# GCE

# Chemistry A

## H032/02: Depth in chemistry

AS Level

# Mark Scheme for June 2022

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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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## MARKING INSTRUCTIONS

### PREPARATION FOR MARKING

### RM ASSESSOR

1. Make sure that you have accessed and completed the relevant training packages for on-screen marking: *RM Assessor Online Training*; *OCR Essential Guide to Marking*.
2. Make sure that you have read and understood the mark scheme and the question paper for this unit.
3. Log-in to RM Assessor and mark the **required number** of practice responses ("scripts") and the **required number** of standardisation responses.

### MARKING

1. Mark strictly to the mark scheme.
2. Marks awarded must relate directly to the marking criteria.
3. The schedule of dates is very important. It is essential that you meet the RM Assessor 50% and 100% (traditional 50% Batch 1 and 100% Batch 2) deadlines. If you experience problems, you must contact your Team Leader (Supervisor) without delay.
4. If you are in any doubt about applying the mark scheme, consult your Team Leader by telephone, email or via the RM Assessor messaging system.
5. Work crossed out:

   **Crossed Out Responses**
   Where a candidate has crossed out a response and provided a clear alternative then the crossed out response is not marked. Where no alternative response has been provided, examiners may give candidates the benefit of the doubt and mark the crossed out response where legible.

**Rubric Error Responses – Optional Questions**
Where candidates have a choice of question across a whole paper or a whole section and have provided more answers than required, then all responses are marked and the highest mark allowable within the rubric is given. Enter a mark for each question answered into RM assessor, which will select the highest mark from those awarded. *(The underlying assumption is that the candidate has penalised themselves by attempting more questions than necessary in the time allowed.)*

**Multiple Choice Question Responses**
When a multiple choice question has only a single, correct response and a candidate provides two responses (even if one of these responses is correct), then no mark should be awarded (as it is not possible to determine which was the first response selected by the candidate).
*When a question requires candidates to select more than one option/multiple options, then local marking arrangements need to ensure consistency of approach.*

**Contradictory Responses**
When a candidate provides contradictory responses, then no mark should be awarded, even if one of the answers is correct.

**Short Answer Questions** (requiring only a list by way of a response, usually worth only **one mark per response**)
Where candidates are required to provide a set number of short answer responses then only the set number of responses should be marked. The response space should be marked from left to right on each line and then line by line until the required number of responses have been considered. The remaining responses should not then be marked. Examiners will have to apply judgement as to whether a 'second response' on a line is a development of the 'first response', rather than a separate, discrete response. *(The underlying assumption is that the candidate is attempting to hedge their bets and therefore getting undue benefit rather than engaging with the question and giving the most relevant/correct responses.)*

**Short Answer Questions** (requiring a more developed response, worth **two or more marks**)
If the candidates are required to provide a description of, say, three items or factors and four items or factors are provided, then mark on a similar basis – that is downwards (as it is unlikely in this situation that a candidate will provide more than one response in each section of the response space.)

**Longer Answer Questions** (requiring a developed response)
Where candidates have provided two (or more) responses to a medium or high tariff question which only required a single (developed) response and not crossed out the first response, then only the first response should be marked. Examiners will need to apply professional judgement as to whether the second (or a subsequent) response is a 'new start' or simply a poorly expressed continuation of the first response.

6. Always check the pages (and additional objects if present) at the end of the response in case any answers have been continued there. If the

candidate has continued an answer there then add a tick to confirm that the work has been seen.

7. There is a NR (No Response) option. Award NR (No Response)

   - if there is nothing written at all in the answer space
   - OR if there is a comment which does not in any way relate to the question (e.g. 'can't do', 'don't know')
   - OR if there is a mark (e.g. a dash, a question mark) which isn't an attempt at the question.

   Note: Award 0 marks – for an attempt that earns no credit (including copying out the question).

8. The RM Assessor **comments box** is used by your Team Leader to explain the marking of the practice responses. Please refer to these comments when checking your practice responses. **Do not use the comments box for any other reason.**

   If you have any questions or comments for your Team Leader, use the phone, the RM Assessor messaging system, or email.

9. Assistant Examiners will send a brief report on the performance of candidates to their Team Leader (Supervisor) via email by the end of the marking period. The report should contain notes on particular strengths displayed as well as common errors or weaknesses. Constructive criticism of the question paper/mark scheme is also appreciated.

10. For answers marked by levels of response:

Read through the whole answer from start to finish, using the Level descriptors to help you decide whether it is a strong or weak answer. The indicative scientific content in the Guidance column indicates the expected parameters for candidates' answers, but be prepared to recognise and credit unexpected approaches where they show relevance. Using a 'best-fit' approach based on the skills and science content evidenced within the answer, first decide which set of level descriptors, Level 1, Level 2 or Level 3, best describes the overall quality of the answer.

Once the level is located, award the higher or lower mark:

**The higher mark** should be awarded where the level descriptor has been evidenced and all aspects of the communication statement (in italics) have been met.

**The lower mark** should be awarded where the level descriptor has been evidenced but aspects of the communication statement (in italics) are missing.

**In summary:**

**The skills and science content determines the level.**

**The communication statement determines the mark within a level.**

Level of response questions on this paper are **4a(i)** and **6**

**The only annotation on a level of response question should be the indication of the level.**

A level annotation should be used where all marks for a level have been achieved.
e.g. if a candidate has 6 marks, they would have this annotation on their script:




If a candidate has achieved 5 marks then they have reached Level 3 but will not have met the communication statement.
They should have the following annotations on their scripts:




The same principle should be applied to Level 2 and Level 1.

No marks (0) should have a cross: 

Place the annotations alongside the mark for the question.

On additional pages, annotate using 

11. Annotations available in RM Assessor

| 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 |
|  | Blank page |

12. Abbreviations, annotations and conventions used in the detailed Mark Scheme (to include abbreviations and subject-specific conventions).

| Annotation | Meaning |
|---|---|
| **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 |

13. **Subject-specific Marking Instructions**

**INTRODUCTION**

Your first task as an Examiner is to become thoroughly familiar with the material on which the examination depends. This material includes:

- the specification, especially the assessment objectives
- the question paper
- the mark scheme.

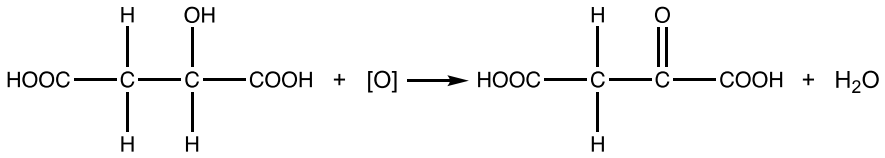
You should ensure that you have copies of these materials.

You should ensure also that you are familiar with the administrative procedures related to the marking process. These are set out in the OCR booklet **Instructions for Examiners**. If you are examining for the first time, please read carefully **Appendix 5 Introduction to Script Marking: Notes for New Examiners**.

Please ask for help or guidance whenever you need it. Your first point of contact is your Team Leader.

<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>AO element</th><th>Guidance</th></tr>
<tr><td>1</td><td>(a)</td><td>(i)</td><td>(Acid) releases $H^+$ ions/ $H^+$ donor ✓</td><td>1</td><td>AO1.1</td><td>ALLOW $H^+$ OR proton</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>(weak acid) partially dissociates/ionises ✓</td><td>1</td><td>AO1.1</td><td>IGNORE vague responses that do not imply a number, e.g.<br>• poor proton donor<br><br>IGNORE ‘doesn’t easily dissociate’<br><br>IGNORE ‘strong acid completely dissociates’</td></tr>
<tr><td></td><td>(b)</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/ $cm^3$</td><td>27.35</td><td>27.65</td><td>27.85</td></tr>
<tr><td>Initial reading/$cm^3$</td><td>0.05</td><td>0.10</td><td>0.45</td></tr>
<tr><td>Titre/$cm^3$</td><td>27.30</td><td>27.55</td><td>27.40</td></tr>
</table>
Initial and final readings<br>All titration readings (×6) correct ✓<br><br>Titres<br>Correct subtractions to obtain final titre values ✓<br><br>Mean titre calculated from concordant results<br>Correct mean titre = 27.35 ($cm^3$) ✓<br><br>Reading recorded to accuracy of burette<br>All values including mean titre recorded to two decimal places with the last figure either 0 or 5 ✓
</td><td>4</td><td>AO1.2<br>×4</td><td>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC<br><br>ALLOW missing zeroes throughout except for last marking point<br><br>e.g. 0.1 for 0.10<br><br>ALLOW ECF from incorrect burette readings<br><br>IF MEAN IS CALCULATED FROM ECF, IT MUST BE FROM CLOSEST TITRES<br>ALLOW any number of decimal places for mean titre for this mark<br><br>Note: Question asks for mean titre to nearest 0.05 $cm^3$</td></tr>
</table>

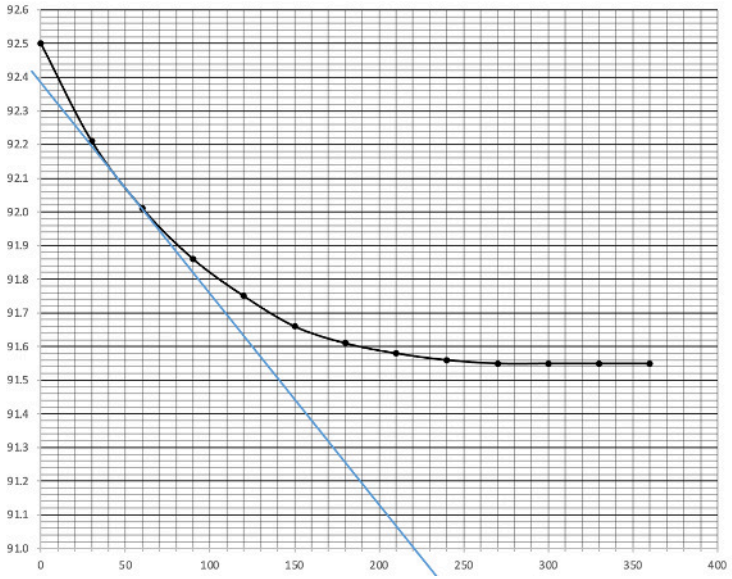
| Question | | | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|---|---|
| | | (ii) | **FIRST CHECK THE ANSWER ON ANSWER LINE**<br>**If answer =** 7.(00) **award 5 marks**<br>---<br><br>*n*(NaOH)<br>$= \frac{27.35 \times 0.800}{1000} = 0.02188$ ✓<br><br>*n*(A) in 25.0 $cm^3$<br>$= \frac{0.02188}{3} = 0.00729(33)$ ✓<br><br>*n*(A) in 250 $cm^3$<br>$= 10 \times 0.00729(33) = 0.0729(33)$ ✓<br><br>mass citric acid in 250 $cm^3$<br>$= 0.0729 \times 192 = 14(.0032)$ (g**)** ✓<br><br>mass citric acid in one lime<br>$= \frac{14.0}{2} = 7.(00)$ (g) ✓ | **5** | AO2.8<br>×4<br><br>AO2.4 | **ANNOTATE ANSWER WITH TICKS AND CROSSES ETC**<br>---<br>ALLOW ECF from incorrect titre calculated in 1(b)(i)<br>Throughout:<br>**ALLOW** 3 SF or more, correctly rounded<br>e.g. *n*(NaOH) = 0.0219 for 0.02188<br><br>**ALLOW ECF** from incorrect *n*(NaOH)<br><br>**ALLOW ECF** for all subsequent steps<br><br>From *n*(NaOH) = 0.0219,<br>*n*(A) = 0.073(0)<br>*mass* citric acid = 14(.016)<br>*mass* in 1 lime = 7(.008) |
| | (c) | | **Action taken to modify method**<br>Use half a lime<br>**OR**<br>Make up lime juice (solution) in 1 $dm^3$ volumetric flask ✓<br><br>**Dilution ratio to justify**<br>4 times less citric acid/lime juice<br>**OR**<br>NaOH is 4 times more dilute (giving same titre)<br>**OR**<br>1:4 ratio for NaOH concentration ✓ | **2** | AO3.4<br>×2 | **ALLOW** any feasible method that would give a dilution factor of 4<br><br>**ALLOW** quartered |

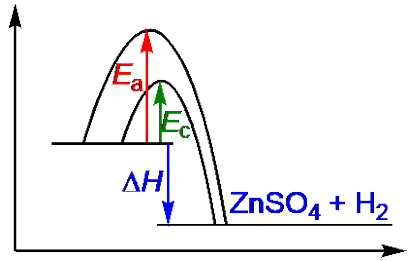
| Question | | | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|---|---|
| | (d) | |   Correct structure of product ✓ Correctly balanced equation ✓ | 2 | AO2.5 AO2.6 | **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous |
| | | | **Total** | **15** | | |

| Question | | | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|---|---|
| 2 | (a) | (i) | $Sr + 2H_2O \rightarrow Sr(OH)_2 + H_2$<br><br>All formulae and balancing correct ✓ | 1 | AO2.6 | **IGNORE STATE SYMBOLS**<br><br>**ALLOW** multiples<br><br>**IGNORE** state symbols (even if wrong) |
| | | (ii) | **Oxidation**<br>Sr from **0** to **+2** ✓<br><br>**Reduction**<br>H from **+1** to **0** ✓ | 2 | AO2.1 ×2 | **ALLOW** 2+ for +2 and 1+ for +1<br>'+' is required in +2 and +1 oxidation numbers<br><br>**ALLOW** $H_2$ for hydrogen<br><br>**ALLOW** 1 mark for elements **AND** all oxidation numbers correct but oxidation and reduction wrong way round **OR** not given.<br><br>**IGNORE** numbers around equation in **(i)**<br>*(treat as rough working)* |

| Question | | | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|---|---|
| | | (iii) | *Atomic radius*<br>Ca has smaller atomic radius<br>**OR** fewer shells ✓ | 3 | AO1.2 | **FULL ANNOTATIONS MUST BE USED**<br>**ORA in terms of Sr**<br>**Comparison** needed for each mark.<br><br>**ALLOW** 'fewer energy levels'<br>**ALLOW** 'electrons closer to nucleus'<br><br>**IGNORE** fewer orbitals **OR** fewer sub-shells<br>**OR** different shell |
| | | | *Effect of nuclear charge/shielding*<br>Ca has **less**/**decreased** shielding ✓ | | AO1.2 | **ALLOW more** electron repulsion from inner shells |
| | | | *Nuclear attraction*<br>Ca has greater nuclear attraction (for electrons)<br>**OR** Ca has a higher ionisation energy<br>**OR** more energy is required to lose the outer electrons✓ | | AO1.2 | **IGNORE** nuclear charge/effective nuclear charge<br>**ALLOW** 'less nuclear pull'<br>**OR** 'electrons held less tightly' |
| | (b) | (i) | Any value in range: 8–14 ✓ | 1 | AO1.1 | |
| | | (ii) | White precipitate/white solid ✓<br><br>$BaSO_4$ ✓ | 2 | AO3.1<br><br>AO3.2 | |
| | | | **Total** | 9 | | |

| Question | | | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|---|---|
| 3 | (a) | (i) | **Rate**<br>(Acid) **concentration** decreases ✓ | 3 | AO1.1 | **IGNORE** amount of acid decreases<br><br>Response **MUST** imply a volume and **NOT** area, e.g. fewer particles/molecules/ions in **same space /volume** |
| | | | **Collisions**<br>Fewer collisions per second **OR** less frequent collisions ✓ | | AO1.1 | **IGNORE** responses not linked to rate, e.g.<br>• 'fewer collisions'<br>• fewer successful collisions<br>• fewer collisions, less chance of collisions<br>*No link to rate.* |
| | | | **Reaction stops**<br>(Acid/reactant/limiting reagent) has reacted/been used up ✓ | | AO2.3 | **AW** |

| Question | | | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|---|---|
| | | (ii) | **Tangent on graph**<br>drawn at approximately $t$ = 50 s (± 10 s) ✓<br><br>**Calculation of rate**<br>= Gradient ($y/x$) of tangent drawn<br>e.g. $\frac{92.4 - 91.0}{220} = \frac{1.4}{220} = 6.36 \times 10^{-3}$ (g $s^{-1}$) ✓<br><br> | **2** | AO3.1<br><br>AO3.2 | **DO NOT ALLOW** interpolation (taking a direct reading from graph), answer must be derived from taking a gradient<br><br>**ALLOW ECF from incorrectly drawn tangent**<br><br>**ALLOW** range of 5.7 x $10^{-3}$ to 6.9 x $10^{-3}$ in calculation of tangent (rounded to 1 d.p.)<br><br>**IGNORE** units<br>**IGNORE** sign<br><br>**Tolerance of readings:**<br>y axis should be ± 0.02 g<br>(i.e. within 1 square)<br><br>x axis should be ± 5 min<br>(i.e. within 1 of a square) |
| | | (iii) | Slope is steeper<br>**AND**<br>levels off earlier ✓<br><br>**Same** loss in mass, i.e. levels off at ~91.55 g ✓ | **2** | AO3.2<br>×2 | Tolerance ± 1 small square |

| Question | | | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|---|---|
| | (b) | (i) | More vigorous bubbling ✓<br><br>Zinc dissolves/disappears more quickly ✓ | 2 | AO2.7 ×2 | **AW**, e.g. bubbles/fizzes more quickly<br><br>For 1 alternative marking point **ALLOW** responses related to displacement of Cu from $CuSO_4$ by Zn:<br>**EITHER** red/brown/black precipitate/solid formed **OR** (blue solution) turns colourless |
| | | (ii) | <br><br><br>**$\Delta H$** $\Delta H$ labelled with product ($ZnSO_4 + H_2$) below reactant<br>**AND**<br>Arrow downwards ✓<br><br>$E_a$ $E_a$ correctly labelled ✓<br><br>$E_c$ $E_c$ correctly labelled with $E_c < E_a$ ✓ | 3 | AO2.1<br><br>AO1.1<br><br>AO1.1 | **ANNOTATE ANSWER WITH TICKS AND CROSSES ETC**<br><br>**IGNORE** state symbols<br><br>**$\Delta H$** **DO NOT ALLOW** $-\Delta H$<br>**DO NOT ALLOW** double headed arrow on $\Delta H$<br><br>**ALLOW** $\Delta H$ arrow even with small gap at the top and bottom,<br>i.e. line does not quite reach reactant or product line.<br><br>**$E_a$ and $E_c$**<br>**ALLOW** no arrowhead or arrowheads at both end of $E_a$ or $E_c$ lines<br><br>$E_a$ or $E_c$ lines must reach maximum (or near to maximum) on curve<br><br>For $E_a$, **ALLOW** AE **OR** $A_E$<br><br>**ALLOW** marks for **$E_a$ and $E_c$** for correctly labelled endothermic diagram (i.e. **ECF** from $\Delta H$) |
| | | | **Total** | 12 | | |

| Question | | | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|---|---|
| 4 | (a) | (i)* | *Please refer to the marking instructions on page 5 of the mark scheme for guidance on how to mark this question.*<br><br>**Level 3 (5-6 marks)**<br>A comprehensive explanation of effect of temperature **AND** pressure on equilibrium is given with some details about rate **AND** operating conditions<br><br>*There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.*<br><br>**Level 2 (3–4 marks)**<br>The candidate attempts three scientific points, but explanations are incomplete.<br><br>*There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.*<br><br>**Level 1 (1–2 marks)**<br>A simple description based on at least two of the main scientific points.<br><br>*There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.*<br><br>**0 marks** No response or no response worthy of credit. | **6** | AO1.2 × 3<br><br>AO2.5 × 3 | **Indicative scientific points may include:**<br>**ALLOW** reverse arguments throughout<br><br>**<u>Effect of Temperature on equilibrium position</u>**<br>• (Forward) reaction is endothermic/Δ*H* is +ve<br>• High temperature shifts equilibrium to right<br><br>**<u>Effect of Pressure on equilibrium position</u>**<br>• Left-hand side has fewer (gaseous) moles<br>• **OR** 2 (gaseous) moles form 4 (gaseous) moles<br>• Low pressure shifts equilibrium to right<br><br>**<u>Effect on rate of reaction</u>**<br>• High temp increases rate<br>• Low pressure reduces rate<br>• Catalyst increases rate<br>• Catalyst lowers activation energy<br>• Discussion using collision theory to support arguments<br><br>**<u>Operating conditions (not inclusive)</u>**<br>• Compromise conditions needed<br>• High temperatures increase energy demand/costs<br>• Slightly higher pressure used than optimum<br>• Higher pressures unsafe<br>• Catalyst reduces need for higher temperatures<br>• Catalyst doesn't effect the position of equilibrium<br>• Excess steam shifts equilibrium to right |

| Question | | | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | (ii) | **FIRST CHECK THE ANSWER ON ANSWER LINE**<br>**IF answer =** 24.1, **award 2 marks**<br>---<br>***$K_c$ expression***<br>$(K_c =) \frac{[CO]\,[H_2]^3}{[CH_4][H_2O]}$ **OR** $\frac{(0.510)\,(1.53)^3}{(0.111)\,(0.682)}$<br>**OR** 24.12…….. ✓<br>**Answer to 3 SF**<br>$K_c$ = 24.1 ✓ | **2** | AO2.5<br>AO2.6 | **IF** there is an alternative answer, check for any **ECF** credit possible using working below.<br>---<br>**ALLOW** calculated value 24.12887731 correctly rounded to 3 or more SF for 1st marking point<br>**ALLOW ECF to 3 SF**<br>**ONLY** from inverted $K_c$ expression → 0.0414<br>**DO NOT ALLOW** $\frac{[CO] + [H_2]^3}{[CH_4] + [H_2O]}$ (no marks)<br>**IGNORE** attempts at units |

| Question | | | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|---|---|
| | | | | | | |
| | (b) | | **FIRST CHECK THE ANSWER ON ANSWER LINE**<br>**IF answer = (+)198 award 3 marks**<br>---<br>*Energy for bonds broken*<br>*(1 × C–C + 5 × C–H + 1 × C–O + 7 × O–H)*<br>347 + 5(415) + 358 + 7(464)<br>**OR** 6028 (kJ) ✓<br><br>*Energy for bonds made ( 6 × H–H + 4 × C=O )*<br>6 × 435 + 4 × 805<br>**OR** 2610 + 3220<br>**OR** 5830 (kJ) ✓<br><br>$\Delta H$ *correctly calculated from above*<br>$\Delta H$ = 6028 – 5830<br>= (+)198 (kJ mol$^{-1}$) ✓ | **3** | AO2.2 ×2<br><br>AO2.6 | **FULL ANNOTATIONS MUST BE USED**<br>---<br>**IGNORE** sign<br><br>**IGNORE** sign<br>---<br>**ALLOW ECF**<br>**DO NOT ALLOW** – sign<br><br>**Common errors for 2 marks**<br>–198 (incorrect cycle)<br>–149 (missed C-C from bonds broken)<br>–2586 (missing 6 x O-H from $H_2O$) |
| | (c) | | $CO_2$ bond angle = 180º<br>**AND**<br>$H_2O$ bond angle = 104.5º ✓<br><br>$CO_2$ has 2 double bonds / 2 bonding regions ✓<br><br>$H_2O$ has 2 bonded pairs **AND** 2 lone pairs ✓<br><br>Lone pairs repel more than bonding pairs ✓ | **4** | AO1.1<br><br>AO2.1 ×3 | **ALLOW** 104–105<br>**IGNORE** Names of shapes even if incorrect<br><br>**ALLOW** alternative phrases/words for repel e.g. 'push apart'<br>**DO NOT ALLOW** atoms repel |
| | | | **Total** | **15** | | |

| Question | | | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|---|---|
| 5 | (a) | (i) | UV **OR** ultraviolet ✓ | 1 | AO1.1 | **ALLOW** Sunlight<br>**IGNORE** Temperature |
| | | (ii) | $CH_3CH_2CH_2CH_3 + Br\bullet \rightarrow CH_3CH_2\dot{C}HCH_3 + HBr$ ✓<br><br>$CH_3CH_2\dot{C}HCH_3 + Br_2 \rightarrow CH_3CH_2CHBrCH_3 + Br\bullet$ ✓ | 2 | AO2.5 ×2 | **ALLOW** Displayed or Skeletal formulae<br>**ALLOW 1 mark** if **BOTH** equations are 'correct' using molecular formulae, i.e.<br>$CH_3CH_2CH_2CH_3 + Br\bullet \rightarrow C_4H_9\bullet + HBr$<br>$C_4H_9\bullet + Br_2 \rightarrow C_4H_9Br + Br\bullet$ ✓<br><br>**IGNORE** position of • within $CH_3CH_2CHCH_3\bullet$<br><br>**ALLOW 1 mark** if incorrect structure of intermediate radical is used, e.g.<br>$CH_3CH_2\mathbf{CH_2CH_2}\bullet$ for $CH_3CH_2\mathbf{CHCH_3}\bullet$ ✓ |
| | | (iii) | Further substitution<br>**OR**<br>formation of di/ tri / etc. bromobutanes<br>**OR**<br>produces different termination products<br>**OR**<br>more than one termination step ✓<br><br>Formation of 1-bromobutane<br>**OR** (Br) subsitution in a different position ✓ | 2 | AO3.2 ×2 | **ALLOW** multisubstitutation, including examples<br>**ALLOW** an example of a different termination product<br>**ALLOW** more than one hydrogen (atom) can be replaced<br>**ALLOW** radicals react with each other to form other products |

| Question | | | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|---|---|
| | (b) | | % atom economy for butane and bromine (5.1)<br>$= \frac{136.9}{217.8} \times 100 = 62.9\%$ ✓<br><br>atom economy for but-2-ene and HBr (5.2) is 100% ✓ | 2 | AO2.2<br><br>AO1.2 | Calculator: 62.85583104<br><br>**ALLOW** calculation for 5.2<br><br>**ALLOW** Calculations not expressed as a % i.e. 0.629 and 1. |
| | (c) | (i) | **FIRST CHECK THE ANSWER ON ANSWER LINE**<br>**If answer = 8.07 g award 3 marks**<br>**CARE: Intermediate rounding may give 8.06 g which is acceptable for 3 marks**<br>---<br><br>*n*(2-bromobutane)<br>$= \frac{10.0}{136.9} = 0.073(0)\ldots.$ (mol) ✓<br><br>*n*($CH_3CH_2CHOHCH_3$)<br>$= 0.0730\ldots. \times \frac{100}{67.0} = 0.109$ (mol) ✓<br><br>mass $CH_3CH_2CHOHCH_3$<br>$= 0.109 \times 74.0 =$ **8.07** g ✓<br>**3 SF** required | 3 | AO2.4<br>×3 | **ALLOW ECF throughout**<br><br>**IGNORE** trailing zeroes in intermediate working, e.g. 0.073 for 0.0730<br><br>**ALLOW** 3 SF or more, correctly rounded<br><br>Calculator: 0.7304601899<br><br>Calculator: 0.1089552239<br><br>**ALLOW alternative method mass**<br>• Theoretical mass of 2-bromobutane<br>$= 100 \times \frac{10.0}{67.0} = 14.9\ldots..$ (g)<br>Calculator: 14.925373<br>• Theoretical *n*($CH_3CH_2CHBrCH_3$)<br>$= \frac{14.923373}{136.9} = 0.1902$ (mol)<br>• Mass of $CH_3CH_2CHOHCH_3$<br>$= 0.109 \times 74.0 =$ **8.07** g ✓<br><br>**Common Errors for 2 marks**<br>5.41 g (no % yield)<br>3.62 g (inverted yield) |

| Question | | | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|---|---|
| | | (ii) | Separating funnel (to separate aqueous and organic layers) ✓<br><br>Dry organic layer with anhydrous salt ✓<br><br>Distil and collect fraction at 91°C ✓ | 3 | AO3.3 ×3 | **ALLOW** Use a drying agent<br>**ALLOW** appropriate example of an anhydrous salt e.g. $MgSO_4$, $CaCl_2$ |
| | | | **Total** | 13 | | |

<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>AO element</th><th>Guidance</th></tr>
<tr><td>6*</td><td></td><td></td><td>

*Please refer to the marking instructions on page 5 of the mark scheme for guidance on how to mark this question.*

**Level 3 (5-6 marks)**
A comprehensive description including most of the evidence to justify the correct structure of **A** (accept *cis* or *trans*).

*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 thoroughly with few omissions.
**AND**
an attempt at a feasible structure with either a C=C **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)**
The correct empirical formula
**AND** a simple description based on at least one of the main scientific points.
**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 or no response worthy of credit.

</td><td>6</td><td>AO3.1 ×3<br><br>AO3.2 ×3</td><td>

**LOOK AT THE SPECTRA** for labelled peaks
**Indicative scientific points may include:**

**Empirical formula**

- empirical formula = $C_2H_3O$

| element | %mass | $A_r$ | moles | ratio |
|---|---|---|---|---|
| C | 55.8 | 12 | 4.65 | 2 |
| H | 7.0 | 1 | 7.0 | 3 |
| O | 37.2 | 16 | 2.325 | 1 |

**Spectra and molecular formula**
**Mass spectrum**

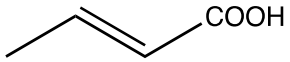
- (molecular ion peak $m/z$ = 86)
- molar mass = 86 g mol$^{-1}$
- molecular formula = $C_4H_6O_2$

**Infrared absorption;**

- broad peak at 2500–3300 cm$^{-1}$, due to O–H in carboxylic acid,
- peak at 1630–1820 cm $^{-1}$ due to C=O
- (peak at 1620–1680 cm $^{-1}$ due to C=C)

**Functional groups, structure and stereochemistry**

- alkene / C=C
- carboxylic acid / –COOH
- mass spectrum; peak at 41 due to loss of COOH
- Correct structural formula: $CH_3CH=CHCOOH$ i.e. *cis* **OR** trans
- *trans* isomer indicates C=C bond with 2 different groups attached to both double bonded carbons
- *trans:* common groups on opposite sides of double bond
- Correct structure:




</td></tr>
</table>

| Question | | | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|---|---|
| | | | | | | **NOTE:** *Correct trans assignment with justification would be an example of a well-developed line of reasoning that is substantiated*. |
| | | | **Total** | **6** | | |

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