# GCE

# Chemistry A

## H432/02: Synthesis and analytical techniques

A Level

# Mark Scheme for June 2024

OCR (Oxford Cambridge and RSA) is a leading UK awarding body, providing a wide range of qualifications to meet the needs of candidates of all ages and abilities. OCR qualifications include AS/A Levels, Diplomas, GCSEs, Cambridge Nationals, Cambridge Technicals, Functional Skills, Key Skills, Entry Level qualifications, NVQs and vocational qualifications in areas such as IT, business, languages, teaching/training, administration and secretarial skills.

It is also responsible for developing new specifications to meet national requirements and the needs of students and teachers. OCR is a not-for-profit organisation; any surplus made is invested back into the establishment to help towards the development of qualifications and support, which keep pace with the changing needs of today's society.

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 **19** and **24**

**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:

L3

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:

L3 ^

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 SEEN

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.

## SECTION A

| Question | Answer | Marks | Guidance |
|---|---|---|---|
| 1 | A | 1 | |
| 2 | C | 1 | |
| 3 | D | 1 | |
| 4 | B | 1 | |
| 5 | C | 1 | |
| 6 | D | 1 | |
| 7 | A | 1 | |
| 8 | C | 1 | |
| 9 | C | 1 | |
| 10 | C | 1 | **ALLOW** 1.5(0) |
| 11 | D | 1 | |
| 12 | A | 1 | **ALLOW** HC$l$ |
| 13 | C | 1 | |
| 14 | B | 1 | |
| 15 | There was an issue with this question which affected candidates' ability to answer it. To make sure all candidates were treated fairly, we have awarded the mark to all candidates for this question. | | |
| | **Total** | **15** | |

## SECTION B

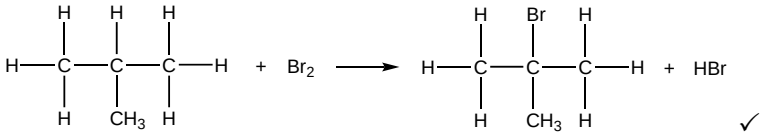
| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| 16 | (a) | | B, C, D **AND** E only ✓ | 1 | **ALLOW** letters in any order |
| 16 | (b) | | A **AND** B only ✓ | 1 | **ALLOW** letters in any order |
| 16 | (c) | | A **AND** D only ✓ | 1 | **ALLOW** letters in any order |
| 16 | (d) | | 1-ethyl-2,4-dimethylbenzene ✓ | 1 | **ALLOW** other unambiguous names using smallest numbering.<br>e.g. **ALLOW** 1,3-dimethyl-4-ethylbenzene<br>2,4-dimethylethylbenzene<br>ethyl-2,4-dimethylbenzene<br>2,4-dimethyl-1-ethylbenzene<br><br>**IGNORE** alphabetical order of methyl and ethyl<br><br>**IGNORE** lack of hyphens, extra hyphens, full stops instead of commas, extra spaces<br><br>**DO NOT ALLOW** 1,5-dimethyl-2-ethylbenzene **OR** 1,3-dimethyl-6-ethylbenzene<br>*Needs smallest numbers*<br><br>**DO NOT ALLOW** the following for dimethyl: dimethy, dimeth, dimethly, dimethanyl<br><br>**DO NOT ALLOW** the following for ethyl:<br>ethy, eth, ethly, ethanyl |

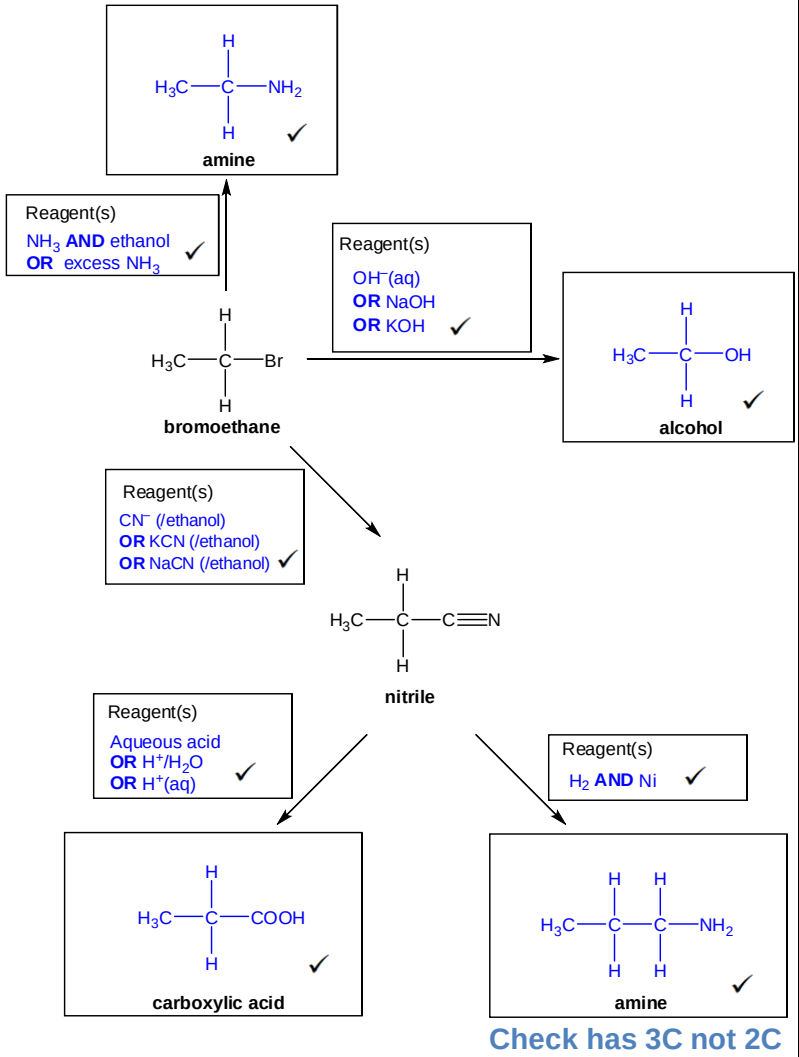
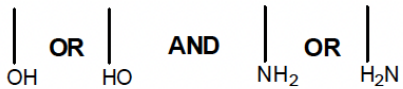
| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| 16 | (e) | | Priority groups are on the same side<br><br>(Highest) priority groups are $CH_3$ **AND** $C_2H_5$<br>**OR**<br>Low(est) priority groups $CH_3$ **AND** H | 2 | **ALLOW** suitable alternatives to 'priority'<br>e.g. Groups with highest atomic **number** or more important groups or major groups etc.<br>**IGNORE** references to (relative) mass of groups including Ar or Mr<br><br>**ALLOW** suitable alternatives to 'same side'<br>e.g. priority groups are both on the top **OR** above the C=C<br>**IGNORE** priority groups in same plane **OR** adjacent<br><br>**IGNORE** Use of 'molecules' instead of groups<br><br>**ALLOW** identification by name e.g. ethyl and methyl<br><br>**IF** 'priority' is not mentioned **ALLOW** one mark for '$CH_3CH_2$ and $CH_3$ are on same side' **OR** 'H and $CH_3$ are on same side' |

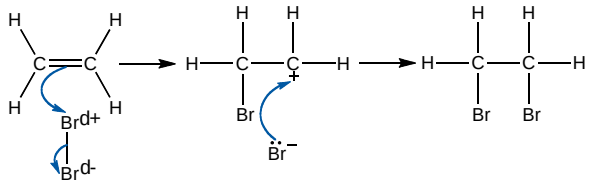
| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| 17 | (a) | | **Reagent and/or catalyst:**<br>$H_2SO_4$ **OR** $H_3PO_4$ **OR** $H^+$ **OR** acid (catalyst) ✓<br><br>**Organic product: (mark independently)**<br>$CH_3CH_2CHCH_2$ ✓ | **2** | **DO NOT ALLOW** other named acids e.g. HCl / hydrochloric acid as can be used for substitution reaction<br>**DO NOT ALLOW** other additional reagents e.g. $H_2O$ / steam, $H_2$ / hydrogen<br>**ALLOW** suitable non-specification alternatives e.g. $Al_2O_3$ **OR** Pumice stone<br>**ALLOW** names of reagents e.g. sulfuric or phosphoric acid, if no formulae given<br>**IGNORE** concentration e.g. dilute/concentrated<br>**IGNORE** (aq) state symbol<br>**IGNORE** conditions e.g. temperature/pressure/reflux<br><br>**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous<br>**IGNORE** names unless no structure is given then accept but-1-ene |
| 17 | (b) | | **Reagent and/or catalyst:**<br>$K_2Cr_2O_7$ **AND** $H_2SO_4$<br>**OR** $Cr_2O_7^{2-}/H^+$ ✓<br><br>**Organic product: (mark independently)**<br>$CH_3CH_2COCH_3$ ✓ | **2** | **ALLOW** $Na_2Cr_2O_7$ for $K_2Cr_2O_7$<br>**ALLOW** names for reagents e.g. acidified dichromate, if no formulae given<br>**IGNORE** Roman numerals e.g. (VI), unless incorrect<br>**IGNORE** [O]<br>**DO NOT ALLOW** other named acids e.g. HCl / hydrochloric acid<br>**DO NOT ALLOW** other additional reagents e.g. $H_2O$, steam<br>**ALLOW** suitable non-specification alternative oxidising agents e.g. $KMnO_4/H^+$ **OR** $CrO_3/H^+$ **OR** $H_2CrO_4$ (chromic acid)<br>**IGNORE** concentration e.g. dilute/concentrated<br>**IGNORE** conditions e.g. reflux/distillation<br><br>**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous<br>**IGNORE** names unless no structure is given then accept butanone |

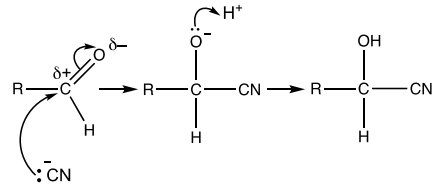
| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| 17 | (c) | | **Mark organic product first:**<br><br>$(CH_3)_2CHCH_2X$<br>where X is identified as Cl, Br, I ✓<br><br>**Reagent and/or catalyst:**<br>Reagent to match organic product<br><br>NaX / KX / $X^-$<br>**AND**<br>$H_2SO_4$ / $H^+$ / acid<br><br>Where X is identified as Cl, Br, I ✓ | 2 | **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous<br>**IGNORE** names unless no structure is given then accept 1-halo-2-methylpropane, where halo is chloro, bromo or iodo (ignore alphabetical order for prefixes)<br><br>**For 2 marks**, the reagent must be consistent with the product given e.g. $(CH_3)_2CHCH_2Cl$ then correct reagent is NaCl / $H_2SO_4$<br><br>**ALLOW** 1 mark if correct reagents given but no or incorrect organic product shown<br><br>**ALLOW** 1 mark if organic product is given with X i.e. $(CH_3)_2CHCH_2X$ **AND** reagent is consistent e.g. NaX / $H^+$ **OR** just states 'halide with acid'<br><br>**ALLOW** HX where X is identified as Cl, Br, I<br><br>**ALLOW** names of reagents e.g. sodium bromide and sulfuric acid, if no formulae given<br><br>**DO NOT ALLOW** other additional reagents e.g. $AlCl_3$<br><br>**ALLOW** suitable non-specification alternative e.g. $PCl_3$, $PCl_5$, (red) phosphorus **AND** bromine **OR** iodine, $SOCl_2$<br><br>**IGNORE** concentration e.g. dilute/concentrated<br>**IGNORE** conditions e.g. reflux/distillation |

| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| 17 | (d) | | **Mark organic product first:**<br><br>A correct ester of $(CH_3)_3COH$ ✓<br>e.g. $(CH_3)_3COOCCH_3$<br><br>**Reagent and/or catalyst:**<br>Reagent to match ester shown<br><br>suitable carboxylic acid **AND** acid / $H^+$ catalyst, e.g. $CH_3COOH/H_2SO_4$<br>**OR**<br>suitable acyl chloride e.g. $CH_3COCl$<br>**OR**<br>suitable acid anhydride e.g. $(CH_3CO)_2O$ ✓ | **2** | **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous<br>**IGNORE** additional byproducts e.g. $H_2O$, HCl or carboxylic acid (from acid anhydride)<br><br>**For 2 marks**, the reagent must be consistent with the product given e.g. $(CH_3)_3COOCCH_3$ then correct reagent is $CH_3COOH$ / $H_2SO_4$<br><br>**ALLOW** 1 mark if correct reagents given but no or incorrect organic product shown<br><br>**ALLOW** 1 mark if ester is given with an R group i.e. $(CH_3)_3COOCR$ **AND** reagent is consistent e.g. RCOOH **OR** just states 'carboxylic acid and acid'<br><br>**ALLOW** names of reagents e.g. ethanoic acid and sulfuric acid.<br><br>**DO NOT ALLOW** other additional reagents e.g. $Cr_2O_7^{2-}$<br><br>**IGNORE** concentration e.g. dilute/concentrated<br>**IGNORE** conditions e.g. reflux/distillation<br><br>**IGNORE** use of acid catalyst with acyl chloride or acid anhydride |

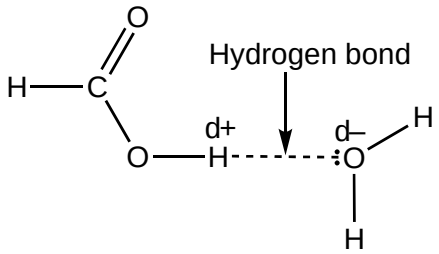
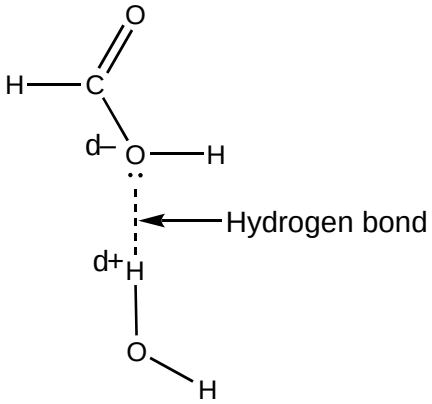
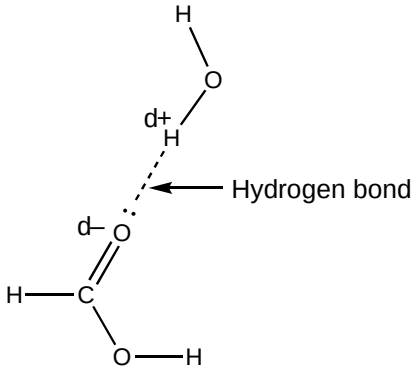
| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| 18 | (a) | (i) | **Equation**<br><br>✓<br><br>**Name**<br>Radical substitution ✓<br><br>**Bond fission**<br>homolytic (fission) ✓ | 3 | **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous<br><br>**IGNORE** mechanism, need overall equation |
| 18 | (a) | (ii) | Further substitution/s<br>**OR**<br>Different termination products<br>**OR**<br>More than one termination step<br><br>Substitution at different positions along (carbon) chain ✓ | 2 | **ALLOW** dibromo/multibromo compounds formed<br>**OR** example of further substitution product e.g $CH_2BrCBr(CH_3)_2$ / $C_4H_8Br_2$ / 1,2-dibromo-2-methylpropane<br>**OR** example of different organic termination product e.g.$C_8H_{18}$<br><br>**ALLOW** more than one H (atom) can be replaced<br>**ALLOW** radicals react with each other to form other products<br><br>**ALLOW** a hydrogen (atom) on a different carbon (atom) can be replaced<br>**ALLOW** Substitutions can occur at other carbons (along the chain)<br>**ALLOW** example of substitution at different position on chain e.g. $CH_2BrCH(CH_3)_2$ / 1-bromo-2-methylpropane<br><br>**IGNORE** references to separation of products<br>**IGNORE** references to atom economy or yield |

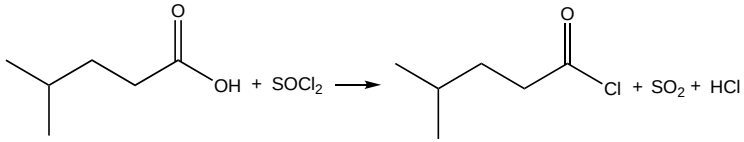
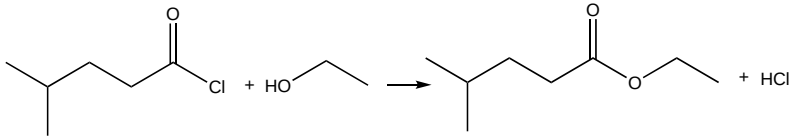
| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| 18 | (b) | |   Check has 3C not 2C | 9 | **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous<br><br>**DO NOT ALLOW** structure if H(s) are missing from **ONE** structural/displayed formula…<br>**BUT ALLOW** any further omissions as **ECF**<br><br>**ALLOW** any vertical bond to the OH **OR** $NH_2$<br> <br>**DO NOT ALLOW** OH–, **OR** $NH_2$– but **ALLOW ECF** for subsequent use in this part<br><br>**ALLOW** names of reagents e.g. ethanolic ammonia, if no formulae given<br>**DO NOT ALLOW** other additional reagents<br>**IGNORE** Conditions<br><br>**For bromoethane to amine:**<br>**IF** a secondary / tertiary amine is given **ALLOW** one mark for a correct structure **AND** one mark for an appropriate reagent to produce the amine shown.<br><br>**For bromoethane to alcohol:**<br>**ALLOW** $H_2O$<br>**IGNORE** ethanol (as a solvent)<br><br>**For bromoethane to nitrile:**<br>**DO NOT ALLOW** HCN **OR** $CN^-$ / $H^+$<br>**DO NOT ALLOW** $H_2O$ / (aq)<br><br>**For nitrile to carboxylic acid:**<br>**ALLOW** any mineral acid<br>**IGNORE** dilute/concentrated<br><br>**For nitrile to amine:**<br>**ALLOW** suitable non-specification alternative e.g. $LiAlH_4$, $H_2$ with Pd or Pt |

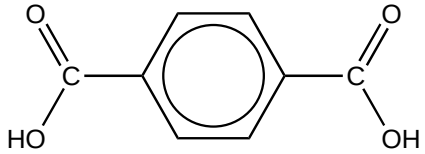
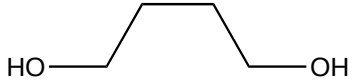
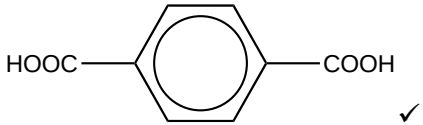
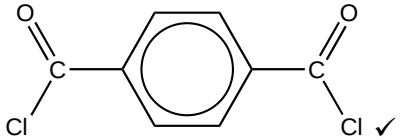
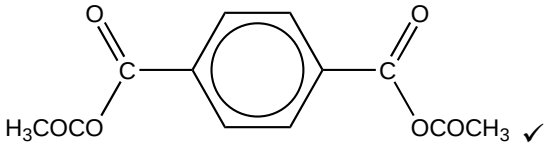
| Question | Answer | Marks | Guidance |
|---|---|---|---|
| 19* | *Refer to marking instructions on page 5 of mark scheme for guidance on marking this question*.<br><br>**Level 3 (5–6 marks)**<br>Describes addition reactions including the mechanisms of **one** alkene **AND one** carbonyl compound **AND** some additional details<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>Describes an addition reaction including the mechanism of **one** alkene **OR one** carbonyl compound **AND** some additional details<br>**OR**<br>Describes addition reactions including an attempt to give the mechanisms of **one** alkene **AND one** carbonyl compound<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>Selects suitable reagents for addition reactions of **one** alkene **AND one** carbonyl compound.<br>**OR**<br>Attempts to describe an addition reaction including an attempt to give the mechanism of **one** alkene **OR one** carbonyl compound.<br><br>*There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* | 6 | **Indicative scientific points may include:**<br><br>**<u>Reaction of alkene and mechanism</u>**<br>• Suitable reaction, e.g.<br>alkene and $Br_2$ **OR** $X_2$ **OR** HX **OR** $H_2O$ **OR** $H_2$ **OR** polymerisation<br>*May be shown within mechanism*<br>• Mechanism, e.g.<br><br><br>**ALLOW** mechanism for $H_2$ **AND** $H_2O$ to be shown as electrophilic addition even though incorrect - consider impact on communication statement.<br><br>**ALLOW** suitable non-specification alternative e.g. HCN<br><br>**Additional details (NOT INCLUSIVE)**<br>• Electrophilic addition<br>• Systematic names of reactants and/or products<br>• Details of functional group interconversion e.g. alkene to dibromo<br>• Details on reagents required e.g.<br>- $H_2$ with Ni Catalyst<br>- $H_2O(g)$ with $H_3PO_4$ catalyst<br>• Explanation of major and minor product from electrophilic addition of HX with unsymmetrical alkene<br>• Explanation of carbocation intermediate stability<br>• Heterolytic fission |

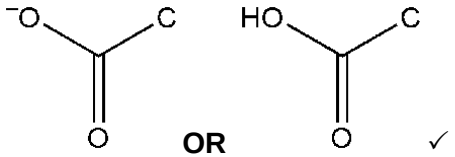
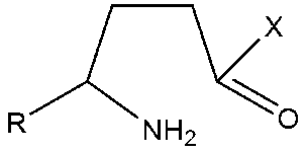
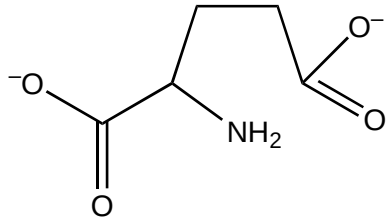
| Question | Answer | Marks | Guidance |
|---|---|---|---|
| | **0 marks** *No response or no response worthy of credit.* | | **Reaction of carbonyl compound and mechanism**<br>Suitable reactions, e.g.<br>• Aldehyde or ketone and HCN **OR** $H^-$<br>e.g. RCHO + HCN → RCH(OH)CN<br>*May be shown within mechanism*<br>• Mechanisms, e.g.<br><br>**OR** $H_2O$ instead of $H^+$ for 2nd stage<br><br>**ALLOW** suitable non-specification alternative e.g. $H_2O$, $NH_3$, 1º amine<br><br>**IGNORE** reactions with carboxylic acids (or derivatives) i.e. addition-elimination mechanism (condensation reaction)<br><br>**Additional details (NOT INCLUSIVE)**<br>• Nucleophilic addition<br>• Systematic names of reactants and/or products<br>• Details of functional group interconversion e.g. aldehyde to hydroxynitrile<br>• In reduction, aldehydes form 1º alcohols and ketones form 2º alcohols<br>• Details on reagents required e.g.<br>- formation of hydroxynitriles with NaCN/$H^+$(aq)<br>- formation of alcohols with $NaBH_4$<br>• Heterolytic fission |

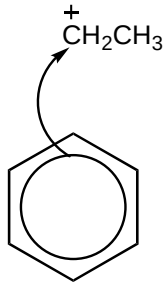
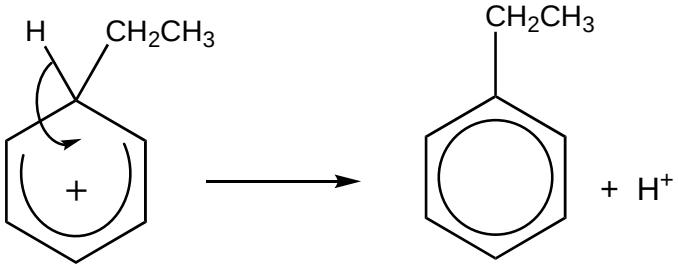
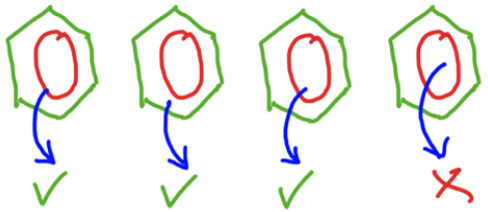
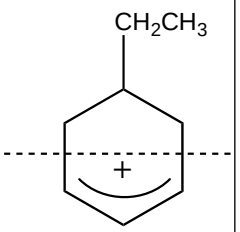
| Question | Answer | Marks | Guidance |
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| | | | Aspects of the **communication statement** being met might typically include:<br>• Curly arrows starting from lone pairs / negative charges / bonds.<br>• All reactants and intermediates have relevant charges and dipoles.<br>• Mechanisms given are chemically feasible for the reactions.<br>• No additional incorrect reactants have been included. |

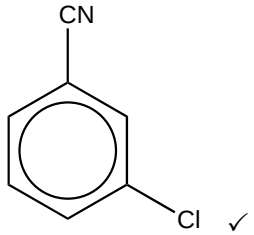
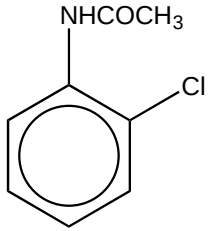
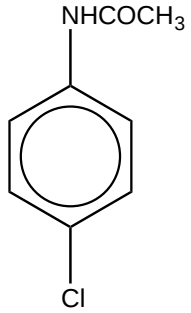
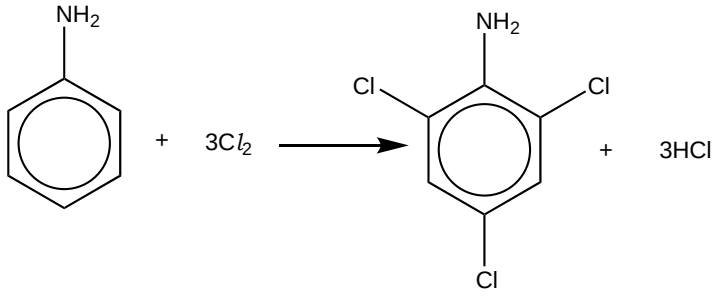
| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| 20 | (a) | | Diagram showing a hydrogen bond between a water molecule and a HCOOH *(dipoles and lone pairs not required)*<br>**AND**<br>Hydrogen bonding / H-bond stated **OR** labelled on diagram ✓<br><br><br>**OR**<br><br><br>H bond originates from lone pair on δ- O and goes to δ+ H (on another molecule) ✓ | 2 | **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous<br><br>**ALLOW** hydrogen bond to $HCOO^-$ (methanoate ion)<br>**DO NOT ALLOW** H bond from **H**–C<br>**DO NOT ALLOW** any marks for a diagram containing $O_2H$<br><br>Hydrogen bond does **NOT** need to be labelled but it must be different from the covalent bond if it is not labelled.<br><br>**IF** more than one hydrogen bond is shown they must **ALL** be correct to award each mark.<br><br>**ALLOW** H bond between C=O and $H_2O$, i.e.<br><br><br>**DO NOT ALLOW** δ+ on H atom of C-H<br>**All Hydrogen bonds must hit a lone pair**<br>**ALLOW** only one lone pair on O atom<br>**DO NOT ALLOW** more than 2 lone pairs on O atom |

| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| 20 | (b) | (i) | ethyl 4-methylpentanoate ✓ | 1 | **ALLOW** one word: ethyl4-methylpentanoate<br>**OR** more words, e.g. ethyl 4-methyl pentanoate<br><br>**DO NOT ALLOW** 1-ethyl-4-methylpentanoate<br><br>**IGNORE** lack of hyphens, extra hyphens, full stops instead of commas, extra spaces<br><br>**DO NOT ALLOW** the following for methyl:<br>methy, meth, methly, methanyl<br><br>**DO NOT ALLOW** the following for ethyl:<br>ethy, eth, ethly, ethanyl |
| 20 | (b) | (ii) | **Step 1**<br><br>**Step 2**<br><br>$SOCl_2$ used **in Step 1** ✓<br><br>Acyl chloride: $(CH_3)_2CHCH_2CH_2COCl$ correct ✓<br>*Seen anywhere*<br><br>**Step 1** correct equation ✓<br><br>**Step 2** correct equation ✓ | 4 | **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous<br>e.g. $(CH_3)_2CHCH_2CH_2COOH + SOCl_2 \rightarrow (CH_3)_2CHCH_2CH_2COCl + SO_2 + HCl$<br><br>$(CH_3)_2CHCH_2CH_2COCl + C_2H_5OH \rightarrow (CH_3)_2CHCH_2CH_2COOC_2H_5 + HCl$<br><br>**DO NOT ALLOW** incorrect connectivity on OH<br>**BUT ALLOW ECF** on subsequent structures<br><br>**ALLOW** suitable non-specification alternatives for step 1<br>e.g. $PCl_3$, $PCl_5$, $COCl_2$<br>e.g. $3(CH_3)_2CHCH_2CH_2COOH + PCl_3 \rightarrow 3(CH_3)_2CHCH_2CH_2COCl + H_3PO_3$<br><br>$(CH_3)_2CHCH_2CH_2COOH + PCl_5 \rightarrow (CH_3)_2CHCH_2CH_2COCl + POCl_3 + HCl$<br><br>$(CH_3)_2CHCH_2CH_2COOH + COCl_2 \rightarrow (CH_3)_2CHCH_2CH_2COCl + HCl + CO_2$ |

| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| 20 | (c) | |  ✓  ✓ | 2 | **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous<br>e.g. **ALLOW**<br> ✓<br>$HO–CH_2CH_2CH_2CH_2–OH$ ✓<br>**ALLOW** Diacyl chloride:<br> ✓<br>**ALLOW** a diacid anhydride of benzene-1,4-dicarboxylic acid, e.g.<br> ✓<br>**DO NOT ALLOW** incorrect connectivity on OH<br>**BUT ALLOW ECF** on subsequent structures<br>**ALLOW** correct Kekulé representation of benzene |

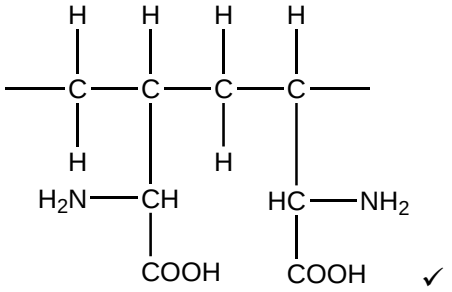
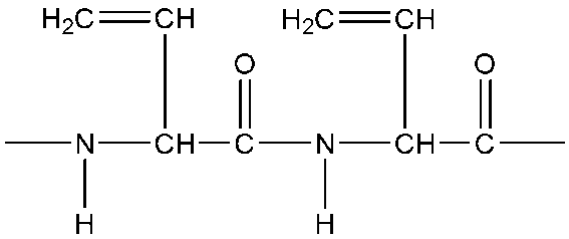
| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| 20 | (d) | | **Hydrolysis of ester:**<br>Methanol / $CH_3$–OH ✓<br><br>**Formation of carboxylate / carboxylic acid from hydrolysis of ester or amide:**<br><br>**OR** ✓<br>*C=O of Carboxylate or carboxylic acid group must be attached to a C But ignore rest of molecule*<br><br>**Hydrolysis of amide:**<br>Breaks amide bond in ring to give: ✓<br><br>*Where R can be H or any other structure*<br>*For X, ignore group attached to C=O*<br><br>**Correct hydrolysis product:**<br><br>✓ | 4 | **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous<br>**DO NOT ALLOW** incorrect connectivity on OH<br>**…BUT ALLOW ECF** on subsequent structures<br><br>**DO NOT ALLOW** $CH_3O^-$ ($Na^+$) **OR** sodium methoxide<br><br>**ALLOW** –$COO^-Na^+$ **OR** –COONa<br>**DO NOT ALLOW** esters or amides<br><br>**ALLOW** $NH_3^+$<br>**IGNORE** missing Hs on carbon chain<br><br>Must be completely correct structure<br>**ALLOW** –$COO^-Na^+$ **OR** –COONa |

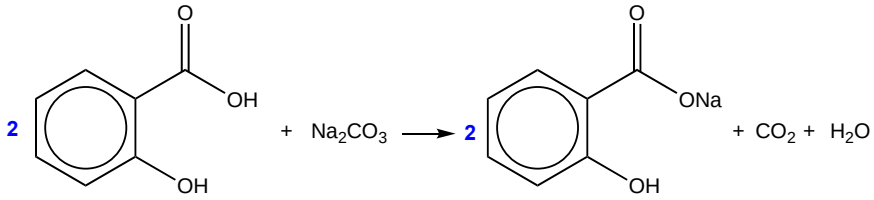
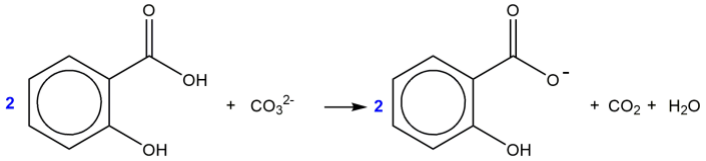
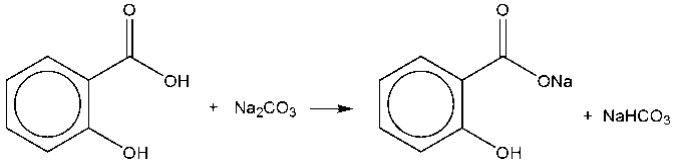
| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| 21 | | | **ALLOW correct Kekulé representation of benzene throughout question 21** | | |
| 21 | (a) | (i) | An electron pair acceptor ✓ | 1 | **ALLOW** gains an electron pair / lone pair |
| 21 | (a) | (ii) | **Generation of electrophile**<br>$AlCl_3 + CH_3CH_2Cl \longrightarrow CH_3CH_2^+ + AlCl_4^-$ ✓<br>**Electrophilic substitution**<br><br><br>Curly arrow from π-bond to $^+CH_2CH_3$ ✓<br><br><br>Correct intermediate ✓<br>Curly arrow from C–H bond to reform π-ring **AND** $H^+$ as product ✓<br>**Regeneration of catalyst**<br>$H^+ + AlCl_4^- \longrightarrow AlCl_3 + HCl$ ✓ | 5 | **ANNOTATE ANSWER WITH TICKS AND CROSSES**<br>**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous<br>**ALLOW** $C_2H_5Cl$ **AND** $C_2H_5^+$<br>**ALLOW** positive charge anywhere on $CH_2CH_3$ e.g. $CH_2CH_3^+$<br>**NOTE**: curly arrows can be straight, snake-like, etc. but **NOT** double headed or half headed arrows<br>**1st curly arrow** must<br>• start from, **OR** close to **circle of benzene ring**<br>**AND**<br>• go to anywhere on $^+CH_2CH_3$<br><br>**DO NOT ALLOW** the following intermediate:<br><br><br>π-ring should cover approximately 4 of the 6 sides of the benzene ring structure<br>**AND**<br>'horseshoe' the right way,<br>*i.e.* gap towards C with $CH_2CH_3$<br>**ALLOW** + sign anywhere inside the 'hexagon' of intermediate |

| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| 21 | (b) | (i) |  ✓<br> ✓<br> ✓ | 3 | **IGNORE** additional copies of the same structures<br>**IGNORE** connectivity to CN and $NHCOCH_3$ in products.<br>**IGNORE** $HCl$ / $H^+$<br>**IGNORE** multisubstituted products<br>**ALLOW** protonation of $NHCOCH_3$ group i.e. $NH_2^+COCH_3$<br>**ALLOW ECF** small slips on $NHCOCH_3$ e.g. extra O or missing 3 on $CH_3$ |
| 21 | (b) | (ii) | <br>Correct organic product ✓<br>Correct balanced equation✓ | 2 | **ALLOW** any trichlorophenyl amine structure<br>**ALLOW** $C_6H_2Cl_3NH_2$ **OR** $C_6H_4Cl_3N$ (allow elements in any order) for correct organic product<br>**IGNORE** incorrect structural or molecular formula **IF** correct structure is drawn<br>**ALLOW** ammonium salt of trichloro product $C_6H_2NH_3Cl_4$<br>**ALLOW** multiples for balanced equation<br>**ALLOW** 1 mark for use of $Br_2$ with a correctly balanced equation |

| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| 21 | (b) | (iii) | (In phenylamine) a (lone) pair of electrons on N is (partially) delocalised / donated into the π-system / ring ✓ | 3 | Must be clear that electrons come from N not just $NH_2$<br><br>**ALLOW** the electron pair (in the p-orbitals) on N atom becomes part of the π-system / ring<br>**ALLOW** diagram to show movement of lone pair into ring from N<br>**ALLOW** lone pair of electrons on N is (partially) drawn / attracted / pulled into π-system / ring<br>**ALLOW** lone pair on N (i.e. no reference to electrons)<br>**ALLOW** π-bond instead of π-system / ring<br><br>**DO NOT ALLOW** (two) lone pair**s** are delocalised/donated into the π-system / ring |
| | | | Electron density increases/is higher (than benzene) ✓<br>**ORA** | | **Responses must be comparative for 2nd and 3rd marking point.**<br><br>**IGNORE** activating<br>**IGNORE** charge density<br>**IGNORE** electronegativity |
| | | | (phenylamine is) **more** susceptible to electrophilic attack<br>**OR**<br>(phenylamine) attracts/accepts electrophile/$Cl_2$ **more**<br>**OR**<br>(phenylamine) polarises electrophile/$Cl_2$ **more** ✓<br>**ORA** | | **IGNORE** phenylamines react more readily with electrophiles/$Cl_2$ *(given in question)*<br><br>**ALLOW** $Cl^+$ for electrophile<br>**IGNORE** Cl for electrophile<br><br>**ALLOW** Benzene can't polarise electrophile/$Cl_2$ but phenylamine can (polarise electrophile/$Cl_2$) |

| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| 22 | (a) | | **IF** answer on answer line = 73518 **AWARD** 3 marks<br>**IF** answer on answer line = 73500 **AWARD** 2 marks<br>---<br>$M_r$ of amino acid = 165 ✓<br><br>$M_r$ of 500 molecules = 500 × 165 = 82500 ✓<br><br>$M_r$ of polymer = 82500 – (499 × 18) = 73518 ✓<br>*(final answer must be given to nearest whole number)* | 3 | **ALLOW ECF** from incorrect $M_r$ of amino acid<br><br>**Alternative method:**<br>Mr of repeat unit = 147 ✓<br>147 x 500 = 73500 ✓<br>73500 + 18 = 73518 ✓<br><br>**Common error for 2 marks**<br>36518 Use of Mr 91<br>82500 Not shown 165 in working<br><br>**Common error for 1 mark**<br>45500 Use of Mr 91 |

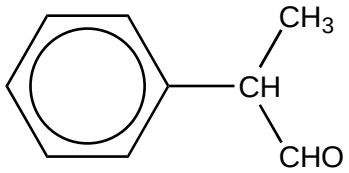
| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| 22 | (b) | | **Addition polymer**<br><br>✓<br><br>**Condensation polymer**<br><br>Amide link ✓<br><br>2 repeat units of correct polymer ✓ | **3** | For **BOTH** structures,<br>**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous<br><br>'End bonds' **MUST** be shown (with either a solid or dashed line)<br>**BUT ALLOW ECF IF** end bonds omitted in both structures<br><br>**DO NOT ALLOW** more than 2 repeat units<br>**BUT ALLOW ECF** in subsequent structure<br><br>**IGNORE** connectivity of side groups in both diagrams<br>---<br>**CARE**: **ALLOW** any consistent repeat unit:<br>side groups can alternate or be on opposite sides of chain<br><br>**ALLOW** NH in amide link i.e. without bond shown<br>**ALLOW** –NH– at either end<br><br>**IGNORE** brackets **IGNORE** *n* or subscript numbers<br><br>**ALLOW** $C_2H_3$ as side chain for condensation polymer<br>**ALLOW** 1 mark if correct structures given by wrong way round |

| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| 23 | (a) | | Idea that reflux is used to prevent loss by evaporation ✓<br><br>e.g. prevents reaction mixture boiling dry<br>e.g. prevents loss of (volatile) compounds / products / reactants<br>e.g. prevent methanol escaping | 1 | **IGNORE** responses related to rate of reaction<br>**IGNORE** responses related to ensuring complete reaction<br><br>**DO NOT ALLOW** reference to incorrect reaction e.g. oxidation, combustion (flammability) |
| 23 | (b) | (i) | **Reaction with $H_2SO_4$**<br><br>$Na_2CO_3 + H_2SO_4 \rightarrow Na_2SO_4 + CO_2 + H_2O$ ✓<br><br>**Reaction with excess G**<br><br><br><br><br>Correct organic product structure✓<br><br>Correct balanced equation ✓ | 3 | **ALLOW** multiples in both equations<br>**IGNORE** state symbols<br><br>**ALLOW** $Na_2CO_3 + 2H_2SO_4 \rightarrow 2NaHSO_4 + CO_2 + H_2O$<br>**ALLOW** ionic equation $CO_3^{2-} + 2H^+ \rightarrow CO_2 + H_2O$<br>**ALLOW** $H_2CO_3$ instead of $CO_2 + H_2O$<br><br>**ALLOW** $–COO^-$ $(Na^+)$ for product structure mark<br>**ALLOW** ionic equation<br><br><br><br>**ALLOW**<br><br><br><br>**ALLOW** $H_2CO_3$ instead of $CO_2 + H_2O$<br><br>**ALLOW** correct Kekulé representation of benzene |

| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| 23 | (b) | (ii) | (NaOH) reacts with phenol / -OH (in compound G / H)<br><br>**OR (**NaOH) would hydrolyse the ester / compound H | 1 | **IGNORE** comment about whether it improves or not<br><br>**DO NOT ALLOW** (NaOH) reacts with alcohol |
| | (c) | | **FIRST CHECK ANSWER ON ANSWER LINE**<br>**If answer = 53.8 (%) award 3 marks**<br>---<br>**Theoretical moles**<br>*n*(**H**) **OR** *n*(**G**)<br>$\frac{8.97}{138.0}$ **OR** 0.065(0) (mol) ✓<br><br>**Actual moles**<br>*n*(methyl salicylate) = $\frac{5.32}{152.0}$ **OR** 0.035(0) (mol) ✓<br><br>% yield = $\frac{0.035}{0.065} \times 100$ = 53.8% to **3 SF** ✓ | 3 | **ALLOW ECF** for each step<br>**TAKE CARE** as value written down may be truncated but with value stored in calculator, depending on rounding, either can be credited.<br><br>**IGNORE** trailing zeroes e.g. 0.065 for 0.0650<br><br>**DO NOT ALLOW ECF** for final mark if value is ≥100%<br>**DO NOT ALLOW** 59.3% **IF** no moles have been calculated for final mark<br>e.g. masses used 5.32/8.97 x 100 = 59.3%<br><br>Calculator = 53.84615385 **BUT** 3 SF required for % yield<br><br>**Alternative method using mass**<br>1. Theoretical moles = 0.065(0) mol ✓<br><br>2. Theoretical mass = 0.065 × 152.0 **OR** 9.88 g ✓<br><br>3. % yield = $\frac{5.32}{9.88} \times 100$ = 53.8% ✓ |

| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| 23 | (d) | | **Steps must be given in correct order:**<br><br>**Step 1**<br>(Add to) separating funnel ✓<br><br>(Use of) bottom layer (containing H / organic) ✓<br><br>**Step 2**<br>**Dry** with an <u>anhydrous salt</u><br>**OR**<br>**Dry** with $MgSO_4$ /magnesium sulfate **OR** $CaCl_2$ /calcium chloride ✓<br><br>**Step 3**<br>(Re)Distil at 222 ºC ✓ | 4 | **Mark each step in order but then don't mark any further if response refers to purification of a solid**<br>e.g. dissolve in minimum amount of hot solvent, evaporate off water to allow solid to crystalise<br><br>**IGNORE** use of carbonate (to remove excess acid) **OR** (saturated) NaCl<br>**ALLOW** (remove) aqueous layer on the top<br>**ALLOW** description that aqueous layer can be determined by adding water and seeing which layer increases in size<br>**IGNORE** distillation **OR** filtration prior to **step 1 OR step 2**<br><br>**ALLOW** 'to remove water' instead of 'dry'<br>**IGNORE** any other named salt, e.g. 'an anhydrous salt e.g. $CaCO_3$' is acceptable<br>**IGNORE** filtration to remove anhydrous salt after **step 2**<br><br>**ALLOW** termperature range of 220-224ºC for distillation<br>**DO NOT ALLOW** if forms a solid product |

| Question | Answer | Marks | Guidance |
|---|---|---|---|
| 24* | *Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.*<br><br>**Level 3 (5–6 marks)**<br>Structure is $C_6H_5CHCH_3CHO$<br>**AND**<br>Analyses data from **all 3** scientific points<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>Structure with **most** key features including O atom(s)<br>**AND**<br>Analyses data from **at least 2** of the scientific points<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>Attempts analysis from **at least 2** of the 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**<br>No response or no response worthy of credit. | 6 | **LOOK ON THE SPECTRA** for labelled peaks and mark as **SEEN**<br><br>**Indicative scientific points:**<br>**1. Empirical (and Molecular) Formulae**<br>• C : H : O = $\frac{80.60}{12.0}$ : $\frac{7.46}{1.0}$ : $\frac{11.94}{16.0}$<br>= 6.72 : 7.46 : 0.746<br>= 9 : 10 : 1<br>• Empirical formula = $C_9H_{10}O$<br><br>**2. Mass spectrum and IR**<br>**Mass spectrum**<br>• uses *m/z* = 134 to give molecular formula: $C_9H_{10}O$<br>• Any possible fragments:<br>- m/z = 105 $C_6H_5CHCH_3^+$<br>- m/z = 77 $C_6H_5^+$<br>- m/z = 29 $CHO^+$<br>**IR**<br>• C=O from ~1700 $cm^{-1}$<br>• Likely to be aldehyde or ketone<br>• C=C (arenes) ~1500 $cm^{-1}$<br>**ALLOW** *Data Sheet* ranges<br><br>**3. $^1$H NMR**<br>• δ = 1.4 ppm, doublet, 3H **$CH_3$**CH-<br>• δ = 3.8 ppm, quintet, 1H next to 4 adjacent H<br>• δ = 7.3 ppm, singlet, 5H **$C_6H_5$-**<br>• δ = 9.0 ppm, doublet, 1H **-**CH**CHO**<br><br>**ALLOW** approximate values for chemical shifts |

| | | | |
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| | | | **Structure**<br>**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous<br>**ALLOW** correct Kekulé representation of benzene<br><br>**Key features**<br>• Benzene ring<br>• C=O<br>• $CH_3$<br><br>**Correct structure**<br><br>• ($C_6H_5CHCH_3CHO$)<br><br>Aspects of the **communication statement** being met might typically include:<br>• Structures given are feasible and unambiguous<br>• Easy to follow layout on empirical formula calculation<br>• Empirical formula is shown to be same as molecular<br>• IR peaks linked clearly to bond it refers to not just functional groups<br>• Positive charge given on MS fragments<br>• MS fragments plausible for the molecular formula determined<br>• Clear information for each NMR peak<br>• No additional irrelevant/incorrect information given |

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