

GCE

Chemistry A

Unit **H032/02**: Depth in Chemistry

Advanced Subsidiary GCE

Mark Scheme for June 2016

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





All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

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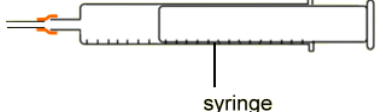
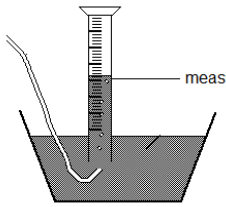
Annotations

Annotation	Meaning
	Correct response
	Incorrect response
	Omission mark
	Benefit of doubt given
	Contradiction
	Rounding error
	Error in number of significant figures
	Error carried forward
	Level 1
	Level 2
	Level 3
	Benefit of doubt not given
	Noted but no credit given
	Ignore

Abbreviations, annotations and conventions.

Annotation	Meaning
/	alternative and acceptable answers for the same marking point
✓	Separates marking points
DO NOT ALLOW	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
()	Words which are not essential to gain credit
—	Underlined words must be present in answer to score a mark
ECF	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

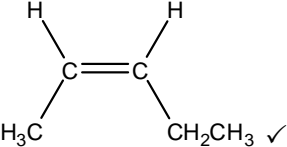
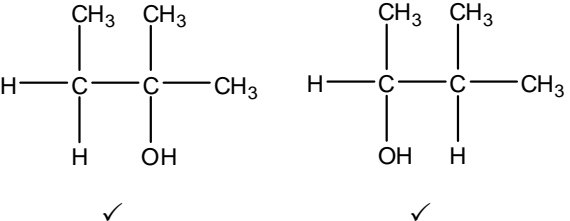
Question			Answer	Marks	AO element	Guidance
1	(a)	(i)	$1s^2 2s^2 2p^6 3s^2$ ✓	1	AO1.1	ALLOW upper case S and P, and subscripts, e.g.2S ₂ 3P ₆
		(ii)	(Mg) loses/transfers/donates two electrons ✓	1	AO1.1	ALLOW Mg loses the 3s electrons provided electronic configuration in (a)(i) is 3s ² ALLOW Mg → Mg ²⁺ + 2e ⁻ IGNORE reference to oxidation numbers / states
	(b)	(i)	$Sr^+(g) \rightarrow Sr^{2+}(g) + e^-$ ✓	1	AO2.5	ALLOW $Sr^+(g) - e^- \rightarrow Sr^{2+}(g)$ ALLOW e for electron (i.e. charge omitted) IGNORE states on the electron
		(ii)	<i>Atomic radius</i> larger atomic radius OR more shells ✓ <i>Effect of nuclear charge/shielding</i> Increased nuclear charge outweighed by increased distance/shielding OR more/increased shielding ✓ <i>Nuclear attraction</i> less nuclear attraction OR less attraction on electrons ✓	3	AO1.2 x3	FULL ANNOTATIONS MUST BE USED ----- ALLOW ORA: comparison needed for each mark. ALLOW 'more/higher energy levels' ALLOW 'electrons further from nucleus' ALLOW 'extra/new shell' IGNORE more orbitals OR more sub-shells OR different shell ALLOW more electron repulsion from inner shells IGNORE responses with no comparison IGNORE nuclear charge/effective nuclear charge ALLOW 'less nuclear pull' OR 'electrons held less tightly'

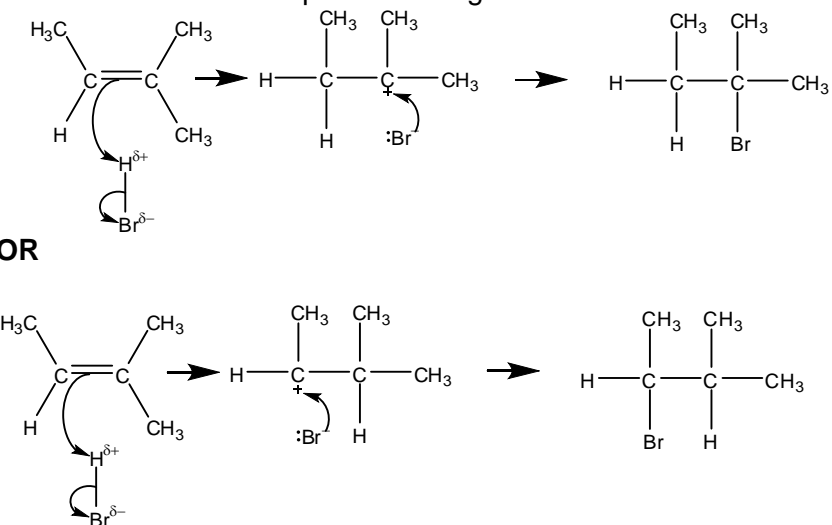
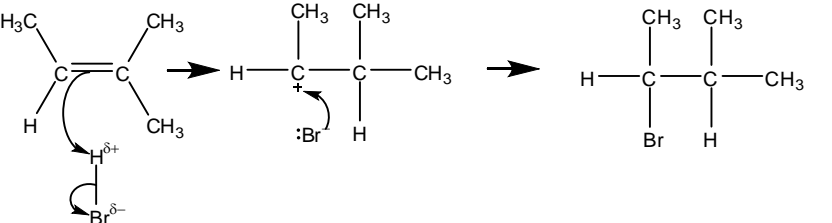
Question	Answer	Marks	AO element	Guidance
(c) (i)	<p>Diagram of labelled reaction vessel for reaction ✓</p> <p>Labelled (gas) syringe OR diagram of gas collection over water in a labelled measuring cylinder / inverted burette. AND closed system with a tube connecting reaction vessel to gas collection apparatus ✓</p>	1	AO3.3 x 2	<p>ALLOW (conical) flask, test-tube or boiling tube.</p> <p>DO NOT ALLOW volumetric flask, beaker, measuring cylinder</p> <p>DO NOT ALLOW delivery tube below reacting solution</p> <p>ALLOW any of these diagrams.</p>  <p>ALLOW a single line for the tube IGNORE Sealed end of delivery tube</p>  <p style="text-align: center;">syringe</p>  <p style="text-align: center;">measuring cylinder</p> <p>DO NOT ALLOW measuring tube</p>

Question	Answer	Marks	AO element	Guidance
(ii)	<p>FIRST CHECK CALCULATED VALUE FOR MOLAR / ATOMIC MASS OF CALCIUM IF answer = 40.1 OR 40.08 is seen anywhere award first two marks</p> <p>$n(\text{H}_2)$ OR $n(\text{Group 2 metal})$ $= \frac{97.0}{24\,000} = 4.04 \times 10^{-3} \text{ (mol)}$ ✓</p> <p>molar mass/atomic mass of Group 2 metal $= \frac{0.162}{0.00404} = 40.1 \text{ (g mol}^{-1}\text{)}$ ✓</p> <p>Group 2 metal: calcium/Ca ✓</p>	<p>1</p> <p>1</p> <p>1</p>	<p>AO2.8</p> <p>AO2.8</p> <p>AO3.2</p>	<p>DO NOT ALLOW $pV = nRT$ for the calculation of the amount in moles for marking point 1.</p> <p>ALLOW 3 SF up to calculator value correctly rounded (0.004041666)</p> <p>ALLOW 3 SF up to calculator value correctly rounded (40.08247423)</p> <p>ALLOW ECF from incorrectly calculated amount in moles</p> <p>DO NOT ALLOW Calcium if no working</p> <p>ALLOW ECF as element in Group 2 closest to the value calculated</p>
(d)	<p>Less (volume/products) AND Smaller amount/fewer moles/fewer atoms of the metal OR element reacting ✓</p>	1	AO3.2	<p>IGNORE higher relative atomic mass/molar mass</p> <p>ALLOW a calculation showing that moles and volume are less</p> <p>$n(\text{H}_2) = 0.162/87.6 = 0.0018493156$ Volume = $0.0018493156 \times 24000 = 44(.4) \text{ cm}^3$</p>
	Total	12		

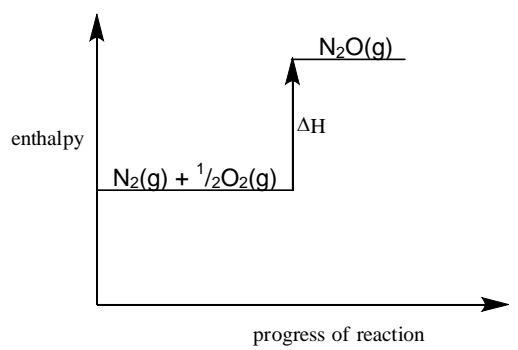
Question		Answer	Marks	AO element	Guidance
2	(a)	Phosphorus has more electrons ✓	1	AO1.1 × 2	ALLOW ORA but comparison should be used for the all marks DO NOT ALLOW Phosphorus has more electrons in the outer shell or larger electron cloud.
		Stronger London forces OR Stronger induced dipole(-dipole) interactions ✓	1		IGNORE Phosphorus molecules are bigger or have greater M_r . ALLOW 'more' for 'stronger' ALLOW stronger van der Waals'/vdW forces
		More energy required to break the intermolecular forces/bonds OR London forces ✓	1	AO2.1	DO NOT ALLOW attraction between atoms-or that covalent bonds are broken
(b)		Magnesium metallic (bonds)✓	1	AO1.1 × 4	ALLOW the (electrostatic) attraction between cations/positive ions and delocalised electrons for both Mg marks ✓ ✓
		cations/positive ions/Mg ²⁺ AND delocalised electrons ✓	1		
		Silicon covalent ✓	1		DO NOT ALLOW molecules for second mark IGNORE 'sea of electrons' ALLOW the attraction between a shared pair of electrons and the nuclei of the (bonded) atoms for both marks ✓ ✓
		between atoms ✓	1		
(c)		$\text{Al}_2\text{S}_3 + 6\text{H}_2\text{O} \rightarrow 2\text{Al}(\text{OH})_3 + 3\text{H}_2\text{S}$ ✓	1	AO2.5	IGNORE state symbols ALLOW correct multiples
Total			8		

Question			Answer	Marks	AO element	Guidance
3	(a)	(i)	<p>Any one from:</p> <ul style="list-style-type: none"> • σ bond is between bonding atoms/nuclei AND π bond is above and below the bonding atoms/nuclei • σ bond has direct/head-on overlap of orbitals AND π bond has sideways overlap • π bond has a lower bond enthalpy / is weaker than a σ bond • σ bond has electron density between bonding atoms AND π bond has electron density above and below bonding atoms ✓ 	1	AO1.1	<p>IGNORE the length of the σ bond and π bond</p> <p>IGNORE the type of orbital for σ bond</p>
		(ii)	<p>One carbon atom (in double bond) is attached to two groups which are identical/the same ✓</p>	1	AO1.1	<p>ALLOW</p> <ul style="list-style-type: none"> • One carbon atom in (double bond) is not attached to (two) different groups / groups of atoms • Right-hand carbon is attached to two groups that are the same/two methyl groups. • Two groups are the same on right-hand side • Three groups are the same (on the double bond) <p>DO NOT ALLOW</p> <ul style="list-style-type: none"> • Two groups on the same side of the double bond <i>Must be right-hand side; Same side could be top or bottom</i>) • Functional groups OR molecules for groups

Question	Answer	Marks	AO element	Guidance
(iii)	 <p>(Z-)pent-2-ene ✓</p>	1	AO2.1	<p>Mark Independently</p> <p>ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous</p> <p>ALLOW C₂H₅ for CH₂CH₃</p> <p>IGNORE connectivity of alkyl groups BUTDO NOT ALLOW -CH₃CH₂</p> <p>DO NOT ALLOW trans-pent-2-ene</p>
(b)	 <p>✓</p> <p>✓</p>	2	AO3.1 × 2	<p>ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous</p> <p>ALLOW any vertical bond to OH,</p> <p>e.g. ALLOW $\begin{array}{c} \text{OH} \\ \end{array}$ OR $\begin{array}{c} \text{OH} \\ \end{array}$</p> <p>DO NOT ALLOW OH-</p>

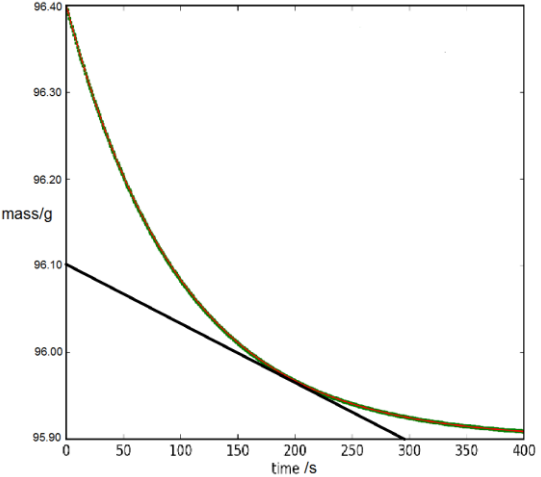
Question	Answer	Marks	AO element	Guidance
(c)	<p><i>Please refer to marking instructions on page 4 of mark scheme for guidance on how to mark this question.</i></p> <p>Level 3 (5–6 marks) A comprehensive description with all three scientific points explained thoroughly.</p> <p><i>There is a well-developed and detailed description of the mechanism, including correct structures, accurately drawn curly arrows and using charges and dipoles consistently. Candidates compare tertiary and secondary carbocation stability to justify major product.</i></p> <p>Level 2 (3–4 marks) Attempts to describe all three scientific points but explanations may be incomplete. OR Explains two scientific points thoroughly with no omissions. <i>The description has some structures with reasonably accurate curly arrows and some charges and dipoles identified.</i></p> <p>Level 1 (1–2 marks) A simple description based on at least two of the main scientific points OR Explains one scientific point thoroughly with few omissions.</p> <p><i>The description is communicated in an unstructured way, including some use of curly arrows, charges or dipoles.</i></p>	6	<p>AO1.2 × 2</p> <p>AO2.5 × 2</p>	<p>Throughout: ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above if unambiguous</p> <p>Indicative scientific points</p> <p><u>1. Two possible products of reaction</u></p> <p>CH₃C(CH₃)BrCH₂CH₃ CH₃CHBrCH(CH₃)CH₃ IGNORE names where correct structures are present</p> <p><u>2. Mechanism for formation of either product.</u></p> <p>Curly arrow from C=C to attack the H atom of the HBr Correct dipole on H–Br Curly arrow from H–Br bond to Br Carbocation with full positive charge on carbon atom Curly arrow from negative charge on Br[–] or lone pair on Br to carbon atom with positive charge</p>  <p>OR</p> 

Question	Answer	Marks	AO element	Guidance
	<p>0 marks No response worthy of credit.</p>		<p>AO3.1 AO3.2</p>	<p>3. Major organic product</p> <p>Major product: 2-bromo-2-methylbutane</p> $ \begin{array}{c} \text{CH}_3 \quad \text{CH}_3 \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{CH}_3 \\ \quad \\ \text{H} \quad \text{Br} \end{array} $ <ul style="list-style-type: none"> Major product is formed from the most stable carbocation intermediate OR -Br is attached to carbon atom with the least hydrogens attached OR the carbon with the most -CH₃ groups attached OR the -H is attached to the carbon atom with most hydrogens attached
	Total	12		

Question			Answer	Marks	AO element	Guidance
4	(a)	(i)	More energy is required for bond breaking than is released by bond making ✓	1	AO2.1	
		(ii)	Enthalpy profile diagram <ul style="list-style-type: none"> • ΔH labelled OR 82 on vertical arrow • Products above reactants (either chemical symbols or the words products and reactants) • Arrow upwards ✓ Formulae AND state symbols $\text{N}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{N}_2\text{O}(\text{g}) \quad \checkmark$	2	AO1.2 AO2.5	 <p>IGNORE activation energy</p> <p>DO NOT ALLOW multiples of equation: 1 mole of N₂O is formed</p>

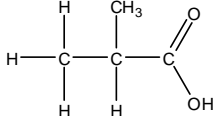
Question	Answer	Marks	AO element	Guidance
(b)	<p>FIRST CHECK ANSWER ON THE ANSWER LINE IF answer = 4.46×10^6 (Pa) award 4 marks</p> <p>Amount of N₂O</p> $n(\text{N}_2\text{O}) = \frac{187}{44} \text{ OR } 4.25 \text{ (mol)} \quad \checkmark$ <p>Unit conversion</p> <p>Volume conversion to $\text{m}^3 = 2.32 \times 10^{-3} \text{ (m}^3\text{)} \quad \checkmark$</p> <p>Ideal gas equation / temperature conversion</p> $p = \frac{nRT}{V} \text{ OR } p = \frac{4.25 \times 8.314 \times 293}{2.32 \times 10^{-3}}$ <p>AND Use of $T = 293 \text{ K} \quad \checkmark$</p> <p>Final answer</p> $p = 4.46 \times 10^6 \text{ (Pa)} \quad \checkmark$ <p><i>Must be calculated in standard form AND to 3 SF</i></p>	<p>1</p> <p>1</p> <p>1</p> <p>1</p>	<p>AO2.2 × 2</p> <p>AO2.6 × 2</p>	<p>If there is an alternative answer, check to see if there is any ECF credit possible</p> <p>ALLOW ECF from incorrect amount of N₂O e.g. use of incorrect M_r for N₂O could still score 3 marks</p> <p>-----</p> <p>Common Errors (3 marks)</p> <p><i>No temperature conversion</i></p> $p = \frac{4.25 \times 8.314 \times 20}{2.32 \times 10^{-3}} = 3.05 \times 10^5$ <p><i>Incorrect volume conversion</i></p> $p = \frac{4.25 \times 8.314 \times 293}{2.32 \times 10^{-6}} = 4.46 \times 10^9$ <p><i>No volume conversion</i></p> $p = \frac{4.25 \times 8.314 \times 293}{2.32} = 4.46 \times 10^3$ <p><i>No standard form = 4460000</i></p>
(c)	<p>Propagation step 1 $\text{NO}\cdot + \text{O}_3 \rightarrow \text{NO}_2\cdot + \text{O}_2 \quad \checkmark$</p> <p>Propagation step 2 $\text{NO}_2\cdot + \text{O} \rightarrow \text{NO}\cdot + \text{O}_2 \quad \checkmark$</p>	<p>1</p> <p>1</p>	<p>AO1.2 × 2</p>	<p>ALLOW one mark for both correct symbol equations with (any or all) dots missing or extra dots</p> <p>e.g. $\text{NO} + \text{O}_3 \rightarrow \text{NO}_2\cdot + \text{O}_2$ $\text{NO}_2 + \text{O} \rightarrow \text{NO} + \text{O}_2\cdot$</p>
	Total	9		

Question			Answer	Marks	AO element	Guidance
5	(a)	(i)	carbon dioxide lost/evolved/given off/or produced as a gas ✓	1	AO3.1	DO NOT ALLOW water or steam or CO ₂ evaporates
		(ii)	<p>FIRST CHECK ANSWER ON THE ANSWER LINE IF answer = 1.85 OR 1.845 g award 3 marks</p> <p>-----</p> $n(\text{HNO}_3)$ $= 1.25 \times \frac{20.0}{1000} = 0.0250 \text{ mol } \checkmark$ $n(\text{SrCO}_3)$ $= \frac{0.0250}{2} = 0.0125 \text{ mol } \checkmark$ $m(\text{SrCO}_3)$ $= 0.0125 \times 147.6 = 1.845 \text{ g OR } 1.85 \text{ g } \checkmark$	3	AO2.8 × 3	<p>If there is an alternative answer, check to see if there is any ECF credit possible</p> <p>ALLOW ECF from incorrect $n(\text{HNO}_3)$</p> <p>molar mass of SrCO₃ = 147.6 (g mol⁻¹) ALLOW ECF from incorrect $n(\text{SrCO}_3)$</p>
	(b)	(i)	<p>rate of reaction decreases AND concentration decreases/reactants are used up ✓</p> <p>less frequent collisions ✓</p>	1 1	AO2.7 AO2.3	<p>ALLOW reaction slows down</p> <p>ALLOW concentration of reactants decreases.</p> <p>ALLOW fewer collisions per unit time OR collisions less often OR decreased rate of collision</p> <p>IGNORE less successful collisions/ less collisions less chance of collisions</p>

Question	Answer	Marks	AO element	Guidance
(ii)	<p>Attempted tangent on graph drawn to line at approximately $t = 200$ s ✓</p> <p>Gradient (y/x) e.g. $\frac{0.20}{290} = 6.9 \times 10^{-4}$ ✓</p> 	<p>1</p> <p>1</p>	<p>AO3.1</p> <p>AO3.2</p>	<p>ALLOW 1 SF up to calculator value, in range 5×10^{-4} to 8×10^{-4}</p> <p>IGNORE units IGNORE sign</p>
(c)	<p>Flask OR beaker AND balance AND stopwatch OR stop clock OR other timing device ✓</p> <p>Records mass at time intervals ✓</p> <p>Time interval quoted between 10-50s ✓</p>	<p>1</p> <p>1</p> <p>1</p>	<p>AO3.3 × 2</p>	<p>DO NOT ALLOW round-bottomed flask.</p> <p>IGNORE weighing scales</p> <p>ALLOW 'weigh at time intervals'</p>
	Total	11		

Question		Answer	Marks	AO element	Guidance
6	(a)	The –OH group is attached to a carbon that is attached to one hydrogen atom OR The –OH group is attached to a carbon that is attached to two C atoms/ alkyl groups/R groups ✓	1	AO1.1	ALLOW alcohol/ hydroxyl/functional group for –OH
	(b)	104.5° ✓ (oxygen atom) has two bond pairs and two lone pairs ✓ Bonded pairs/lone pairs/electron pairs repel ✓ Lone pairs repel more than bonding pairs ✓ NOTE: ‘Lone pairs repel more than bonding pairs’ would gain the last two marking points	1 1 1	AO1.1 AO1.1 AO2.1 AO2.1	ALLOW 104–105 ALLOW lp and bp ALLOW bonding regions for bond pairs IGNORE bonds repel / electrons repel DO NOT ALLOW atoms repel ALLOW alternative phrases/words to repel e.g. ‘push apart’
	(c) (i)	Equation $\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{CH}_3 + [\text{O}] \rightarrow \text{CH}_3\text{COCH}_2\text{CH}_3 + \text{H}_2\text{O}$ ✓ Structure of product could be allowed from equation $\text{CH}_3\text{COCH}_2\text{CH}_3$ ✓	2	AO2.7 × 2	ALLOW molecular formulae: $\text{C}_4\text{H}_{10}\text{O}$ and $\text{C}_4\text{H}_8\text{O}$ ALLOW $\text{C}_4\text{H}_9\text{OH}$ ALLOW C_2H_5 for CH_3CH_2 ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous
	(ii)	Butan-2-ol/butanone is flammable OR Butan-2-ol/butanone is volatile/low boiling point OR Butan-2-ol /butanone will evaporate/boil away ✓ (Heat under) reflux OR a description of reflux with vertical condenser and a round bottomed or pear shaped flask with source of heat. ✓	1 1	AO3.4 × 2	IGNORE vague answers about health and safety ALLOW alcohol for butan-2-ol ALLOW ketone for butanone DO NOT ALLOW the product or reactant. DO NOT ALLOW distillation DO NOT ALLOW any reference to closed system.

Question	Answer	Marks	AO element	Guidance
(d)	<p>FIRST CHECK ANSWER ON THE ANSWER LINE IF answer = 67.4% award all 3 marks for calculation</p> <p>$n(\text{butan-2-ol}) (m/M)$ $= 20.2/74$ OR $= 0.273 \text{ mol } \checkmark$</p> <p>$n(2\text{-bromobutane } (m/M)$ $= 25.2/136.9$ OR $= 0.184 \text{ mol } \checkmark$</p> <p>% yield $= (0.184/0.273) \times 100 = 67.4\% \checkmark$</p>	<p>1</p> <p>1</p> <p>1</p>	<p>AO1.1</p> <p>AO2.4</p> <p>AO2.4</p>	<p>If there is an alternative answer, check to see if there is any ECF credit possible</p> <p>ALLOW 3 SF: 0.273 up to calculator value of 0.272972973 correctly rounded</p> <p>ALLOW 3 SF: 0.184 up to calculator value of 0.184075967 correctly rounded ALLOW $(25.2/137) = 0.183941605$</p> <p>ALLOW 67% if evidence shows 67.4% in answer</p> <p>ALLOW 67.4% up to calculator value correctly rounded.</p> <p>Common ECFs (2 marks) Incorrect M_r resulting in incorrect moles of butan-2-ol or 2-bromobutane</p> <p>ALLOW calculation in mass for 2nd and 3rd marks $m(\text{CH}_3\text{CHBrCH}_2\text{CH}_3) = 0.273 \times 136.9 = 37.4 \text{ g}$</p> <p>% yield = $(25.2/37.4) \times 100 = 67.4\%$</p>
	Total	12		

Question	Answer	Marks	AO element	Guidance																				
7	<p><i>Please refer to marking instructions on page 4 of mark scheme for guidance on how to mark this question.</i></p> <p>Level 3 (5–6 marks) A comprehensive description with all three scientific points explained thoroughly. C identified as a carboxylic acid containing four carbon atoms linked to the peak in the mass spectrum at 43.</p> <p><i>The explanation makes use of all the evidence including the secondary carbocation in justifying the correct structure of C.</i></p> <p>Level 2 (3–4 marks) Attempts all three scientific points but explanations may be incomplete. OR Explains two scientific points thoroughly with few omissions.</p> <p><i>The analysis is clear and includes some interpretation of IR and MS peaks.</i></p> <p>Level 1 (1–2 marks) A simple explanation based on at least two of the main scientific points. OR Explains one scientific point thoroughly with few errors.</p> <p><i>The analysis is communicated in an unstructured way and includes interpretation of peaks from IR OR MS spectrum</i></p> <p>0 marks – No response worthy of credit.</p>	6	<p>AO3.1 × 2</p> <p>AO3.1 × 2</p> <p>AO3.2 × 2</p>	<p>LOOK ON THE SPECTRA for labelled peaks. Indicative scientific points may include:</p> <p>1. Molecular formula</p> <table border="1" data-bbox="1379 403 2047 509"> <thead> <tr> <th>Element</th> <th>% mass</th> <th>Ar</th> <th>moles</th> <th>ratio</th> </tr> </thead> <tbody> <tr> <td>C</td> <td>54.5</td> <td>12</td> <td>4.54</td> <td>2</td> </tr> <tr> <td>H</td> <td>9.1</td> <td>1</td> <td>9.1</td> <td>4</td> </tr> <tr> <td>O</td> <td>36.4</td> <td>16</td> <td>2.28</td> <td>1</td> </tr> </tbody> </table> <ul style="list-style-type: none"> empirical formula = C₂H₄O molecular ion peak <i>m/z</i> or Mr = 88 molecular formula = C₄H₈O₂ <p>2. Infrared spectrum</p> <ul style="list-style-type: none"> peak at 2500–3500 (cm⁻¹) is O–H peak at 1630–1820 (cm⁻¹) is C=O C is a carboxylic acid <p>ALLOW stated values within the ranges above IGNORE references to C–O peaks</p> <p>3. Identifying the carboxylic acid</p> <ul style="list-style-type: none"> (CH₃CH₂CH₂COOH OR (CH₃)₂CHCOOH) Mass spectrum peak at <i>m/z</i> = 43 = C₃H₇(⁺) secondary carbocation: CH₃C⁺HCH₃ compound C: (CH₃)₂CHCOOH  <p>IGNORE name of carboxylic acid if structure given</p>	Element	% mass	Ar	moles	ratio	C	54.5	12	4.54	2	H	9.1	1	9.1	4	O	36.4	16	2.28	1
Element	% mass	Ar	moles	ratio																				
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