m*(C_2H_5OH) = (46/160) × 8000 = 2300 g Energy = 5700/114 × 5470 + 2300/46 × 1367 = 341850 (kJ) **ALLOW 2 SF or more** correctly rounded -- **Common errors** **310800 → 2 marks** *Use of equal masses (4 kg) of C_8H_{18} & C_2H_5OH (rather than equal moles)* **Example**  **Examiner's Comments** This question took the novel context introduced in 5b a stage further by considering the energy released during the combustion of this fuel. Most candidates were able to obtain some credit, and many obtained the correct energy of 341,850 kJ. The commonest error was for candidates to assume that the 8 kg mixture would contain 4 kg of octane and 4 kg of ethanol, rather than an equal moles of each. Such an approach could still be partly given marks by ECF, provided that the method was sound and clear.
			Total	**4**	
8 1			**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 × 2.16 × 10^{-5} = 2.16 × 10^{-4} (mol) ✓ *M*(Vitamin C: $C_6H_8O_6$) = 176 **OR** (12	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 marks** **FINAL MARK LOST BY SCALING**

			× 6) + (1 × 8) + (16 × 6) *Seen anywhere* Mass vitamin C in 150 cm^3 of orange = $2.16 \times 10^{-4} \times 176.0 = 0.038016$ g = 38 (**mg**) ✓ ***2 SF or more***		 **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**	

8 2		i	**FIRST CHECK ANSWER ON THE ANSWER LINE** **If answer = 2.19 χ 10^{-3} award 3 marks** -- ***n*(Cl_2)** = 420/24 = 17.5 (mol) ✓ ***n*($Ca(ClO)_2$)** = $\frac{17.5}{2}$ = 8.75 (mol) ✓ Concentration $Ca(ClO)_2$ $= \frac{8.75}{4 \times 1000}$ = **2.19 χ 10^{-3}** (mol dm^{-3}) ✓ **3SF AND standard form**	3 (3 ×AO2.2)	Use of ideal gas equation for all 3 marks provided 'sensible' *p* and *T* used: e.g. from 101 kPa and 298 K → *n* = 17.122 → 2.14 χ 10^{-3} from 100 kPa and 298 K → *n* = 16.952 → 2.12 χ 10^{-3} Examples of 'sensible' *p* = 100 kPa, 101 kPa, 101,325 Pa *T* = 273 - 298 K **ALLOW ECF** ------------------------------------ **Common errors** 4.38 χ 10^{-3} (no ÷ 2) → 2 marks 2.19 χ 10^{n} → 2 marks 4.38 χ 10^{n} → 1 mark 2.2 χ 10^{-3} → 2 marks *not appropriate SF* __Examiner's Comments__ Most candidates calculated the amounts of Cl_2 and $Ca(ClO)_2$ correctly as 17.5 mol and 8.75 mol respectively. Only the least successful did not use the equation's stoichiometry to halve 17.5 to 8.75. For the final step in the calculation, candidates needed to convert 4.00 m^3 into 4000 dm^3 and to then determine the concentration to an appropriate number of significant figures and standard form. As all the data had been provided to 3 significant figures, the final answer was also required to 3 significant figures, as 2.09 × 10^{-3} mol dm^{-3}. Answers such as 2.2 × 10^{-3}, 2.1875 × 10^{-3} and 2.19 × 10^{-6} and 0.00219 illustrate errors in these areas.
		ii	**Equation** 3 $Ca(ClO)_2$ → 2 $CaCl_2$ + $Ca(ClO_3)_2$ ✓ **Reduction** *Cl* reduced from +1 to -1 ✓ **Oxidation** *Cl* oxidised from +1 to +5 ✓ *+1 starting oxidation number seen once* *Cl required for both explanation marks*	3 (AO2.6) (2 ×AO1.2)	**ALLOW** multiples **ALLOW** 3 ClO^- → 2 Cl^- + ClO_3^- **ALLOW** 1 out of 2 redox marks if oxidation number changes are **BOTH** correct **...BUT** reduction/oxidation is incorrectly assigned, i.e. *Cl* is oxidised from +1 to -1 *Cl* is reduced from +1 to +5 **ALLOW** 1 out of 2 redox marks if oxidation changes correct but red and ox not stated *Cl* **changes** from +1 to -1

			IGNORE oxidation numbers shown below/above equation *(treat as rough working)* **BUT** If **no** oxidation numbers in explanation, *look at equation for oxidation numbers*		C*l* **changes** from +1 to +5 -- **General:** **ALLOW number before sign in ox no, e.g.** 1- for -1 **IGNORE** ionic charges, e.g. Cl^{5+} **IGNORE** '1' (signs required) **IGNORE** references to electron loss/gain (even if wrong) **<u>Examiner's Comments</u>** Candidates were required to write a balanced equation from provided reactants and products and to use oxidation numbers to illustrate disproportionation. In the equation, the reactants and products were sometimes unbalanced, or incorrectly balanced. A common error was to balance the equation after first adding O_2 as an extra reactant. Illustrating disproportionation proved to be easier with the oxidation number changes from the initial +1 being required. Otherwise, more successful responses sometimes missed out on marks if they omitted detail. For example, the oxidation number changes were stated but the candidate omitted to state which change was oxidation and which was reduction. The best responses identified $Ca(ClO_3)_2$ as the oxidation product and $CaCl_2$ as the reduction product. One unexpected error on many scripts was for calcium to be identified as the element undergoing disproportionation, with oxidation number changes from +6 to +14 and +2. It was difficult to see why this happened, with Ca forming +2 compounds, but the error was common.
			Total	**6**	
8 3		i	Cl^- /It/They react with $AgNO_3$ / Ag^+ /silver ions **OR** AgC*l* formed **OR** $Ag^+ + Cl^- \rightarrow AgCl$ ✓	1 (AO3.2)	**IGNORE** chlorine/C*l* for chloride ion **IGNORE** $AgCl_2$ **<u>Examiner's Comments</u>** Almost all candidates realised that Cl^- ions would react with the added $AgNO_3$ at time = t_1.

		ii	$[CoCl_4^{2-}]$ decreases **AND** $[Co(H_2O)_6]^{2+}$ increases ✓ Cl^- increase is 4 × change in $[CoCl_4^{2-}]$ / $[Co(H_2O)_6]^{2+}$ ✓ Equilibrium shifts to right ✓	3 (2 ×AO3.1) (1 ×AO3.2)	**IGNORE** missing charges and small slips in formulae, e.g. $CoCl_4$ missing bracket, etc **IGNORE** Cl^- for changes in concentration **ALLOW** suitable alternatives for 'shifts to right', e.g. towards products **OR** in forward direction **OR** 'favours the right' **<u>Examiner's Comments</u>** In contrast with Question 4 (a), most candidates did interpret the graphical information provided and related this to the reduced concentration of $CoCl_4^{2-}$ ions and the increased concentration of $[Co(H_2O)_6]^{2+}$ ions. Most candidates also referred to Equilibrium 4.1 to conclude that the equilibrium shifts to the right. Only the very best candidates recognised that the increase in Cl^- concentration following the initial addition of $AgNO_3$ was 4 times greater than the increase in the concentration of $Co(H_2O)_6]^{2+}$, arising from the 4 : 1 ratio in the stoichiometry in the equation.
			Total	**4**	