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.

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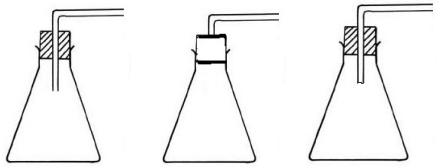
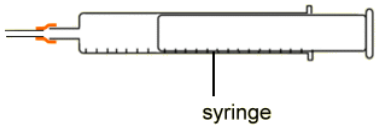
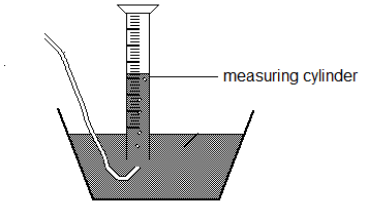
Annotations

| 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 |

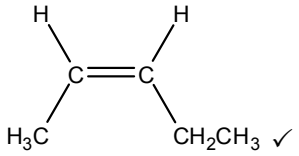
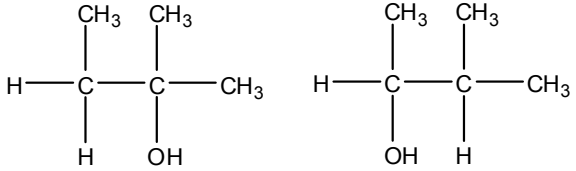
| Question | | | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|---|---|
| 1 | (a) | (i) | $1s^2 2s^2 2p^6 3s^2$ ✓ | 1 | AO1.1 | **ALLOW** upper case S and P, and subscripts, e.g. ……$2S_2 3P_6$ |
| | | (ii) | (Mg) loses/transfers/donates **two** electrons ✓ | 1 | AO1.1 | **ALLOW** Mg loses the 3s electrons provided electronic configuration in **(a)(i)** is $3_s^2$<br><br>**ALLOW** $Mg \rightarrow Mg^{2+} + 2e^-$<br><br>**IGNORE** reference to oxidation numbers / states |
| | (b) | (i) | $Sr^+(g) \rightarrow Sr^{2+}(g) + e^-$ ✓ | 1 | AO2.5 | **ALLOW** $Sr^+(g) - e^- \rightarrow Sr^{2+}(g)$<br><br>**ALLOW** e for electron (i.e. charge omitted)<br><br>**IGNORE** states on the electron |
| | | (ii) | *Atomic radius*<br>larger atomic radius<br>**OR**<br>more shells ✓<br><br>*Effect of nuclear charge/shielding*<br>Increased nuclear charge outweighed by increased distance/shielding<br>**OR**<br>**more**/**increased** shielding ✓<br><br>*Nuclear attraction*<br>less nuclear attraction<br>**OR**<br>less attraction on electrons ✓ | 3 | AO1.2 ×3 | **FULL ANNOTATIONS MUST BE USED**<br>**----------**<br>**ALLOW ORA:** comparison needed for each mark.<br><br>**ALLOW** 'more/higher energy levels'<br>**ALLOW** 'electrons further from nucleus'<br>**ALLOW** 'extra/new shell'<br><br>**IGNORE** more orbitals **OR** more sub-shells **OR** different shell<br><br>**ALLOW more** electron repulsion from inner shells<br>**IGNORE** responses with no comparison<br><br>**IGNORE** nuclear charge/effective nuclear charge<br>**ALLOW** 'less nuclear pull'<br>**OR** 'electrons held less tightly' |

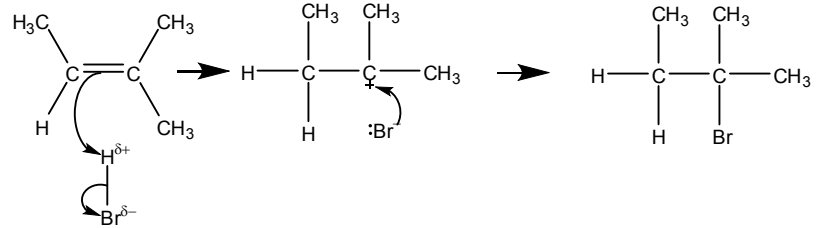
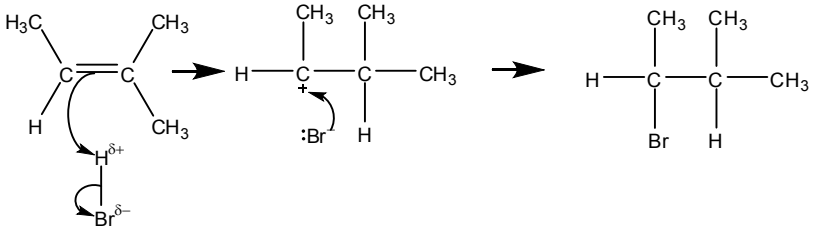
| Question | | | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|---|---|
| | (c) | (i) | Diagram of **labelled** reaction vessel for reaction ✓ | 1 | AO3.3 × 2 | **ALLOW** (conical) flask, test-tube or boiling tube.<br><br>**DO NOT ALLOW** volumetric flask, beaker, measuring cylinder<br>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

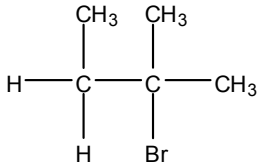
| Question | | | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|---|---|
| | | (ii) | **FIRST CHECK CALCULATED VALUE FOR MOLAR / ATOMIC MASS OF CALCIUM**<br>**IF answer = 40.1 OR 40.08 is seen anywhere award first two marks** | | | **DO NOT ALLOW** $pV = nRT$ for the calculation of the 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)<br>**ALLOW ECF** from incorrectly calculated amount in moles |
| | | | Group 2 metal:<br>calcium/Ca ✓ | **1** | AO3.2 | **DO NOT ALLOW** Calcium if no working<br>**ALLOW ECF** as element in Group 2 closest to the value calculated |
| | **(d)** | | Less (volume/products)<br>**AND**<br>Smaller amount/fewer moles/fewer atoms of the **metal OR** element reacting✓ | **1** | AO3.2 | **IGNORE** higher relative atomic mass/molar mass<br>**ALLOW** a calculation **showing** that moles and volume are less<br>$n(H_2) = 0.162/87.6 = 0.0018493156$<br>Volume = 0.0018493156 × 24000 = 44(.4) cm$^3$ |
| | | | **Total** | **12** | | |

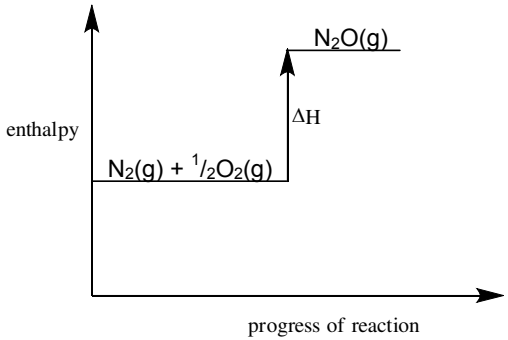
| Question | | | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|---|---|
| 2 | (a) | | Phosphorus has<br>more electrons ✓ | 1 | AO1.1<br>× 2 | **ALLOW ORA** but comparison should be used for the all marks<br>**DO NOT ALLOW** Phosphorus has more electrons in the outer shell or larger electron cloud.<br><br>**IGNORE** Phosphorus molecules are bigger or have greater $M_r$. |
| | | | Stronger London forces<br>**OR**<br>Stronger induced dipole(-dipole) interactions ✓ | 1 | | **ALLOW** 'more' for 'stronger'<br>**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**<br>metallic (bonds)✓ | 1 | AO1.1<br>× 4 | **ALLOW** the (electrostatic) attraction between cations/positive ions and delocalised electrons for both Mg marks ✓ ✓ |
| | | | cations/positive ions/$Mg^{2+}$<br>**AND**<br>**delocalised** electrons ✓ | 1 | | **DO NOT ALLOW** molecules for second mark<br>**IGNORE** 'sea of electrons' |
| | | | **Silicon**<br>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<br>**ALLOW** correct multiples |
| | | | **Total** | 8 | | |

| Question | | | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|---|---|
| 3 | (a) | (i) | Any **one** from:<br>• σ bond is between bonding atoms/nuclei **AND** π bond is above and below the bonding atoms/nuclei<br>• σ bond has direct/head-on overlap of orbitals **AND** π bond has sideways overlap<br>• π bond has a lower bond enthalpy / is weaker than a σ bond<br>• 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<br><br>**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**<br>• One carbon atom in (double bond) is not attached to (two) different groups / groups of atoms<br>• Right-hand carbon is attached to two groups that are the same/two methyl groups.<br>• Two groups are the same on **right-hand side**<br>• Three groups are the same (on the double bond)<br>**DO NOT ALLOW**<br>• Two groups on the same side of the double bond *Must be right-hand side; Same side could be top or bottom)*<br>• Functional groups **OR** molecules for groups |

| Question | | | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|---|---|
| | | (iii) |  ✓ | 1 | AO2.1 | **Mark Independently**<br>**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous<br>**ALLOW** $C_2H_5$ for $CH_2CH_3$<br>**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<br>**ALLOW any** vertical bond to OH,<br>e.g. **ALLOW** OH **OR** OH<br>**DO NOT ALLOW** OH– |

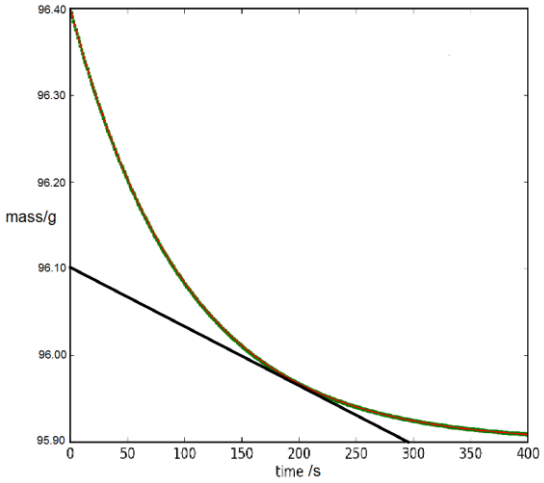
| Question | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|
| (c) | *Please refer to marking instructions on page 4 of mark scheme for guidance on how to mark this question.*<br><br>**Level 3 (5–6 marks)**<br>A comprehensive description with all three scientific points explained thoroughly.<br><br>*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.*<br><br>**Level 2 (3–4 marks)**<br>Attempts to describe all three scientific points but explanations may be incomplete.<br>**OR** Explains two scientific points thoroughly with no omissions.<br>*The description has some structures with reasonably accurate curly arrows and some charges and dipoles identified.*<br><br>**Level 1 (1–2 marks)**<br>A simple description based on at least two of the main scientific points<br>**OR** Explains one scientific point thoroughly with few omissions.<br><br>*The description is communicated in an unstructured way, including some use of curly arrows, charges or dipoles.* | **6** | AO1.2 × 2<br><br>AO2.5 × 2 | Throughout: **ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above if unambiguous<br><br>**Indicative scientific points**<br><br>**<u>1. Two possible products of reaction</u>**<br><br>$CH_3C(CH_3)BrCH_2CH_3$<br>$CH_3CHBrCH(CH_3)CH_3$<br>**IGNORE** names where correct structures are present<br><br>**<u>2. Mechanism for formation of either product.</u>**<br><br>Curly arrow from C=C to attack the H atom of the HBr<br>Correct dipole on H–Br<br>Curly arrow from H–Br bond to Br<br>Carbocation with full positive charge on carbon atom<br>Curly arrow from negative charge on $Br^-$ or lone pair on $Br^-$ to carbon atom with positive charge<br><br>**OR**<br> |

| Question | | | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|---|---|
| | | | **0 marks**<br>No response worthy of credit. | | AO3.1<br>AO3.2 | **3. Major organic product**<br><br>Major product: 2-bromo-2-methylbutane<br><br><br>• Major product is formed from the most stable carbocation intermediate<br>**OR** –Br is attached to carbon atom with the least hydrogens attached<br>**OR** the carbon with the most $–CH_3$ groups attached<br>**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<br><br>• $\Delta H$ labelled **OR** 82 on vertical arrow<br>• Products above reactants (either chemical symbols or the words products and reactants)<br>• Arrow upwards ✓ | 2 | AO1.2 | <br>**IGNORE** activation energy |
| | | | Formulae **AND** state symbols<br>$N_2(g) + {}^1/_2O_2(g) \rightarrow N_2O(g)$ ✓ | | AO2.5 | **DO NOT ALLOW** multiples of equation:<br>1 mole of $N_2O$ is formed |

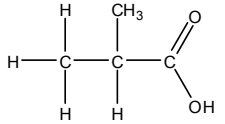
| Question | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|
| (b) | **FIRST CHECK ANSWER ON THE ANSWER LINE**<br>**IF answer = 4.46 × $10^6$ (Pa) award 4 marks**<br><br>**Amount of $N_2O$**<br><br>$n(N_2O) = \frac{187}{44}$ **OR** 4.25 (mol) ✓<br><br>**Unit conversion**<br><br>Volume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

| Question | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|
| (ii) | Attempted tangent on graph drawn to line at approximately $t$ = 200 s ✓<br><br>Gradient ($y/x$)<br>e.g. $\frac{0.20}{290}$ = $6.9 \times 10^{-4}$ ✓<br><br><br> | 1<br><br>1 | AO3.1<br><br>AO3.2 | **ALLOW** 1 SF up to calculator value, in range $5 \times 10^{-4}$ to $8 \times 10^{-4}$<br><br>**IGNORE** units<br>**IGNORE** sign |
| (c) | Flask **OR** beaker<br>**AND**<br>balance<br>**AND**<br>stopwatch **OR** stop clock **OR** other timing device ✓<br><br>Records **mass** at time intervals ✓<br><br>Time interval quoted between 10-50s ✓ | 1<br><br>1<br><br>1 | AO3.3 × 2 | **DO NOT ALLOW** round-bottomed flask.<br><br>**IGNORE** weighing scales<br><br>**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<br>**OR**<br>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 ✓<br><br>(oxygen atom) has two bond pairs and two lone pairs ✓<br><br>Bonded pairs/lone pairs/electron pairs repel ✓<br><br>Lone pairs repel **more than bonding pairs** ✓<br><br>**NOTE**: 'Lone pairs repel more than bonding pairs' would gain the last two marking points | **1**<br><br>**1**<br><br>**1**<br><br>**1** | AO1.1<br><br>AO1.1<br><br>AO2.1<br><br>AO2.1 | **ALLOW** 104–105<br><br>**ALLOW** lp and bp<br>**ALLOW** bonding regions for bond pairs<br><br>**IGNORE** bonds repel / electrons repel<br>**DO NOT ALLOW** atoms repel<br><br>**ALLOW** alternative phrases/words to repel e.g. 'push apart' |
| | (c) | (i) | **Equation**<br>$CH_3CH(OH)CH_2CH_3 + [O] \rightarrow CH_3COCH_2CH_3 + H_2O$ ✓<br><br>**Structure of product could be allowed from equation**<br><br>$CH_3COCH_2CH_3$ ✓ | **2** | AO2.7 × 2 | **ALLOW** molecular formulae: $C_4H_{10}O$ and $C_4H_8O$<br>**ALLOW** $C_4H_9OH$<br>**ALLOW** $C_2H_5$ for $CH_3CH_2$<br>**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous |
| | | (ii) | Butan-2-ol/butanone is flammable<br>**OR**<br>Butan-2-ol/butanone is volatile/low boiling point<br>**OR**<br>Butan-2-ol /butanone will evaporate/boil away ✓<br><br>(Heat under) reflux **OR** a description of reflux with vertical condenser and a round bottomed or pear shaped flask with source of heat. ✓ | <br><br><br><br>**1**<br><br>**1** | <br><br><br><br>AO3.4 × 2 | **IGNORE** vague answers about health and safety<br>**ALLOW** alcohol for butan-2-ol<br>**ALLOW** ketone for butanone<br><br>**DO NOT ALLOW** the product or reactant.<br>**DO NOT ALLOW** distillation<br>**DO NOT ALLOW** any reference to closed system. |

| Question | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|
| (d) | **FIRST CHECK ANSWER ON THE ANSWER LINE**<br>**IF answer = 67.4% award all 3 marks for calculation**<br><br>*n*(butan-2-ol) (*m*/*M*)<br>= 20.2/74<br>**OR**<br>= 0.273 mol ✓ | **1** | AO1.1 | **If there is an alternative answer, check to see if there is any ECF credit possible**<br><br>**ALLOW 3 SF:** 0.273 up to calculator value of 0.272972973 correctly rounded |
| | *n*(2-bromobutane (*m*/*M*)<br>= 25.2/136.9<br>**OR**<br>= 0.184 mol ✓ | **1** | AO2.4 | **ALLOW 3 SF:** 0.184 up to calculator value of 0.184075967 correctly rounded<br>**ALLOW** (25.2/137) = 0.183941605<br><br>**ALLOW** 67% if evidence shows 67.4% in answer |
| | % yield<br>= (0.184/0.273) × 100) = 67.4% ✓ | **1** | AO2.4 | **ALLOW** 67.4% up to calculator value correctly rounded.<br><br>**Common ECFs** (2 marks)<br>Incorrect $M_r$ resulting in incorrect moles of butan-2-ol or 2-bromobutane<br><br>**ALLOW** calculation in mass for 2nd and 3rd marks<br>*m*($CH_3CHBrCH_2CH_3$) = 0.273 × 136.9 = 37.4 g<br><br>% 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.<br><br>
Level 3 (5–6 marks)<br>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.<br><br>
The explanation makes use of all the evidence including the secondary carbocation in justifying the correct structure of C.<br><br>
Level 2 (3–4 marks)<br>Attempts all three scientific points but explanations may be incomplete.<br>OR Explains two scientific points thoroughly with few omissions.<br><br>
The analysis is clear and includes some interpretation of IR and MS peaks.<br><br>
Level 1 (1–2 marks)<br>A simple explanation based on at least two of the main scientific points.<br>OR<br>Explains one scientific point thoroughly with few errors.<br><br>
The analysis is communicated in an unstructured way and includes interpretation of peaks from IR OR MS spectrum<br><br>
0 marks – No response worthy of credit.
</td><td>6</td><td>AO3.1 × 2<br><br>AO3.1 × 2<br><br>AO3.2 × 2</td><td>
LOOK ON THE SPECTRA for labelled peaks.<br>Indicative scientific points may include:<br><br>
<u>1. Molecular formula</u><br>
<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 = $C_2H_4O$<br>
• molecular ion peak $m/z$ or Mr = 88<br>
• molecular formula = $C_4H_8O_2$<br><br>
<u>2. Infrared spectrum</u><br>
• peak at 2500–3500 ($cm^{-1}$) is O–H<br>
• peak at 1630-1820 ($cm^{-1}$) is C=O<br>
• C is a carboxylic acid<br>
ALLOW stated values within the ranges above<br>IGNORE references to C–O peaks<br><br>
<u>3. Identifying the carboxylic acid</u><br>
• ($CH_3CH_2CH_2COOH$ OR $(CH_3)_2CHCOOH$)<br>
• Mass spectrum peak at $m/z$ = 43 = $C_3H_7(^+)$<br>
• secondary carbocation: $CH_3C^+HCH_3$<br>
• compound C: $(CH_3)_2CHCOOH$<br>
<br>
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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