OCR
Oxford Cambridge and RSA

GCE

Chemistry A

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

Advanced Subsidiary GCE

Mark Scheme for June 2016

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This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

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.

OCR will not enter into any discussion or correspondence in connection with this mark scheme.

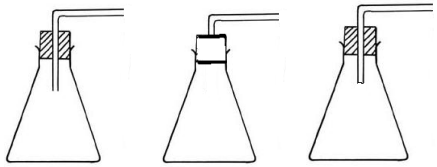
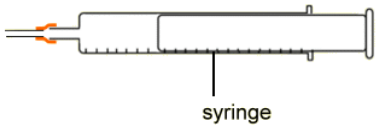
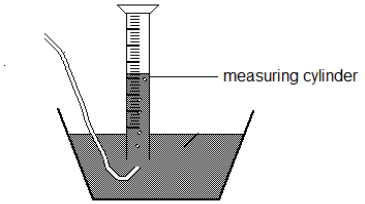
Annotations

Annotation	Meaning
	Correct response
	Incorrect response
	Omission mark
BOD	Benefit of doubt given
CON	Contradiction
RE	Rounding error
SF	Error in number of significant figures
ECF	Error carried forward
L1	Level 1
L2	Level 2
L3	Level 3
NBOD	Benefit of doubt not given
SEEN	Noted but no credit given
I	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

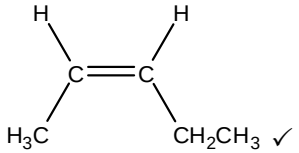
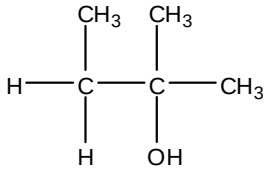
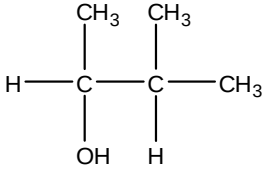
Question			Answer	Marks	AO element	Guidance
1	(a)	(i)	$1s^2 2s^2 2p^6 3s^2$ ✓	1	AO1.1	**ALLOW** upper case S and P, and subscripts, e.g. ……$2S_2 3P_6$
		(ii)	(Mg) loses/transfers/donates **two** electrons ✓	1	AO1.1	**ALLOW** Mg loses the 3s electrons provided electronic configuration in **(a)(i)** is 3_s^2 **ALLOW** $Mg \rightarrow Mg^{2+} + 2e^-$ **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)	*Atomic radius* larger atomic radius **OR** more shells ✓ *Effect of nuclear charge/shielding* Increased nuclear charge outweighed by increased distance/shielding **OR** **more/increased** shielding ✓ *Nuclear attraction* less nuclear attraction **OR** less attraction on electrons ✓	3	AO1.2 ×3	**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'

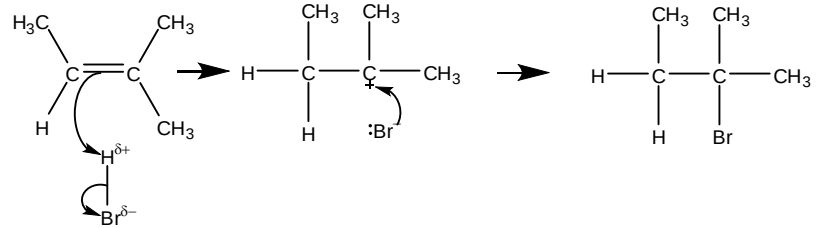
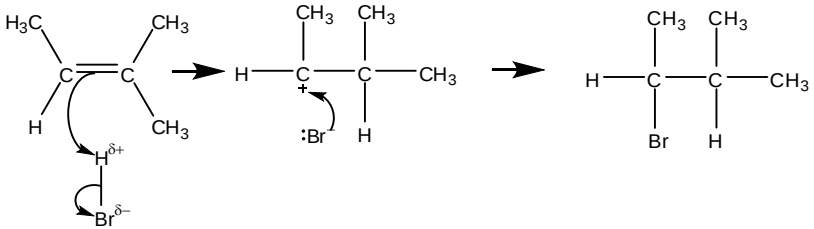
Question			Answer	Marks	AO element	Guidance
	(c)	(i)	Diagram of **labelled** reaction vessel for reaction ✓	**1**	AO3.3 × 2	**ALLOW** (conical) flask, test-tube or boiling tube. **DO NOT ALLOW** volumetric flask, beaker, measuring cylinder **DO NOT ALLOW** delivery tube below reacting solution **ALLOW** any of these diagrams.  **ALLOW** a single line for the tube **IGNORE** Sealed end of delivery tube
			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 ✓	**1**		  **DO NOT ALLOW** measuring tube

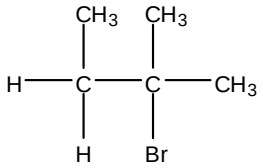
Question			Answer	Marks	AO element	Guidance
		(ii)	**FIRST CHECK CALCULATED VALUE FOR MOLAR / ATOMIC MASS OF CALCIUM** **IF answer = 40.1 OR 40.08 is seen anywhere award first two marks**			**DO NOT ALLOW** $pV = nRT$ for the calculation of the amount in moles for marking point 1.
			$n(H_2)$ **OR** n(Group 2 metal) $= \frac{97.0}{24\,000} = 4.04 \times 10^{-3}$ (mol) ✓	**1**	AO2.8	**ALLOW** 3 SF up to calculator value correctly rounded (0.004041666)
			molar mass/atomic mass of Group 2 metal $= \frac{0.162}{0.00404} = 40.1$ (g mol^{-1}) ✓	**1**	AO2.8	**ALLOW** 3 SF up to calculator value correctly rounded (40.08247423) **ALLOW ECF** from incorrectly calculated amount in moles
			Group 2 metal: calcium/Ca ✓	**1**	AO3.2	**DO NOT ALLOW** Calcium if no working **ALLOW ECF** as element in Group 2 closest to the value calculated
	(d)		Less (volume/products) **AND** Smaller amount/fewer moles/fewer atoms of the **metal OR** element reacting✓	**1**	AO3.2	**IGNORE** higher relative atomic mass/molar mass **ALLOW** a calculation **showing** that moles and volume are less $n(H_2) = 0.162/87.6 = 0.0018493156$ Volume = 0.0018493156 × 24000 = 44(.4) cm^3
			Total	**12**		

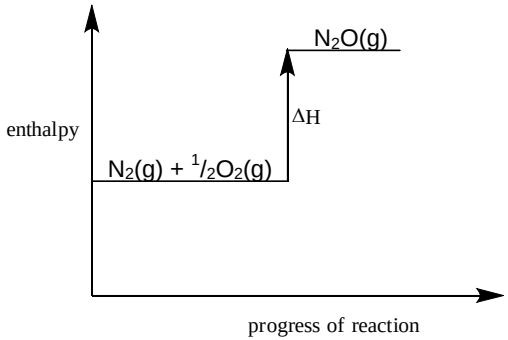
Question			Answer	Marks	AO element	Guidance
2	(a)		Phosphorus has more electrons ✓	1	AO1.1 × 2	**ALLOW ORA** but comparison should be used for the all marks **DO NOT ALLOW** Phosphorus has more electrons in the outer shell or larger electron cloud. **IGNORE** Phosphorus molecules are bigger or have greater M_r.
			Stronger London forces **OR** Stronger induced dipole(-dipole) interactions ✓	1		**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		**DO NOT ALLOW** molecules for second mark **IGNORE** 'sea of electrons'
			Silicon covalent ✓	1		**ALLOW** the attraction between a shared pair of electrons and the nuclei of the (bonded) atoms for both marks ✓ ✓
			between atoms ✓	1		**DO NOT ALLOW** any intermolecular forces in marking points 2 and 4 or silicon molecules
	(c)		$Al_2S_3 + 6H_2O \rightarrow 2Al(OH)_3 + 3H_2S$ ✓	1	AO2.5	**IGNORE** state symbols **ALLOW** correct multiples
			Total	8		

Question			Answer	Marks	AO element	Guidance
3	(a)	(i)	Any **one** from: • 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	**IGNORE** the length of the σ bond and π bond **IGNORE** the type of orbital for σ bond
		(ii)	One carbon atom (in double bond) is attached to two groups which are identical/the same ✓	**1**	AO1.1	**ALLOW** • 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) **DO NOT ALLOW** • Two groups on the same side of the double bond *Must be right-hand side; Same side could be top or bottom)* • Functional groups **OR** molecules for groups

Question			Answer	Marks	AO element	Guidance
		(iii)	 ✓	1	AO2.1	**Mark Independently** **ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous **ALLOW** C_2H_5 for CH_2CH_3 **IGNORE** connectivity of alkyl groups **BUT** **…….DO NOT ALLOW** $–CH_3CH_2$
			(Z-)pent-2-ene ✓	1	AO2.5	**DO NOT ALLOW** trans-pent-2-ene
	(b)		 ✓  ✓	2	AO3.1 × 2	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous **ALLOW any** vertical bond to OH, e.g. **ALLOW** OH **OR** OH **DO NOT ALLOW** OH–

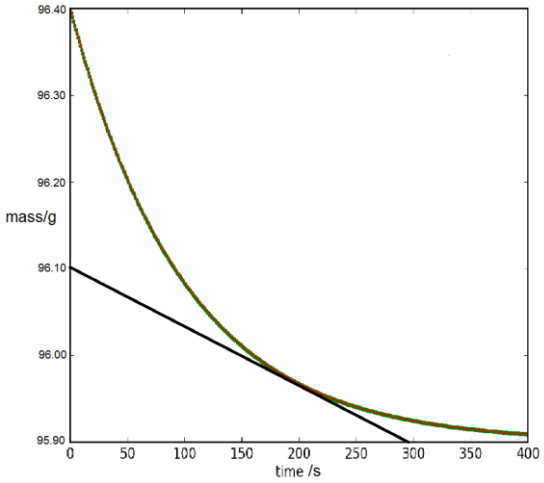
Question	Answer	Marks	AO element	Guidance
(c)	*Please refer to marking instructions on page 4 of mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** A comprehensive description with all three scientific points explained thoroughly. *There is a well-developed and detailed description 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.* **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. *The description has some structures with reasonably accurate curly arrows and some charges and dipoles identified.* **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. *The description is communicated in an unstructured way, including some use of curly arrows, charges or dipoles.*	**6**	AO1.2 × 2 AO2.5 × 2	Throughout: **ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above if unambiguous **Indicative scientific points** **<u>1. Two possible products of reaction</u>** $CH_3C(CH_3)BrCH_2CH_3$ $CH_3CHBrCH(CH_3)CH_3$ **IGNORE** names where correct structures are present **<u>2. Mechanism for formation of either product.</u>** 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  **OR** 

Question			Answer	Marks	AO element	Guidance
			0 marks No response worthy of credit.		AO3.1 AO3.2	**3. Major organic product** Major product: 2-bromo-2-methylbutane  • 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 $–CH_3$ 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 • ΔH labelled **OR** 82 on vertical arrow • Products above reactants (either chemical symbols or the words products and reactants) • Arrow upwards ✓	2	AO1.2	 **IGNORE** activation energy
			Formulae **AND** state symbols $N_2(g) + {}^1/_2O_2(g) \rightarrow N_2O(g)$ ✓		AO2.5	**DO NOT ALLOW** multiples of equation: 1 mole of N_2O is formed

Question	Answer	Marks	AO element	Guidance
(b)	**FIRST CHECK ANSWER ON THE ANSWER LINE** **IF answer = 4.46 × 10^6 (Pa) award 4 marks** **Amount of N_2O** $n(N_2O) = \frac{187}{44}$ **OR** 4.25 (mol) ✓ **Unit conversion** Volume conversion to m^3 = 2.32 × 10^{-3} (m^3) ✓ **Ideal gas equation / temperature conversion** $p = \frac{nRT}{V}$ **OR** $p = \frac{4.25 \times 8.314 \times 293}{2.32 \times 10^{-3}}$ **AND** Use of T = 293 K ✓ **Final answer** p = 4.46 × 10^6 (Pa) ✓ *Must be calculated in standard form **AND** to 3 SF*	**1** **1** **1** **1**	AO2.2 × 2 AO2.6 × 2	**If there is an alternative answer, check to see if there is any ECF credit possible** **ALLOW ECF** from incorrect amount of N_2O e.g. use of incorrect M_r for N_2O could still score 3 marks --- **Common Errors (3 marks)** *No temperature conversion* $p = \frac{4.25 \times 8.314 \times 20}{2.32 \times 10^{-3}} = 3.05 \times 10^5$ *Incorrect volume conversion* $p = \frac{4.25 \times 8.314 \times 293}{2.32 \times 10^{-6}} = 4.46 \times 10^9$ *No volume conversion* $p = \frac{4.25 \times 8.314 \times 293}{2.32} = 4.46 \times 10^3$ *No standard form* = 4460000
(c)	Propagation step 1 $NO^{\bullet} + O_3 \rightarrow NO_2^{\bullet} + O_2$ ✓ Propagation step 2 $NO_2^{\bullet} + O \rightarrow NO^{\bullet} + O_2$ ✓	**1** **1**	AO1.2 × 2	**ALLOW** one mark for both correct symbol equations with (any or all) dots missing or extra dots e.g. $NO + O_3 \rightarrow NO_2^{\bullet} + O_2$ $NO_2 + O \rightarrow NO + O_2^{\bullet}$
	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)	**FIRST CHECK ANSWER ON THE ANSWER LINE** **IF answer = 1.85 OR 1.845 g award 3 marks** --- $n(HNO_3)$ $= 1.25 \times \frac{20.0}{1000} = 0.0250$ mol ✓ $n(SrCO_3)$ $= \frac{0.0250}{2} = 0.0125$ mol ✓ $m(SrCO_3)$ $= 0.0125 \times 147.6 = 1.845$ g **OR** 1.85 g ✓	3	AO2.8 × 3	**If there is an alternative answer, check to see if there is any ECF credit possible** **ALLOW ECF** from incorrect $n(HNO_3)$ molar mass of $SrCO_3 = 147.6$ (g mol^{-1}) **ALLOW ECF** from incorrect $n(SrCO_3)$
	(b)	(i)	rate of reaction decreases **AND** concentration decreases/reactants are used up ✓	1	AO2.7	**ALLOW** reaction slows down **ALLOW** concentration of reactants decreases.
			less frequent collisions ✓	1	AO2.3	**ALLOW** fewer collisions per unit time **OR** collisions less often **OR** decreased rate of collision **IGNORE** less successful collisions/ less collisions less chance of collisions

Question			Answer	Marks	AO element	Guidance
		(ii)	Attempted tangent on graph drawn to line at approximately t = 200 s ✓ Gradient (y/x) e.g. $\frac{0.20}{290}$ = 6.9×10^{-4} ✓  	**1** **1**	AO3.1 AO3.2	**ALLOW** 1 SF up to calculator value, in range 5×10^{-4} to 8×10^{-4} **IGNORE** units **IGNORE** sign
	(c)		Flask **OR** beaker **AND** balance **AND** stopwatch **OR** stop clock **OR** other timing device ✓ Records **mass** at time intervals ✓ Time interval quoted between 10-50s ✓	 **1** **1** **1**	 AO3.3 × 2	**DO NOT ALLOW** round-bottomed flask. **IGNORE** weighing scales **ALLOW** ‘weigh at time intervals’
			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)		104.5º ✓ (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** **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** $CH_3CH(OH)CH_2CH_3 + [O] \rightarrow CH_3COCH_2CH_3 + H_2O$ ✓ **Structure of product could be allowed from equation** $CH_3COCH_2CH_3$ ✓	**2**	AO2.7 × 2	**ALLOW** molecular formulae: $C_4H_{10}O$ and C_4H_8O **ALLOW** C_4H_9OH **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)	**FIRST CHECK ANSWER ON THE ANSWER LINE** **IF answer = 67.4% award all 3 marks for calculation** *n*(butan-2-ol) (*m*/*M*) = 20.2/74 **OR** = 0.273 mol ✓	**1**	AO1.1	**If there is an alternative answer, check to see if there is any ECF credit possible** **ALLOW 3 SF:** 0.273 up to calculator value of 0.272972973 correctly rounded
	n(2-bromobutane (*m*/*M*) = 25.2/136.9 **OR** = 0.184 mol ✓	**1**	AO2.4	**ALLOW 3 SF:** 0.184 up to calculator value of 0.184075967 correctly rounded **ALLOW** (25.2/137) = 0.183941605 **ALLOW** 67% if evidence shows 67.4% in answer
	% yield = (0.184/0.273) × 100) = 67.4% ✓	**1**	AO2.4	**ALLOW** 67.4% up to calculator value correctly rounded. **Common ECFs** (2 marks) Incorrect M_r resulting in incorrect moles of butan-2-ol or 2-bromobutane **ALLOW** calculation in mass for 2nd and 3rd marks *m*($CH_3CHBrCH_2CH_3$) = 0.273 × 136.9 = 37.4 g % yield = (25.2/37.4) × 100 = 67.4%
	Total	**12**		

<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>AO element</th><th>Guidance</th></tr>
<tr><td>7</td><td></td><td></td><td>Please refer to marking instructions on page 4 of mark scheme for guidance on how to mark this question.

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.

The explanation makes use of all the evidence including the secondary carbocation in justifying the correct structure of C.

Level 2 (3–4 marks)
Attempts all three scientific points but explanations may be incomplete.
OR Explains two scientific points thoroughly with few omissions.

The analysis is clear and includes some interpretation of IR and MS peaks.

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.

The analysis is communicated in an unstructured way and includes interpretation of peaks from IR OR MS spectrum

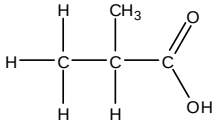
0 marks – No response worthy of credit.</td><td>6</td><td>AO3.1 × 2

AO3.1 × 2

AO3.2 × 2</td><td>LOOK ON THE SPECTRA for labelled peaks.
Indicative scientific points may include:

<u>1. Molecular formula</u>
<table><tr><td>Element</td><td>% mass</td><td>Ar</td><td>moles</td><td>ratio</td></tr><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></table>• empirical formula = C_2H_4O
• molecular ion peak m/z or Mr = 88
• molecular formula = $C_4H_8O_2$

<u>2. Infrared spectrum</u>
• peak at 2500–3500 (cm^{-1}) is O–H
• peak at 1630-1820 (cm^{-1}) is C=O
• C is a carboxylic acid
ALLOW stated values within the ranges above
IGNORE references to C–O peaks

<u>3. Identifying the carboxylic acid</u>
• ($CH_3CH_2CH_2COOH$ OR $(CH_3)_2CHCOOH$)
• Mass spectrum peak at m/z = 43 = $C_3H_7(^+)$
• secondary carbocation: $CH_3C^+HCH_3$
• compound C: $(CH_3)_2CHCOOH$
 
IGNORE name of carboxylic acid if structure given</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>6</td><td></td><td></td></tr>
</table>

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