

Synthesis and analytical techniques

June 2024 exam series

MARK SCHEME

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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 

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 HCl
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. e.g. ALLOW 1,3-dimethyl-4-ethylbenzene 2,4-dimethylethylbenzene ethyl-2,4-dimethylbenzene 2,4-dimethyl-1-ethylbenzene IGNORE alphabetical order of methyl and ethyl IGNORE lack of hyphens, extra hyphens, full stops instead of commas, extra spaces DO NOT ALLOW 1,5-dimethyl-2-ethylbenzene OR 1,3-dimethyl-6-ethylbenzene <i>Needs smallest numbers</i> DO NOT ALLOW the following for dimethyl: dimethy, dimeth, dimethly, dimethanyl DO NOT ALLOW the following for ethyl: ethy, eth, ethly, ethanyl

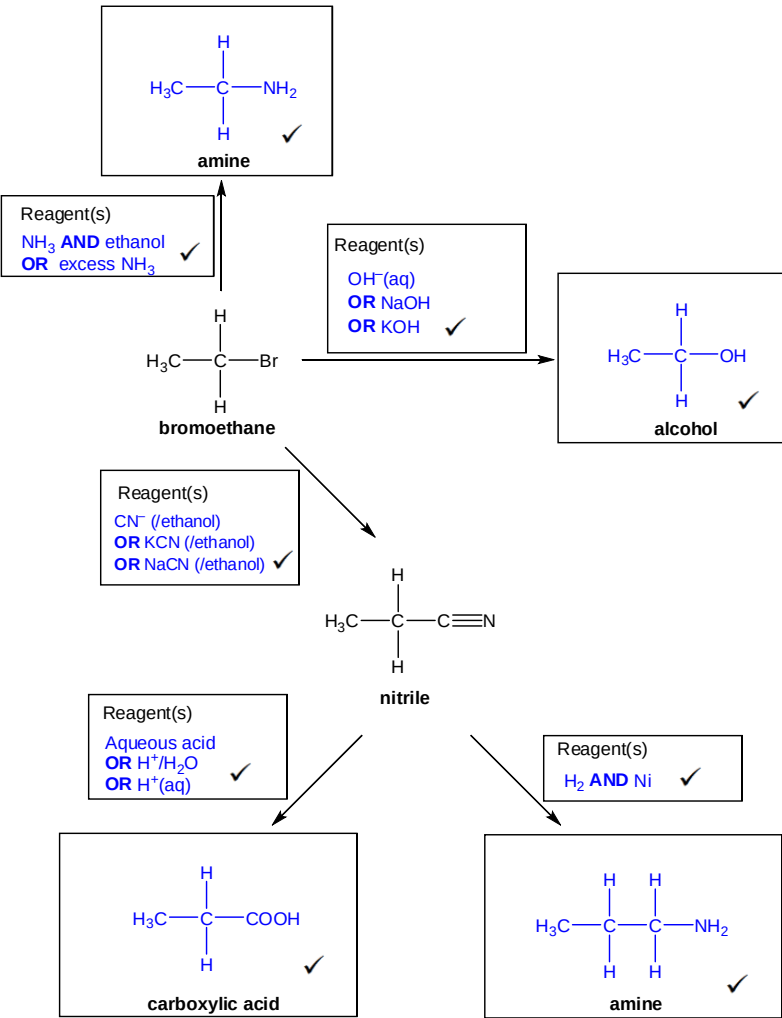
Question			Answer	Marks	Guidance
16	(e)		Priority groups are on the same side (Highest) priority groups are CH₃ AND C₂H₅ OR Low(est) priority groups CH₃ AND H	2	ALLOW suitable alternatives to ‘priority’ e.g. Groups with highest atomic number or more important groups or major groups etc. IGNORE references to (relative) mass of groups including Ar or Mr ALLOW suitable alternatives to ‘same side’ e.g. priority groups are both on the top OR above the C=C IGNORE priority groups in same plane OR adjacent IGNORE Use of ‘molecules’ instead of groups ALLOW identification by name e.g. ethyl and methyl IF ‘priority’ is not mentioned ALLOW one mark for ‘CH₃CH₂ and CH₃ are on same side’ OR ‘H and CH₃ are on same side’

Question		Answer	Marks	Guidance
17	(a)	Reagent and/or catalyst: H_2SO_4 OR H_3PO_4 OR H^+ OR acid (catalyst) ✓ Organic product: (mark independently) $\text{CH}_3\text{CH}_2\text{CHCH}_2$ ✓	2	DO NOT ALLOW other named acids e.g. HCl / hydrochloric acid as can be used for substitution reaction DO NOT ALLOW other additional reagents e.g. H_2O / steam, H_2 / hydrogen ALLOW suitable non-specification alternatives e.g. Al_2O_3 OR Pumice stone ALLOW names of reagents e.g. sulfuric or phosphoric acid, if no formulae given IGNORE concentration e.g. dilute/concentrated IGNORE (aq) state symbol IGNORE conditions e.g. temperature/pressure/reflux ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous IGNORE names unless no structure is given then accept but-1-ene
17	(b)	Reagent and/or catalyst: $\text{K}_2\text{Cr}_2\text{O}_7$ AND H_2SO_4 OR $\text{Cr}_2\text{O}_7^{2-}/\text{H}^+$ ✓ Organic product: (mark independently) $\text{CH}_3\text{CH}_2\text{COCH}_3$ ✓	2	ALLOW $\text{Na}_2\text{Cr}_2\text{O}_7$ for $\text{K}_2\text{Cr}_2\text{O}_7$ ALLOW names for reagents e.g. acidified dichromate, if no formulae given IGNORE Roman numerals e.g. (VI), unless incorrect IGNORE [O] DO NOT ALLOW other named acids e.g. HCl / hydrochloric acid DO NOT ALLOW other additional reagents e.g. H_2O, steam ALLOW suitable non-specification alternative oxidising agents e.g. KMnO_4/H^+ OR CrO_3/H^+ OR H_2CrO_4 (chromic acid) IGNORE concentration e.g. dilute/concentrated IGNORE conditions e.g. reflux/distillation ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous IGNORE names unless no structure is given then accept butanone

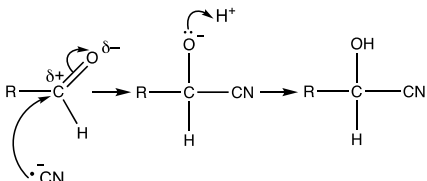
Question		Answer	Marks	Guidance
17	(c)	Mark organic product first: $(\text{CH}_3)_2\text{CHCH}_2\text{X}$ where X is identified as Cl, Br, I ✓ Reagent and/or catalyst: Reagent to match organic product NaX / KX / X⁻ AND H₂SO₄ / H⁺ / acid Where X is identified as Cl, Br, I ✓	2	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous 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) For 2 marks, the reagent must be consistent with the product given e.g. $(\text{CH}_3)_2\text{CHCH}_2\text{Cl}$ then correct reagent is NaCl / H₂SO₄ ALLOW 1 mark if correct reagents given but no or incorrect organic product shown ALLOW 1 mark if organic product is given with X i.e. $(\text{CH}_3)_2\text{CHCH}_2\text{X}$ AND reagent is consistent e.g. NaX / H⁺ OR just states 'halide with acid' ALLOW HX where X is identified as Cl, Br, I ALLOW names of reagents e.g. sodium bromide and sulfuric acid, if no formulae given DO NOT ALLOW other additional reagents e.g. AlCl₃ ALLOW suitable non-specification alternative e.g. PCl₃, PCl₅, (red) phosphorus AND bromine OR iodine, SOCl₂ IGNORE concentration e.g. dilute/concentrated IGNORE conditions e.g. reflux/distillation

Question	Answer	Marks	Guidance
17 (d)	Mark organic product first: A correct ester of $(\text{CH}_3)_3\text{COH}$ ✓ e.g. $(\text{CH}_3)_3\text{COOCCH}_3$ Reagent and/or catalyst: Reagent to match ester shown suitable carboxylic acid AND acid / H^+ catalyst, e.g. $\text{CH}_3\text{COOH}/\text{H}_2\text{SO}_4$ OR suitable acyl chloride e.g. CH_3COCl OR suitable acid anhydride e.g. $(\text{CH}_3\text{CO})_2\text{O}$ ✓	2	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous IGNORE additional byproducts e.g. H_2O, HCl or carboxylic acid (from acid anhydride) For 2 marks, the reagent must be consistent with the product given e.g. $(\text{CH}_3)_3\text{COOCCH}_3$ then correct reagent is $\text{CH}_3\text{COOH} / \text{H}_2\text{SO}_4$ ALLOW 1 mark if correct reagents given but no or incorrect organic product shown ALLOW 1 mark if ester is given with an R group i.e. $(\text{CH}_3)_3\text{COOCR}$ AND reagent is consistent e.g. RCOOH OR just states 'carboxylic acid and acid' ALLOW names of reagents e.g. ethanoic acid and sulfuric acid. DO NOT ALLOW other additional reagents e.g. $\text{Cr}_2\text{O}_7^{2-}$ IGNORE concentration e.g. dilute/concentrated IGNORE conditions e.g. reflux/distillation IGNORE use of acid catalyst with acyl chloride or acid anhydride

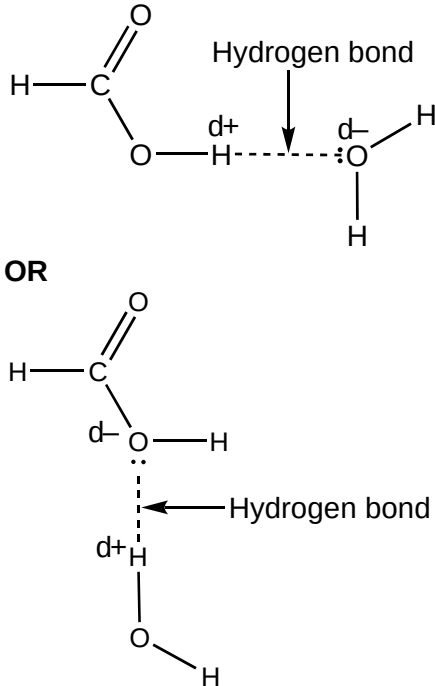
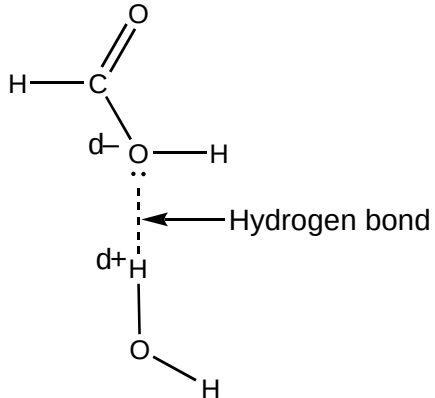
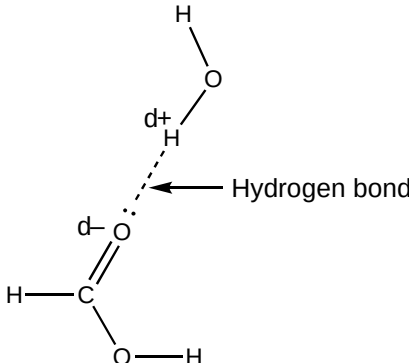
Question			Answer	Marks	Guidance
18	(a)	(i)	Equation $ \begin{array}{c} \text{H} & \text{H} & \text{H} \\ & & \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{H} \\ & & \\ \text{H} & \text{CH}_3 & \text{H} \end{array} + \text{Br}_2 \longrightarrow \begin{array}{c} \text{H} & \text{Br} & \text{H} \\ & & \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{H} \\ & & \\ \text{H} & \text{CH}_3 & \text{H} \end{array} + \text{HBr} \quad \checkmark $ Name Radical substitution ✓ Bond fission homolytic (fission) ✓	3	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous IGNORE mechanism, need overall equation
18	(a)	(ii)	Further substitution/s OR Different termination products OR More than one termination step Substitution at different positions along (carbon) chain ✓	2	ALLOW dibromo/multibromo compounds formed OR example of further substitution product e.g. $\text{CH}_2\text{BrCBr}(\text{CH}_3)_2$ / $\text{C}_4\text{H}_8\text{Br}_2$ / 1,2-dibromo-2-methylpropane OR example of different organic termination product e.g. C_8H_{18} ALLOW more than one H (atom) can be replaced ALLOW radicals react with each other to form other products ALLOW a hydrogen (atom) on a different carbon (atom) can be replaced ALLOW Substitutions can occur at other carbons (along the chain) ALLOW example of substitution at different position on chain e.g. $\text{CH}_2\text{BrCH}(\text{CH}_3)_2$ / 1-bromo-2-methylpropane IGNORE references to separation of products IGNORE references to atom economy or yield

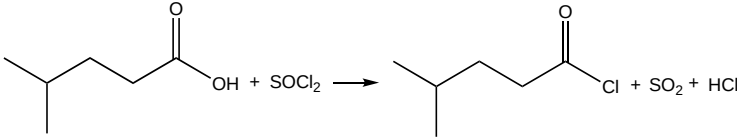
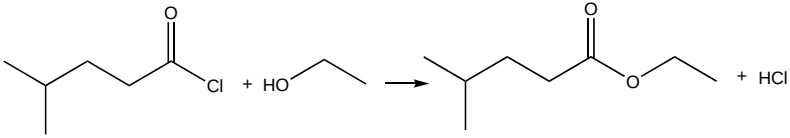
Question	Answer	Marks	Guidance
18 (b)	 Reagent(s) NH₃ AND ethanol OR excess NH₃ ✓ Reagent(s) OH⁻(aq) OR NaOH OR KOH ✓ Reagent(s) CN⁻ (/ethanol) OR KCN (/ethanol) OR NaCN (/ethanol) ✓ Reagent(s) Aqueous acid OR H⁺/H₂O OR H⁺(aq) ✓ Reagent(s) H₂ AND Ni ✓ amine alcohol carboxylic acid amine Check has 3C not 2C	9	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous DO NOT ALLOW structure if H(s) are missing from ONE structural/displayed formula... BUT ALLOW any further omissions as ECF ALLOW any vertical bond to the OH OR NH₂ OH OR HO AND NH₂ OR H₂N DO NOT ALLOW OH⁻, OR NH₂⁻ but ALLOW ECF for subsequent use in this part ALLOW names of reagents e.g. ethanolic ammonia, if no formulae given DO NOT ALLOW other additional reagents IGNORE Conditions For bromoethane to amine: 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. For bromoethane to alcohol: ALLOW H₂O IGNORE ethanol (as a solvent) For bromoethane to nitrile: DO NOT ALLOW HCN OR CN⁻ / H⁺ DO NOT ALLOW H₂O / (aq) For nitrile to carboxylic acid: ALLOW any mineral acid IGNORE dilute/concentrated For nitrile to amine: ALLOW suitable non-specification alternative e.g. LiAlH₄, H₂ with Pd or Pt

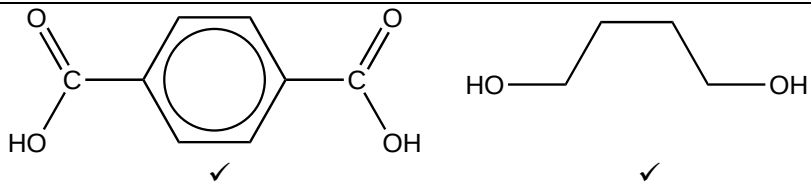
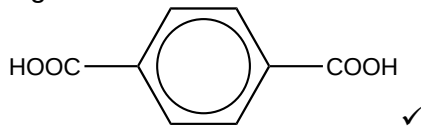
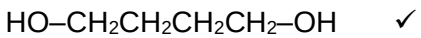
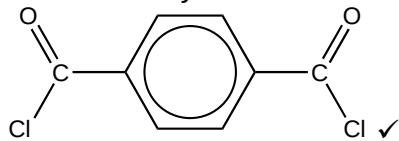
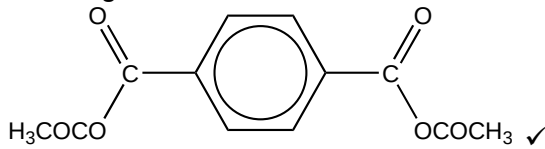
Question	Answer	Marks	Guidance
19*	Refer to marking instructions on page 5 of mark scheme for guidance on marking this question. Level 3 (5–6 marks) Describes addition reactions including the mechanisms of one alkene AND one carbonyl compound AND some additional details <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Describes an addition reaction including the mechanism of one alkene OR one carbonyl compound AND some additional details OR Describes addition reactions including an attempt to give the mechanisms of one alkene AND one carbonyl compound <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1–2 marks) Selects suitable reagents for addition reactions of one alkene AND one carbonyl compound. OR Attempts to describe an addition reaction including an attempt to give the mechanism of one alkene OR one carbonyl compound. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i>	6	Indicative scientific points may include: Reaction of alkene and mechanism - Suitable reaction, e.g. alkene and Br₂ OR X₂ OR HX OR H₂O OR H₂ OR polymerisation <i>May be shown within mechanism</i> - Mechanism, e.g. ALLOW mechanism for H₂ AND H₂O to be shown as electrophilic addition even though incorrect - consider impact on communication statement. ALLOW suitable non-specification alternative e.g. HCN Additional details (NOT INCLUSIVE) - Electrophilic addition - Systematic names of reactants and/or products - Details of functional group interconversion e.g. alkene to dibromo - Details on reagents required e.g. - H₂ with Ni Catalyst - H₂O(g) with H₃PO₄ catalyst - Explanation of major and minor product from electrophilic addition of HX with unsymmetrical alkene - Explanation of carbocation intermediate stability - Heterolytic fission

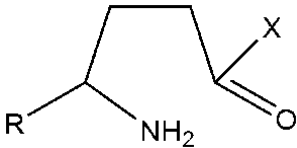
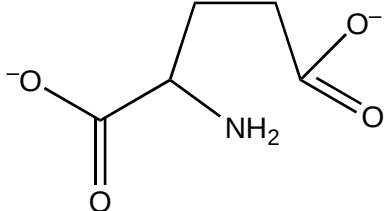
Question	Answer	Marks	Guidance
	0 marks No response or no response worthy of credit.		<u>Reaction of carbonyl compound and mechanism</u> Suitable reactions, e.g. - Aldehyde or ketone and HCN OR H^- e.g. $\text{RCHO} + \text{HCN} \rightarrow \text{RCH(OH)CN}$ <i>May be shown within mechanism</i> - Mechanisms,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

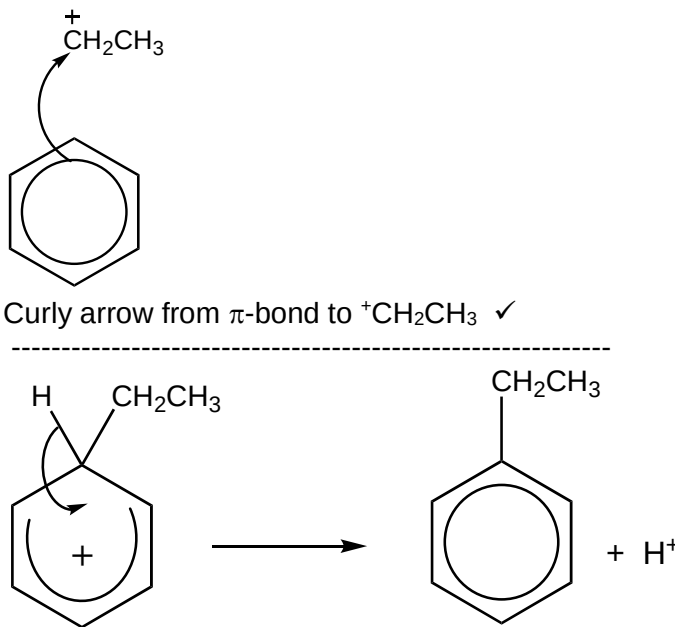
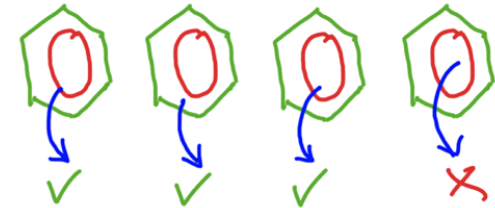
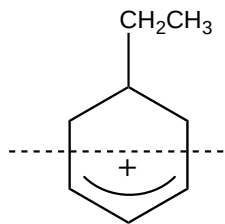
Question	Answer	Marks	Guidance
			Aspects of the communication statement being met might typically include: • Curly arrows starting from lone pairs / negative charges / bonds. • All reactants and intermediates have relevant charges and dipoles. • Mechanisms given are chemically feasible for the reactions.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

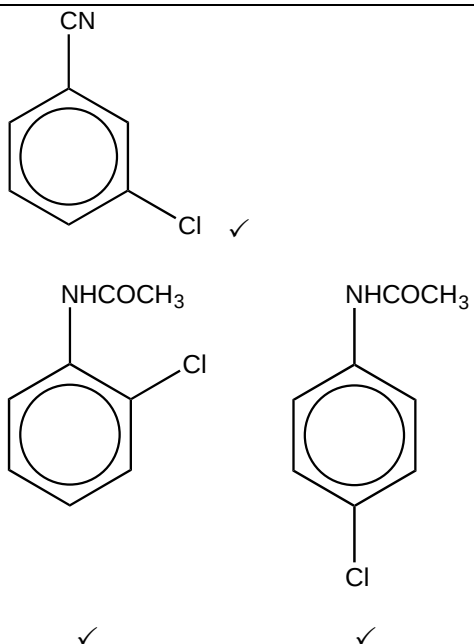
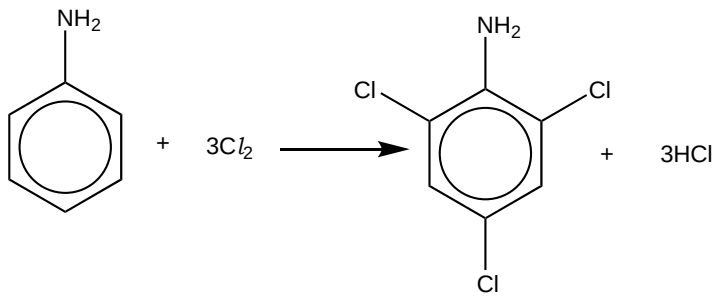
Question	Answer	Marks	Guidance
20 (a)	Diagram showing a hydrogen bond between a water molecule and a HCOOH (<i>dipoles and lone pairs not required</i>) AND Hydrogen bonding / H-bond stated OR labelled on diagram ✓  OR  H bond originates from lone pair on δ- O and goes to δ+ H (on another molecule) ✓	2	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous ALLOW hydrogen bond to HCOO⁻ (methanoate ion) DO NOT ALLOW H bond from H-C DO NOT ALLOW any marks for a diagram containing O₂H Hydrogen bond does NOT need to be labelled but it must be different from the covalent bond if it is not labelled. IF more than one hydrogen bond is shown they must ALL be correct to award each mark. ALLOW H bond between C=O and H₂O, i.e.  DO NOT ALLOW δ+ on H atom of C-H All Hydrogen bonds must hit a lone pair ALLOW only one lone pair on O atom 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 OR more words, e.g. ethyl 4-methyl pentanoate DO NOT ALLOW 1-ethyl-4-methylpentanoate IGNORE lack of hyphens, extra hyphens, full stops instead of commas, extra spaces DO NOT ALLOW the following for methyl: methy, meth, methly, methanyl DO NOT ALLOW the following for ethyl: ethy, eth, ethly, ethanyl
20 (b) (ii)	Step 1  Step 2  SOCl₂ used in Step 1 ✓ Acyl chloride: (CH₃)₂CHCH₂CH₂COCl correct ✓ <i>Seen anywhere</i> Step 1 correct equation ✓ Step 2 correct equation ✓	4	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous e.g. (CH₃)₂CHCH₂CH₂COOH + SOCl₂ → (CH₃)₂CHCH₂CH₂COCl + SO₂ + HCl (CH₃)₂CHCH₂CH₂COCl + C₂H₅OH → (CH₃)₂CHCH₂CH₂COOC₂H₅ + HCl DO NOT ALLOW incorrect connectivity on OH BUT ALLOW ECF on subsequent structures ALLOW suitable non-specification alternatives for step 1 e.g. PCl₃, PCl₅, COCl₂ e.g. 3(CH₃)₂CHCH₂CH₂COOH + PCl₃ → 3(CH₃)₂CHCH₂CH₂COCl + H₃PO₃ (CH₃)₂CHCH₂CH₂COOH + PCl₅ → (CH₃)₂CHCH₂CH₂COCl + POCl₃ + HCl (CH₃)₂CHCH₂CH₂COOH + COCl₂ → (CH₃)₂CHCH₂CH₂COCl + HCl + CO₂

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

Question	Answer	Marks	Guidance
20 (d)	Hydrolysis of ester: Methanol / CH₃–OH ✓ Formation of carboxylate / carboxylic acid from hydrolysis of ester or amide: $\begin{array}{c} \text{O}^- \\ \\ \text{C} \\ \\ \text{O} \end{array}$ OR $\begin{array}{c} \text{HO} \\ \\ \text{C} \\ \\ \text{O} \end{array}$ ✓ <i>C=O of Carboxylate or carboxylic acid group must be attached to a C But ignore rest of molecule</i> Hydrolysis of amide: Breaks amide bond in ring to give: ✓  <i>Where R can be H or any other structure For X, ignore group attached to C=O</i> Correct hydrolysis product:  ✓	4	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous DO NOT ALLOW incorrect connectivity on OH ...BUT ALLOW ECF on subsequent structures DO NOT ALLOW CH₃O[–] (Na⁺) OR sodium methoxide ALLOW –COO[–]Na⁺ OR –COONa DO NOT ALLOW esters or amides ALLOW NH₃⁺ IGNORE missing Hs on carbon chain Must be completely correct structure ALLOW –COO[–]Na⁺ OR –COONa

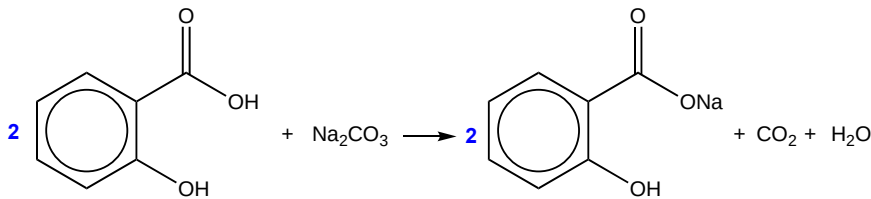
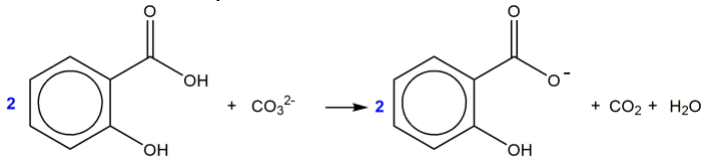
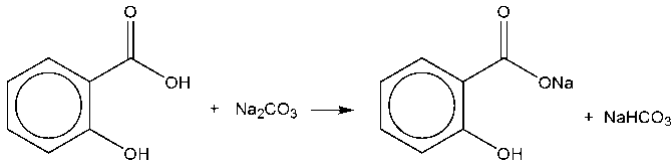
Question	Answer	Marks	Guidance
21			ALLOW correct Kekulé representation of benzene throughout question 21
21 (a) (i)	An electron pair acceptor ✓	1	ALLOW gains an electron pair / lone pair
21 (a) (ii)	Generation of electrophile $AlCl_3 + CH_3CH_2Cl \longrightarrow CH_3CH_2^+ + AlCl_4^-$ ✓ Electrophilic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

Question			Answer	Marks	Guidance
21	(b)	(i)		3	IGNORE additional copies of the same structures IGNORE connectivity to CN and NHCOCH₃ in products. IGNORE HCl / H⁺ IGNORE multisubstituted products ALLOW protonation of NHCOCH₃ group i.e. NH₂⁺COCH₃ ALLOW ECF small slips on NHCOCH₃ e.g. extra O or missing 3 on CH₃
21	(b)	(ii)	 Correct organic product ✓ Correct balanced equation ✓	2	ALLOW any trichlorophenyl amine structure ALLOW C₆H₂Cl₃NH₂ OR C₆H₄Cl₃N (allow elements in any order) for correct organic product IGNORE incorrect structural or molecular formula IF correct structure is drawn ALLOW ammonium salt of trichloro product C₆H₂NH₃Cl₄ ALLOW multiples for balanced equation ALLOW 1 mark for use of Br₂ 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 ✓ Electron density increases/is higher (than benzene) ✓ ORA (phenylamine is) more susceptible to electrophilic attack OR (phenylamine) attracts/accepts electrophile/Cl_2 more OR (phenylamine) polarises electrophile/Cl_2 more ✓ ORA	3	Must be clear that electrons come from N not just NH_2 ALLOW the electron pair (in the p-orbitals) on N atom becomes part of the π-system / ring ALLOW diagram to show movement of lone pair into ring from N ALLOW lone pair of electrons on N is (partially) drawn / attracted / pulled into π-system / ring ALLOW lone pair on N (i.e. no reference to electrons) ALLOW π-bond instead of π-system / ring DO NOT ALLOW (two) lone pairs are delocalised/donated into the π-system / ring Responses must be comparative for 2nd and 3rd marking point. IGNORE activating IGNORE charge density IGNORE electronegativity IGNORE phenylamines react more readily with electrophiles/Cl_2 (<i>given in question</i>) ALLOW Cl^+ for electrophile IGNORE Cl for electrophile 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 IF answer on answer line = 73500 AWARD 2 marks ----- M_r of amino acid = 165 ✓ M_r of 500 molecules = $500 \times 165 = 82500$ ✓ M_r of polymer = $82500 - (499 \times 18) = 73518$ ✓ <i>(final answer must be given to nearest whole number)</i>	3	ALLOW ECF from incorrect M_r of amino acid Alternative method: M_r of repeat unit = 147 ✓ $147 \times 500 = 73500$ ✓ $73500 + 18 = 73518$ ✓ Common error for 2 marks 36518 Use of M_r 91 82500 Not shown 165 in working Common error for 1 mark 45500 Use of M_r 91

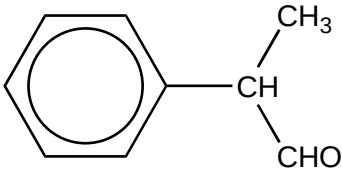
Question	Answer	Marks	Guidance
22 (b)	Addition polymer $ \begin{array}{cccc} \text{H} & \text{H} & \text{H} & \text{H} \\ & & & \\ -\text{C} & -\text{C} & -\text{C} & -\text{C}- \\ & & & \\ \text{H} & \text{H}_2\text{N}-\text{CH} & \text{H} & \text{HC}-\text{NH}_2 \\ & & & \\ & \text{COOH} & & \text{COOH} \end{array} $ ✓ Condensation polymer $ \begin{array}{ccccccc} \text{H}_2\text{C}=\text{CH} & & \text{H}_2\text{C}=\text{CH} & & & & \\ & & & & & & \\ -\text{N}-\text{CH}-\text{C}(=\text{O})-\text{N}-\text{CH}-\text{C}(=\text{O})- \\ & & & & & & \\ \text{H} & & \text{H} & & & & \end{array} $ Amide link ✓ 2 repeat units of correct polymer ✓	3	For BOTH structures, ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous ‘End bonds’ MUST be shown (with either a solid or dashed line) BUT ALLOW ECF IF end bonds omitted in both structures DO NOT ALLOW more than 2 repeat units BUT ALLOW ECF in subsequent structure IGNORE connectivity of side groups in both diagrams ----- CARE: ALLOW any consistent repeat unit: side groups can alternate or be on opposite sides of chain ALLOW NH in amide link i.e. without bond shown ALLOW –NH– at either end IGNORE brackets IGNORE <i>n</i> or subscript numbers ALLOW C₂H₃ as side chain for condensation polymer 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 ✓ e.g. prevents reaction mixture boiling dry e.g. prevents loss of (volatile) compounds / products / reactants e.g. prevent methanol escaping	1	IGNORE responses related to rate of reaction IGNORE responses related to ensuring complete reaction DO NOT ALLOW reference to incorrect reaction e.g. oxidation, combustion (flammability)
23 (b) (i)	Reaction with H₂SO₄ $\text{Na}_2\text{CO}_3 + \text{H}_2\text{SO}_4 \rightarrow \text{Na}_2\text{SO}_4 + \text{CO}_2 + \text{H}_2\text{O}$ ✓ Reaction with excess G  Correct organic product structure ✓ Correct balanced equation ✓	3	ALLOW multiples in both equations IGNORE state symbols ALLOW $\text{Na}_2\text{CO}_3 + 2\text{H}_2\text{SO}_4 \rightarrow 2\text{NaHSO}_4 + \text{CO}_2 + \text{H}_2\text{O}$ ALLOW ionic equation $\text{CO}_3^{2-} + 2\text{H}^+ \rightarrow \text{CO}_2 + \text{H}_2\text{O}$ ALLOW H_2CO_3 instead of $\text{CO}_2 + \text{H}_2\text{O}$ ALLOW $-\text{COO}^- (\text{Na}^+)$ for product structure mark ALLOW ionic equation  ALLOW  ALLOW H_2CO_3 instead of $\text{CO}_2 + \text{H}_2\text{O}$ ALLOW correct Kekulé representation of benzene

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

Question		Answer	Marks	Guidance
23	(d)	Steps must be given in correct order: Step 1 (Add to) separating funnel ✓ (Use of) bottom layer (containing H / organic) ✓ Step 2 Dry with an <u>anhydrous salt</u> OR Dry with MgSO_4 /magnesium sulfate OR CaCl_2 /calcium chloride ✓ Step 3 (Re)Distil at 222 °C ✓	4	Mark each step in order but then don't mark any further if response refers to purification of a solid e.g. dissolve in minimum amount of hot solvent, evaporate off water to allow solid to crystallise IGNORE use of carbonate (to remove excess acid) OR (saturated) NaCl ALLOW (remove) aqueous layer on the top ALLOW description that aqueous layer can be determined by adding water and seeing which layer increases in size IGNORE distillation OR filtration prior to step 1 OR step 2 ALLOW 'to remove water' instead of 'dry' IGNORE any other named salt, e.g. 'an anhydrous salt e.g. CaCO_3' is acceptable IGNORE filtration to remove anhydrous salt after step 2 ALLOW temperature range of 220-224°C for distillation 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. Level 3 (5–6 marks) Structure is $\text{C}_6\text{H}_5\text{CHCH}_3\text{CHO}$ AND Analyses data from all 3 scientific points <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Structure with most key features including O atom(s) AND Analyses data from at least 2 of the scientific points <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1–2 marks) Attempts analysis from at least 2 of the scientific points <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit.	6	LOOK ON THE SPECTRA for labelled peaks and mark as SEEN Indicative scientific points: <u>1. Empirical (and Molecular) Formulae</u> $\text{C} : \text{H} : \text{O} = \frac{80.60}{12.0} : \frac{7.46}{1.0} : \frac{11.94}{16.0}$ $= 6.72 : 7.46 : 0.746$ $= 9 : 10 : 1$ - Empirical formula = $\text{C}_9\text{H}_{10}\text{O}$ <u>2. Mass spectrum and IR</u> Mass spectrum - uses $m/z = 134$ to give molecular formula: $\text{C}_9\text{H}_{10}\text{O}$ - Any possible fragments: $m/z = 105$ $\text{C}_6\text{H}_5\text{CHCH}_3^+$ $m/z = 77$ C_6H_5^+ $m/z = 29$ CHO^+ IR $\text{C}=\text{O}$ from $\sim 1700 \text{ cm}^{-1}$ - Likely to be aldehyde or ketone $\text{C}=\text{C}$ (arenes) $\sim 1500 \text{ cm}^{-1}$ ALLOW Data Sheet ranges <u>3. ^1H NMR</u> $\delta = 1.4$ ppm, doublet, 3H $\text{CH}_3\text{CH}-$ $\delta = 3.8$ ppm, quintet, 1H next to 4 adjacent H $\delta = 7.3$ ppm, singlet, 5H C_6H_5- $\delta = 9.0$ ppm, doublet, 1H $-\text{CHCHO}$ ALLOW approximate values for chemical shifts

		Structure ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous ALLOW correct Kekulé representation of benzene Key features • Benzene ring • C=O • CH₃ Correct structure  • (C₆H₅CHCH₂CHO) Aspects of the communication statement being met might typically include: • Structures given are feasible and unambiguous • Easy to follow layout on empirical formula calculation • Empirical formula is shown to be same as molecular • IR peaks linked clearly to bond it refers to not just functional groups • Positive charge given on MS fragments • MS fragments plausible for the molecular formula determined • Clear information for each NMR peak • No additional irrelevant/incorrect information given
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