



GCE

Chemistry A

H432/02: Synthesis and analytical techniques

A Level

Mark Scheme for June 2025

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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. These are available in RM Assessor
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 40% 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 or the RM Assessor messaging system, or by email.
5. **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).

Team Leaders must confirm the correct use of the NR button with their markers before live marking commences and should check this when reviewing scripts.

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 e-mail.

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 **17*** and **23(b)***.

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. a candidate has 6 marks, so they would have this annotation on their script:

L3

If a candidate has achieved 5 marks then they have reached Level 3 but with one mark omitted. 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 

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11. Annotations

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

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Annotation	Meaning
	Ignore
	Blank page

12. Subject Specific Marking Instructions

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

Annotation	Meaning
/; OR	alternative and acceptable answers for the same marking point
✓	Separates marking points
DO NOT ALLOW	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
()	Words which are not essential to gain credit
—	Underlined words must be present in answer to score a mark
ECF	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

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.

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SECTION A

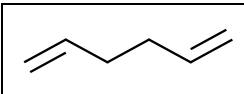
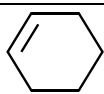
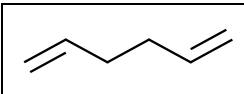
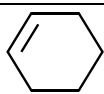
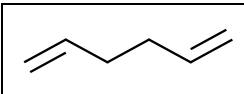
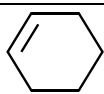
Question	Answer	Marks	Guidance
1	C	1	
2	B	1	
3	C	1	ALLOW 17
4	A	1	
5	B	1	
6	A	1	
7	B	1	
8	C	1	
9	D	1	ALLOW A
10	D	1	ALLOW 8
11	A	1	
12	A	1	
13	B	1	
14	B	1	
15	D	1	
	Total	15	

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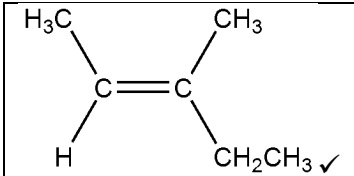
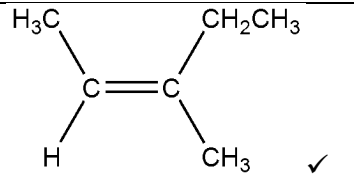
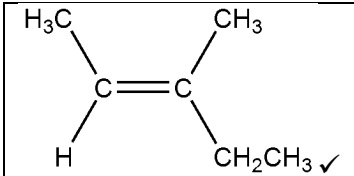
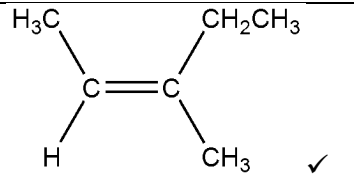
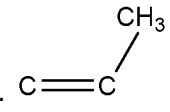
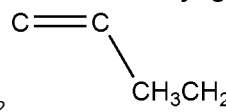
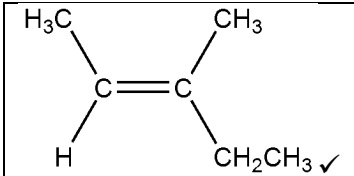
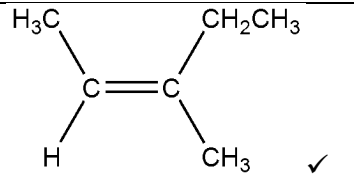
SECTION B

Question			Answer	Mark	Guidance												
16	(a)		2-methylpent-2-ene ✓	1	IGNORE lack of hyphens, or addition of commas DO NOT ALLOW the following for methyl: methy, meth, methly, methyle, methanyl DO NOT ALLOW 2-methylpentan-2-ene												
16	(b)		<table><tr><td></td><td></td><td></td></tr><tr><td>Molecular formula</td><td>C₆H₁₀</td><td>C₆H₁₀</td></tr><tr><td>Number of σ bonds</td><td>15</td><td>16</td></tr><tr><td>Number of π bonds</td><td>2</td><td>1</td></tr></table> One row correct ✓ Two rows correct ✓✓ Three rows correct ✓✓✓				Molecular formula	C ₆ H ₁₀	C ₆ H ₁₀	Number of σ bonds	15	16	Number of π bonds	2	1	3	One mark per row If no other marks awarded, ALLOW 1 mark for a correct column
																	
Molecular formula	C ₆ H ₁₀	C ₆ H ₁₀															
Number of σ bonds	15	16															
Number of π bonds	2	1															

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Question			Answer	Mark	Guidance				
16	(c)	(i)	<table><tr><td></td><td></td></tr><tr><td>E</td><td>Z</td></tr></table>			E	Z	2	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous ALLOW one mark if both stereoisomers of compound A are shown but in the incorrect columns ALLOW –C₂H₅ for ethyl group ALLOW connectivity to any part of methyl or CH₂ in ethyl e.g.  BUT DO NOT ALLOW ethyl group bonded via CH₃  e.g. -CH₃CH₂
									
E	Z								

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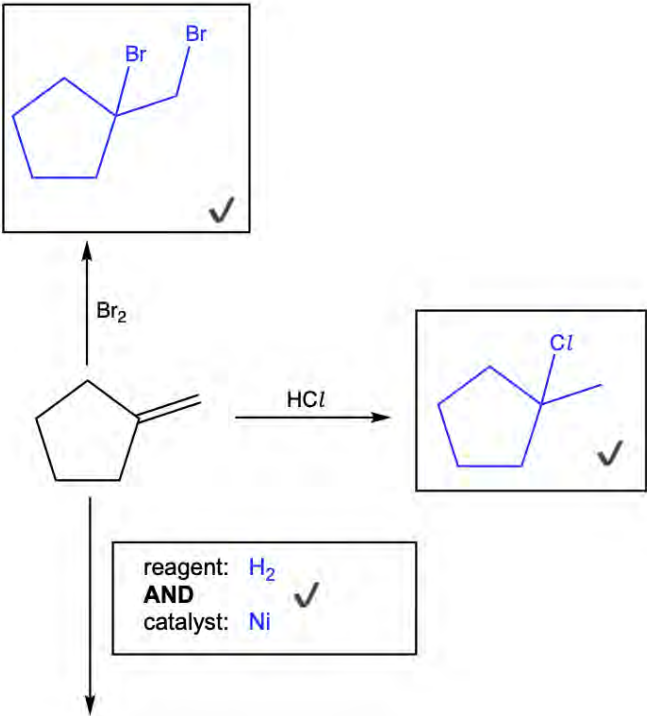
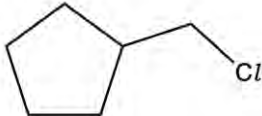
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Question			Answer	Mark	Guidance
16	(c)	(ii)	C=C / double bond does not rotate OR restricted rotation of the C=C/double bond ✓ Each carbon atom in C=C/double bond has (two) different groups/atoms (bonded) ✓	2	ALLOW π/pi bond does not rotate ALLOW C=C / double bond does not twist IGNORE groups are fixed in position IGNORE 'bond does not move' OR 'bond has restricted movement' ALLOW each end of the π/pi -bond is bonded to different groups/atoms DO NOT ALLOW 'functional groups' OR 'molecules' OR 'compounds' OR 'species' for 'groups' IGNORE C=C bond has two different groups IGNORE two different groups either side of the double bond <i>(could be above or below must be clear it is on each C)</i> IGNORE references to 'priority' (even if incorrect) IGNORE attempts to give definition of stereoisomerism e.g. same structural formula but different arrangement of atoms in space
16	(d)		$\text{C}_6\text{H}_{14} + 6\text{O}_2 \rightarrow 5\text{CO} + \text{C} + 7\text{H}_2\text{O} \quad \checkmark$	1	DO NOT ALLOW any equations which show H_2 as a product ALLOW $\text{C}_6\text{H}_{14} + 6\text{O}_2 \rightarrow 2\text{CO}_2 + \text{CO} + 3\text{C} + 7\text{H}_2\text{O}$ ALLOW $\text{C}_6\text{H}_{14} + 6\text{O}_2 \rightarrow \text{CO}_2 + 3\text{CO} + 2\text{C} + 7\text{H}_2\text{O}$ ALLOW multiples that show a 1:6 ratio e.g. $2\text{C}_6\text{H}_{14} + 12\text{O}_2 \rightarrow 10\text{CO} + 2\text{C} + 14\text{H}_2\text{O}$ OR $2\text{C}_6\text{H}_{14} + 12\text{O}_2 \rightarrow 5\text{CO}_2 + 7\text{C} + 14\text{H}_2\text{O}$

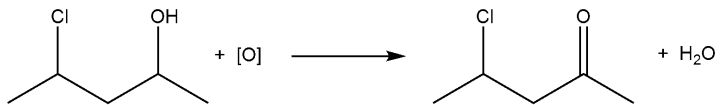
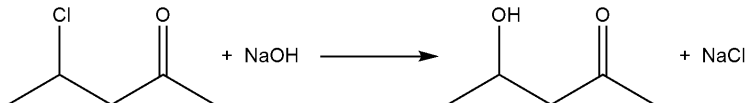
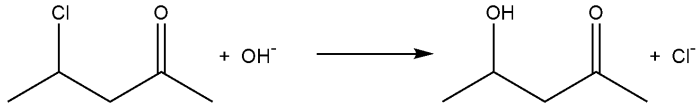
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Question	Answer	Mark	Guidance
16 (e)		3	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous ALLOW names for reagents e.g. hydrogen, if no formulae given DO NOT ALLOW minor product, i.e.  ALLOW reagent and catalyst on either answer line For catalyst ALLOW Pt / Pd or any suitable non-specification alternative IGNORE state symbols IGNORE conditions i.e. temp and pressure

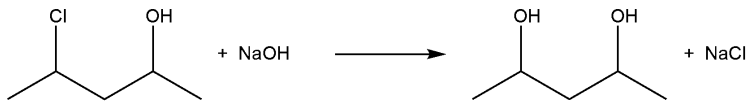
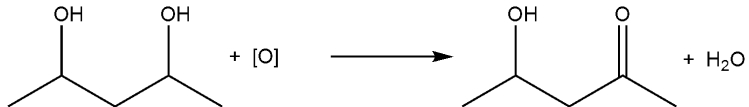
Question	Answer	Mark	Guidance
17*	Level 3 (5–6 marks) Correct calculation of mass of D required AND Gives correct reagents for both stages of the synthesis in the correct order with both equations mostly correct <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Correct calculation of mass of D required AND Gives correct reagents for one stage of the synthesis with equation mostly correct OR Calculation of mass of D is partly correct AND Gives correct reagents for both stages of the synthesis OR Gives correct reagents for both stages of the synthesis, in the correct order, with equations mostly correct <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i>	6	Mark additional answer space P15 as SEEN Indicative scientific points may include: <u>Calculation of mass of D</u> Using moles: $n(\text{F}) = \frac{2.50}{102} = 0.0245\ldots$ (mol) $n(\text{D}) = 0.0245\ldots \times \frac{100}{31.5} = 0.0778\ldots$ (mol) $m(\text{D}) = 0.0778\ldots \times 122.5 = 9.53$ (g) Using mass: - Theoretical $m(\text{F}) = 2.50 \times \frac{100}{31.5} = 7.94$ (g) - Theoretical $n(\text{D}) = \frac{7.94}{102} = 0.0778\ldots$ (mol) $m(\text{D}) = 0.0778\ldots \times 122.5 = 9.53$ (g) ALLOW small slip/rounding errors such as errors in Mr e.g. use of Mr of 101 instead of 102 for F Note: allow use of calculator value, or values rounded to min. 3SF Examples of partly correct calculations: Mass = 0.946 (g) from $0.0245\ldots \times \frac{31.5}{100} \times 122.5$ (inverted % yield) Mass = 3.00 (g) from $0.0245\ldots \times 122.5$ (omission of % yield) Mass = 6.61 (g) from Mr values wrong way round

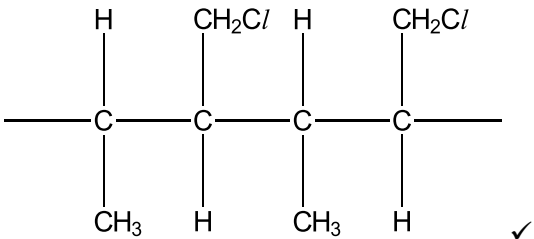
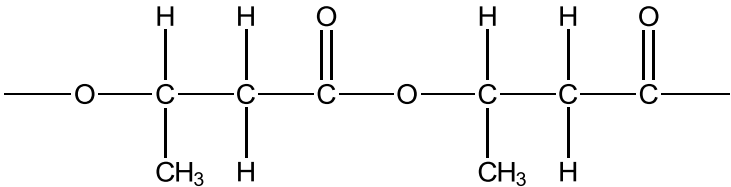
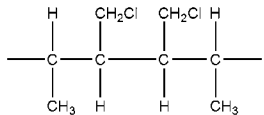
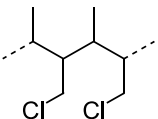
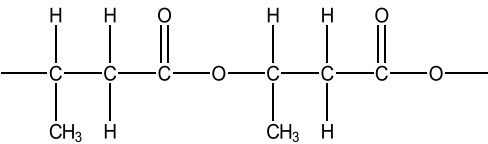
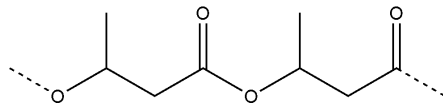
Question	Answer	Mark	Guidance
	Level 1 (1–2 marks) Calculation of mass of D is partly correct OR Gives correct reagents for both stages of the synthesis OR Describes one stage of the synthesis with reagents and equation mostly correct OR Attempts to calculate the mass of D but makes little progress AND Correct reagent for one stage of the synthesis <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 <i>No response or no response worthy of credit.</i>		Synthesis In equations, ALLOW any unambiguous formulae IGNORE conditions or solvents Stage 1 (oxidation of 2° alcohol) Reagents: $\text{H}^+/\text{Cr}_2\text{O}_7^{2-}$ ALLOW $\text{K}_2\text{Cr}_2\text{O}_7$ OR $\text{Na}_2\text{Cr}_2\text{O}_7$ AND H_2SO_4 ALLOW names for reagents e.g. acidified dichromate, if no formulae given IGNORE Roman numerals e.g. (VI), unless incorrect Equation:  Stage 2 (substitution of Cl) Reagents: NaOH OR KOH OR OH^- ALLOW H_2O Equation:  ALLOW correct ionic equation/mechanism showing OH^- and Cl^- 

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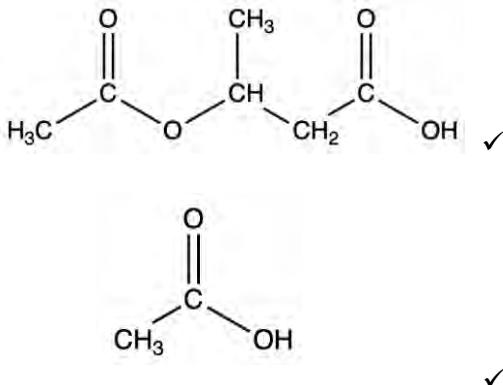
Question	Answer	Mark	Guidance
			IF stage 2 (substitution of Cl) attempted first Equation:  Then oxidation step follows Equation:  Aspects of the communication statement might typically have been met when: • All information given is correct and relevant using appropriate scientific language, for example: - o no additional incorrect reagents e.g. NaOH and H₂SO₄ for substitution - o use of an inappropriate acid e.g. HCl for oxidation • Equations are correctly balanced • Calculations are set out in a clear and logical way • No small slips/rounding errors • Final value for mass given to an appropriate number of significant figures/decimal places.

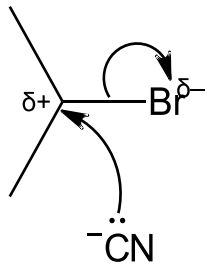
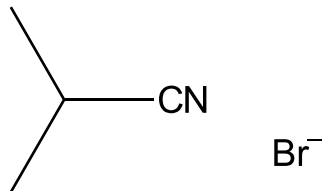
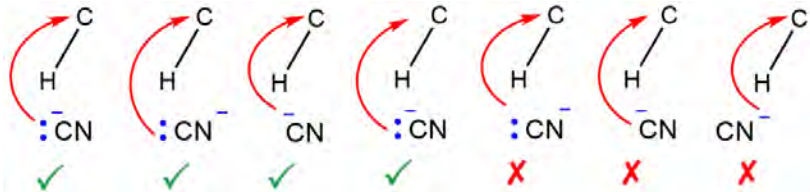
Question	Answer	Mark	Guidance
18 (a)	Two repeat units of polymer of 1-chlorobut-2-ene  Two repeat units of polymer of 3-hydroxybutanoic acid  Ester link shown ✓ Two complete repeat units ✓ Type of polymerisation 1-chlorobut-2-ene: addition AND 3-hydroxybutanoic acid: condensation ✓	4	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous IGNORE brackets and use of <i>n</i> or subscript numbers IGNORE connectivity ALLOW alternating side chains i.e.  End bonds MUST be shown (solid or dotted) e.g.  BUT ALLOW ECF IF end bonds omitted in both structures ALLOW any whole repeat units e.g.  End bonds MUST be shown (solid or dotted) e.g.  DO NOT ALLOW only one repeat unit OR more than 2 repeat units BUT ALLOW ECF in subsequent structure DO NOT ALLOW 'additional'

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Question			Answer	Mark	Guidance
18	(b)	(i)	(Chlorine containing polymers) produces toxic (products when incinerated) ✓	1	ALLOW suitable alternatives for 'produces' e.g. forms, releases (<i>must be clear that it is a product</i>) ALLOW produces HCl /hydrogen chloride/ hydrochloric acid ALLOW 'poisonous' for toxic IGNORE harmful / pollutant / dangerous
18	(b)	(ii)	Ester / ester bond / ester group / polyester ✓	1	ALLOW displayed formula for an ester functional group $\begin{array}{c} \text{O} \\ \\ \text{---C---O---C} \end{array}$ i.e. IGNORE reference to hydrogen bonding
18	(c)			2	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous e.g. $\text{CH}_3\text{COOCH}(\text{CH}_3)\text{CH}_2\text{COOH}$ CH_3COOH ALLOW products in either box IGNORE Connectivity BUT DO NOT ALLOW -HO

Question	Answer	Mark	Guidance
19 (a) (i)	Curly arrow from CN^- to $\text{C}^{\delta+}$ of C–Br bond ✓ Dipole shown on C–Br bond, $\text{C}^{\delta+}$ and $\text{Br}^{\delta-}$ AND curly arrow from C–Br bond to Br atom ✓  Correct organic product AND Br^- ✓ 	3	ANNOTATIONS MUST BE USED ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous NOTE: curly arrows can be straight, snake-like etc., but NOT double headed or half headed arrows 1st curly arrow must: - go to C of C–Br AND - start from, OR be traced back to any point across width of the lone pair on C of CN^- OR start from – charge on C of CN^-  2nd curly arrow must start from, OR be traced back to, any part of C–Br bond and go to Br IGNORE presence of K^+ BUT KBr does NOT show Br^- ALLOW $\text{S}_{\text{N}}1$ mechanism: - Dipole on C–Br bond AND curly arrow from the C–Br bond to Br ✓ - Correct carbocation AND Curly arrow from CN^- to C^+ on carbocation ✓ - Correct organic product AND Br^- ✓

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Question			Answer	Mark	Guidance
19	(a)	(ii)	Nucleophilic substitution ✓	1	
19	(b)	(i)	NaBr AND H ₂ SO ₄ ✓	1	ALLOW HBr (IGNORE additional acid if given e.g HBr and H₂SO₄) ALLOW KBr instead of NaBr ALLOW H₃PO₄ OR HNO₃ in place of H₂SO₄ BUT NOT HCl ALLOW PBr₃ ALLOW names if no formulae given IGNORE conc OR dilute OR (aq) IGNORE H⁺/Acid (<i>must be clear which acid should be used</i>)

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Mark Scheme

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Question			Answer	Mark	Guidance
19	(b)	(ii)	Step 1 (Add to) separating funnel ✓ (Use of) bottom layer (containing 1-bromopropane / organic) ✓ Step 2 Dry with (one of the following) • an anhydrous salt • MgSO_4 /magnesium sulfate • CaCl_2 /calcium chloride ✓ Step 3 (Re)Distil (and collect the fraction) at 71°C ✓	4	ANNOTATIONS MUST BE USED 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 base/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 salt IGNORE filtration to remove anhydrous salt after step 2 ALLOW temperature range of $70 - 72^\circ\text{C}$ for distillation DO NOT ALLOW if forms a solid product

H432/02

Mark Scheme

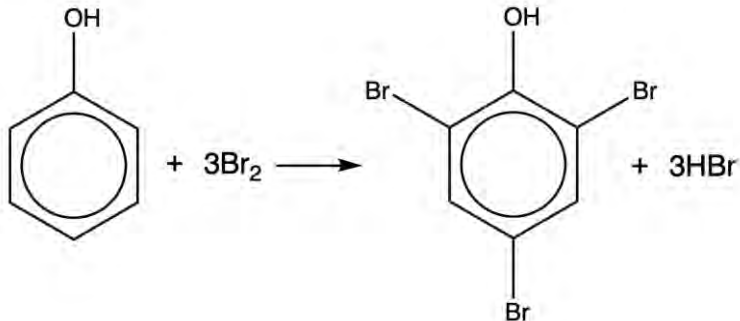
June 2025

Question			Answer	Mark	Guidance
20	(a)		(In the delocalised model): (C–C) bond length is between single (C–C) and double bond (C=C) OR all (C–C) bond lengths are the same ✓ (Enthalpy change of) hydrogenation is less exothermic (than expected) ✓	2	IGNORE less susceptible to electrophilic attack (given in question) DO NOT ALLOW enthalpy of hydration OR $\Delta_{\text{hyd}}H$ ALLOW 'less negative' OR 'more positive' OR 'less (heat) energy released' for 'less exothermic' IGNORE higher/lower ALLOW comparison of values that show delocalised is less exothermic e.g. Kekulé is -360 delocalised is -208
20	(b)	(i)	(In phenol) a (lone) pair of electrons on O is (partially) delocalised/donated into the ring / π-system ✓ Electron density increases/is higher (than benzene) ✓ ORA (phenol is) more susceptible to electrophilic attack OR (phenol can) attract/accept electrophile/Br_2 more OR (phenol can) polarise electrophile/Br_2 more ✓ ORA	3	ALLOW the electron pair in a p-orbital on O atom becomes part of the ring / π-system ALLOW diagram to show movement of lone pair into ring ALLOW lone pair of electrons on O is (partially) drawn/attracted/pulled/ into ring / π-system ALLOW lone pair on O DO NOT ALLOW (two) lone pairs are (partially) delocalised into ring / π-system Responses must be comparative for 2nd and 3rd marking point IGNORE activating IGNORE charge density IGNORE electronegativity ALLOW Br^+ for electrophile IGNORE Br for electrophile ALLOW Benzene can't polarise electrophile/Br_2 but phenol can (polarise electrophile/Br_2) ORA IGNORE phenol reacts more readily/easily with electrophiles

H432/02

Mark Scheme

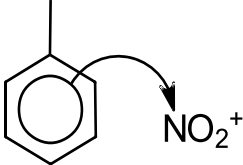
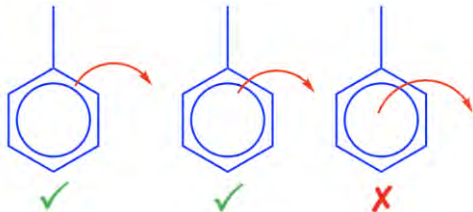
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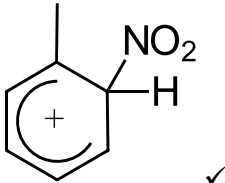
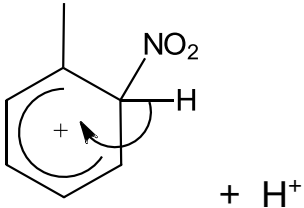
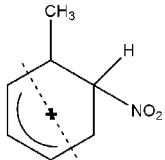
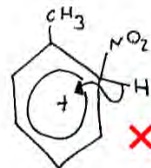
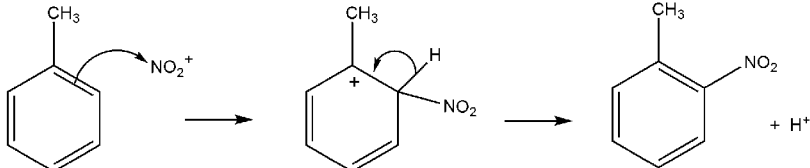
Question			Answer	Mark	Guidance
20	(b)	(ii)	 2,4,6-tribromophenol product ✓ Rest of equation and balancing ✓	2	ALLOW Kekulé structure DO NOT ALLOW substitution at any three positions on ring, must be 2, 4, 6. IGNORE molecular formula even if incorrect DO NOT ALLOW ECF for organic product with incorrect number of substituted Br (Second mark is dependent on getting first mark)
20	(c)	(i)	CH_3Cl AND AlCl_3 ✓	1	ALLOW names if no formulae given ALLOW CH_3Br for reagent ALLOW AlBr_3 OR FeCl_3 OR FeBr_3 for the Lewis acid ALLOW suitable non-specification alternative Lewis acids e.g. zeolite, BF_3

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Mark Scheme

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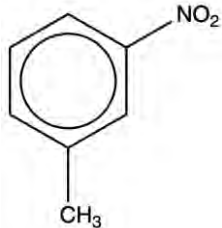
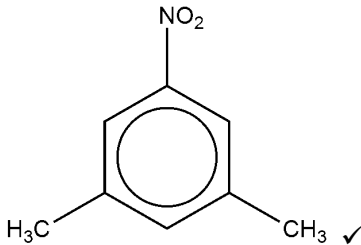
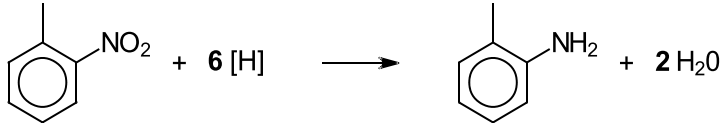
Question	Answer	Mark	Guidance
20 (c) (ii)	Role of H₂SO₄ catalyst 2 marks <i>Forming electrophile</i> $\text{HNO}_3 + \text{H}_2\text{SO}_4 \rightarrow \text{NO}_2^+ + \text{HSO}_4^- + \text{H}_2\text{O} \checkmark$ <i>Reforming catalyst</i> $\text{H}^+ + \text{HSO}_4^- \rightarrow \text{H}_2\text{SO}_4 \checkmark$ Electrophilic attack 1 mark Curly arrow from π-bond to NO_2^+ $\checkmark$ 	5	ANNOTATIONS MUST BE USED ALLOW for forming an electrophile $\text{HNO}_3 + 2\text{H}_2\text{SO}_4 \rightarrow \text{NO}_2^+ + 2\text{HSO}_4^- + \text{H}_3\text{O}^+$ ALLOW for forming an electrophile $\text{HNO}_3 + \text{H}_2\text{SO}_4 \rightarrow \text{H}_2\text{NO}_3^+ + \text{HSO}_4^-$ AND then $\text{H}_2\text{NO}_3^+ \rightarrow \text{NO}_2^+ + \text{H}_2\text{O}$ NOTE: curly arrows can be straight, snake-like etc. but NOT double headed or half headed arrows ALLOW use of $^+\text{NO}_2$ OR NO_2^+ 1st curly arrow must: - start from, OR close to circle or benzene ring AND - go to anywhere on NO_2^+ 

Question	Answer	Mark	Guidance
	Correct intermediate 1 mark  Reforming benzene ring 1 mark Curly arrow from C-H bond to reform π-ring AND H^+ as product ✓ 		DO NOT ALLOW mark for intermediate if methyl group is missing, or substitution is in wrong position IGNORE connectivity (<i>mark is for correct substitution position and position of π-ring</i>) DO NOT ALLOW following intermediates:  OR  π-ring should cover approximately 4 of the 6 sides of the benzene ring structure AND the correct orientation, i.e. gap towards C with NO_2 and H ALLOW + sign anywhere inside the 'hexagon' of intermediate 2nd curly arrow must: - start from, OR be traced back to any part of the C – H bond AND - go inside the 'hexagon' of the intermediate ALLOW mechanism using Kekulé structures with wheland intermediate 

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Question	Answer	Mark	Guidance
20 (c) (iii)	(Synthesis 1 shows that the) $-\text{CH}_3$ is 2, (4)-directing AND (Synthesis 2 is not successful because) $-\text{NO}_2$ / nitro group is 3-directing ✓  OR 	2	ALLOW CH_3 is 2, (4)-directing AND $-\text{NO}_2$ / nitro group is not (2, 4-directing) ALLOW $-\text{NO}_2$ / nitro group is 3-directing AND $-\text{CH}_3$ is not IGNORE CH_3 and NO_2 have different directing effects (the directing effect of at least one of the groups must be specified) ALLOW alternatives for 'directing' e.g. substitutes at ALLOW $-\text{NO}_2$ / nitro group is meta directing ALLOW $-\text{CH}_3$ is ortho, (para) directing IGNORE 5-directing for $-\text{NO}_2$ IGNORE 6-directing for $-\text{CH}_3$ ALLOW Kekulé structure
20 (c) (iv)	Reagents Sn AND HCl ✓ Equation  H_2O product AND balancing ✓	2	ALLOW names if no formulae given IGNORE dilute for HCl IGNORE H_2 (with Sn and HCl) IGNORE NaOH if seen as a reagent to convert nitro group into amine e.g. 'Sn/(concentrated) HCl then NaOH' scores the mark ALLOW suitable non-specification alternatives: e.g. Zn AND HCl OR H_2 AND Ni

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Mark Scheme

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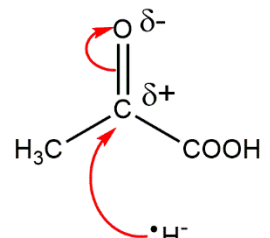
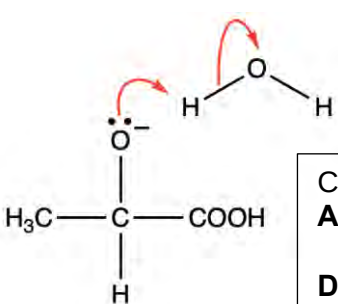
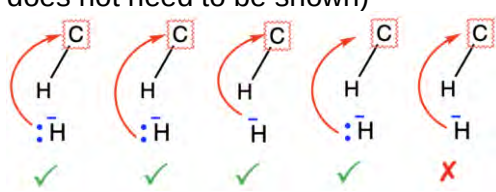
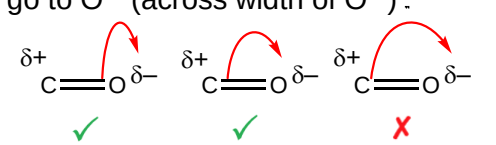
Question			Answer	Mark	Guidance
21	(a)		An atom/ group of atoms/part of molecule responsible for the characteristic reactions (of a compound) ✓	1	ALLOW 'part of an organic compound' for 'part of molecule' ALLOW 'chemical properties' OR 'reactions' OR 'reactivity' for 'characteristic reactions' IGNORE references to physical properties
21	(b)		2,4-DNP ✓ Red/orange/yellow precipitate ✓	2	ALLOW 2,4-dinitrophenylhydrazine OR 2,4-DNPH OR Brady's (Reagent) ALLOW ppt OR solid OR crystals as an alternative for precipitate Mark second point independently of response for first marking point

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Mark Scheme

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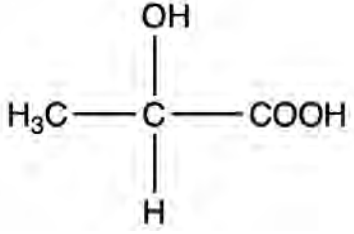
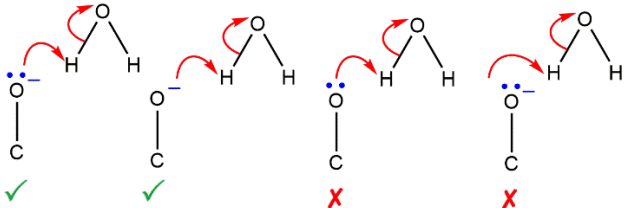
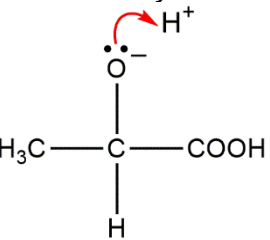
Question			Answer	Mark	Guidance																			
21	(c)		<table><tr><th rowspan="2">Chemical test</th><th colspan="3">Expected observations</th></tr><tr><th>Pyruvic acid</th><th>Methylglyoxal</th><th>Acetol</th></tr><tr><td>Tollens' reagent</td><td>no change</td><td>Silver mirror</td><td>no change OR Silver mirror</td></tr><tr><td>Na₂CO₃(aq)</td><td>Effervescence OR Bubbles OR Fizzing</td><td>no change</td><td>no change</td></tr><tr><td>Cr₂O₇²⁻(aq) / H⁺(aq)</td><td>no change (orange solution)</td><td>(Orange to) Green (solution)</td><td>(Orange to) Green (solution)</td></tr></table> One row correct ✓ Two rows correct ✓✓ Three rows correct ✓✓✓	Chemical test	Expected observations			Pyruvic acid	Methylglyoxal	Acetol	Tollens' reagent	no change	Silver mirror	no change OR Silver mirror	Na ₂ CO ₃ (aq)	Effervescence OR Bubbles OR Fizzing	no change	no change	Cr ₂ O ₇ ²⁻ (aq) / H ⁺ (aq)	no change (orange solution)	(Orange to) Green (solution)	(Orange to) Green (solution)	3	ALLOW alternatives for 'no change' such as 'no observation', 'no reaction', 'nothing' or 'X' For Tollen's ALLOW Silver/Grey/Black AND precipitate/ppt/solid ALLOW acetol to give a positive result (<i>it is an alpha hydroxy ketone so can tautomerize to give an aldehyde, not covered in the specification</i>) For Na₂CO₃ IGNORE gas / CO₂ formed i.e. must be an observable change IGNORE test with limewater BUT DO NOT ALLOW other gas tests If no other marks awarded, ALLOW 1 mark for a correct column
Chemical test	Expected observations																							
	Pyruvic acid	Methylglyoxal	Acetol																					
Tollens' reagent	no change	Silver mirror	no change OR Silver mirror																					
Na ₂ CO ₃ (aq)	Effervescence OR Bubbles OR Fizzing	no change	no change																					
Cr ₂ O ₇ ²⁻ (aq) / H ⁺ (aq)	no change (orange solution)	(Orange to) Green (solution)	(Orange to) Green (solution)																					

Question	Answer	Mark	Guidance
21 (d)	NOTE: curly arrows can be straight, snake-like, etc. but NOT double headed or half headed arrows Nucleophilic attack 2 marks  Curly arrow from H⁻ to C of C=O ✓ Correct dipole shown on C=O AND curly arrow showing breaking of C=O ✓ Intermediate 1 mark  Correct intermediate AND curly arrow from O⁻ to H in H₂O ✓ DO NOT ALLOW delta- on O of intermediate IGNORE attempt to draw curly arrow showing breaking of H-O in H₂O IGNORE lack of dipole on H₂O IGNORE absence of OH⁻ as 2nd product IGNORE connectivity of H₃C-	4	ANNOTATIONS MUST BE USED 1st curly arrow must - go to the C atom of C=O AND - start from, OR be traced back to any point across width of lone pair on ⁻H OR start from – charge on ⁻H (then lone pair on H⁻ does not need to be shown)  IF the carboxylic acid is attacked, in addition to the ketone, then ALLOW first two marks provided all arrows and dipoles are correct 2nd curly arrow must - start from, OR be traced back to any part of ^{delta+}C=O ^{delta-} bond AND - go to O^{delta-} (across width of O^{delta-}) . 

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Question	Answer	Mark	Guidance
	Product <i>1 mark</i>  Correct product ✓		3rd curly arrow must - go to H of H₂O AND - start from, OR be traced back to any point across width of lone pair on :O⁻ OR start from - charge of O⁻ of intermediate  NOTE: For arrow to H of H₂O ALLOW curly arrow from O⁻ of intermediate to H⁺  IGNORE Connectivity

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Question	Answer	Mark	Guidance
21 (e)	Reaction scheme for question 21(e): Pyruvic acid ($\text{CH}_3\text{C}(=\text{O})\text{COOH}$) is the starting material. Reagents and products: SOCl_2 → acyl chloride ($\text{CH}_3\text{C}(=\text{O})\text{COCl}$) - excess NH_3 → compound P ($\text{CH}_3\text{C}(=\text{O})\text{CONH}_2$) NaOH(aq) → sodium pyruvate ($\text{CH}_3\text{C}(=\text{O})\text{COONa}$) $\text{CH}_3\text{OH}/\text{H}_2\text{SO}_4$ → methyl pyruvate ($\text{CH}_3\text{C}(=\text{O})\text{COOCH}_3$) $\text{HCN OR NaCN} / \text{H}^+$ → hydroxycyanoacetic acid ($\text{CH}_3\text{C}(\text{OH})(\text{CN})\text{COOH}$) H_2/Ni → 2-amino-3-hydroxybutanoic acid ($\text{H}_2\text{NCH}_2\text{CH}(\text{OH})\text{COOH}$)	7	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous ALLOW names for reagents if no formulae given IGNORE connectivity IGNORE conditions IGNORE inorganic products DO NOT ALLOW $-\text{CONH}_3^+$ in compound P For SOCl_2, ALLOW PCl_3 OR PCl_5 OR COCl_2 IGNORE additional H^+ OR HCl OR H_2SO_4 DO NOT ALLOW H_2O or (aq) ALLOW carboxylate ion, COO^- (Na^+) ALLOW NaCN OR KCN OR CN^- AND H^+ OR H_2SO_4 OR HNO_3 OR HCl <i>Acid is required for mark</i> IGNORE solvent OR (aq) ALLOW any vertical bond to the OH or CN e.g. ALLOW $\begin{array}{c} \\ \text{OH} \end{array}$ OR $\begin{array}{c} \\ \text{OH} \end{array}$ OR $\begin{array}{c} \\ \text{CN} \end{array}$ OR $\begin{array}{c} \\ \text{CN} \end{array}$ BUT DO NOT ALLOW $-\text{HO}$ OR $-\text{NC}$

Question			Answer	Mark	Guidance
22	(a)	(i)	Calculation of R_f values $R_f = \frac{34.5}{46} = 0.75$ AND $R_f = \frac{11.5}{46} = 0.25 \checkmark$	1	ALLOW ± 1 mm on each measurement, i.e. $R_f = 0.71 - 0.79$ $R_f = 0.22 - 0.28$ ALLOW values that round to 2dp to give a value in the acceptable range Working is not required

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Mark Scheme

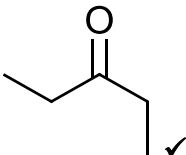
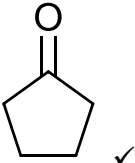
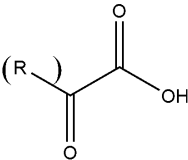
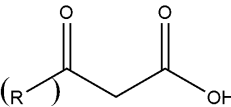
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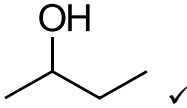
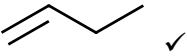
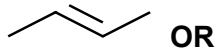
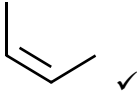
Question			Answer	Mark	Guidance
22	(a)	(ii)	Any 2 from the following: ✓✓ $ \begin{array}{c} \text{H} \quad \text{O} \quad \text{H} \quad \text{O} \\ \quad \quad \quad \\ \text{H}_2\text{N}-\text{C}-\text{C}-\text{N}-\text{C}-\text{C}-\text{OH} \\ \quad \quad \\ \text{CH}_3 \quad \text{H} \quad \text{CH}(\text{CH}_3)_2 \end{array} $ $ \begin{array}{c} \text{H} \quad \text{O} \quad \text{H} \quad \text{O} \\ \quad \quad \quad \\ \text{H}_2\text{N}-\text{C}-\text{C}-\text{N}-\text{C}-\text{C}-\text{OH} \\ \quad \quad \\ \text{CH}(\text{CH}_3)_2 \quad \text{H} \quad \text{CH}_3 \end{array} $ $ \begin{array}{c} \text{H} \quad \text{O} \quad \text{O} \quad \text{H} \\ \quad \quad \quad \\ \text{H}_2\text{N}-\text{C}-\text{C}-\text{O}-\text{C}-\text{C}-\text{NH}_2 \\ \quad \quad \quad \\ \text{CH}_3 \quad \quad \quad \text{CH}(\text{CH}_3)_2 \end{array} $	2	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous IGNORE connectivity Check structures carefully to ensure they are different from each other ALLOW ECF from wrong R_f values in 22a(i) R group should be consistent with R_f values however ALLOW ECF if incorrect R group is repeated in second structure ALLOW ECF for one small slip e.g. missing H on NH group

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Question			Answer	Mark	Guidance
22	(b)	(i)	Pentan-3-one  Cyclopentanone 	2	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous IGNORE non-organic products e.g. CO₂, O=C=O, H₂O etc
22	(b)	(ii)	Mark is for a clear description of the relative positions of the C=O/ketone and carboxylic acid/COOH in alpha and beta keto acids Alpha-keto acids: ketone/C=O is adjacent/next/bonded to carboxylic acid/COOH AND Beta-keto acids: ketone/C=O two carbons away from carboxylic acid/COOH ✓ OWTTE	1	ALLOW labelled structures e.g.  α-keto acid  β-keto acid Alpha-keto acids: ALLOW ketone/C=O is on the adjacent C to the carboxylic acid//COOH (<i>matches alpha amino acid description</i>) ALLOW Bonded to the same C Beta-keto acids: ALLOW ketone/C=O on 3rd carbon (from COOH) ALLOW has carbon in-between functional groups IGNORE bonded to different C (must be specific) Alternative approach – comparison of decomposition ALLOW alpha keto acids decompose to form an aldehyde and beta keto acids form a ketone OWTTE

Question		Answer	Mark	Guidance
23	(a)	Functional group and reasoning for compound K alcohol AND OH AND peak at 3200 – 3600 (cm⁻¹) ✓ Possible structures of K, L and M K =  ✓ L =  ✓ M =  OR  ✓	4	DO NOT ALLOW any other functional group e.g. phenol, carboxylic acid IGNORE 'hydroxyl' for 'alcohol' BUT ALLOW for O-H ALLOW any stated value in range 3100 to 3600 (cm⁻¹) <i>(consistent with spectrum provided)</i> IGNORE reference to C-O If no or incomplete answer, check spectrum for annotations – credit can be given from a correctly labelled peak (values are not needed) ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous ALLOW one mark if L and M both correct but in the wrong boxes

Question	Answer	Mark	Guidance
23 (b)*	<i>Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Structure is either $\text{CH}_3\text{CH}_2\text{COOCH}(\text{CH}_3)_2$ OR $(\text{CH}_3)_2\text{CHCOOCH}_2\text{CH}_3$ AND Most of the data analysed <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 has a molecular formula of $\text{C}_6\text{H}_{12}\text{O}_2$ with at least two key features present AND Analyses some of the data from the NMR <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	Mark spectra page as SEEN Indicative scientific points: 1. Empirical Formula $\text{C} : \text{H} : \text{O} = \frac{62.07}{12.0} : \frac{10.34}{1.0} : \frac{27.59}{16.0}$ $= 5.17 : 10.34 : 1.72$ $= 3 : 6 : 1$ - Empirical formula = $\text{C}_3\text{H}_6\text{O}$ ALLOW Alternative method using Mr of 116 e.g $(0.6270 \times 116) \div 12 = 6$ 2. Molecular Formula and Mass Spectrum - uses $m/z = 116.0$ to determine molecular formula as $\text{C}_6\text{H}_{12}\text{O}_2$ - Any possible fragments, for example: $m/z = 43$ $(\text{CH}_3)_2\text{CH}^+$ $m/z = 29$ CH_3CH_2^+ 3. ^1H NMR analysis $\delta = 1.1$ ppm, triplet, 3H CH_3CH_2- $\delta = 1.4$ ppm, doublet, 6 H $-\text{CH}(\text{CH}_3)_2$ $\delta = 2.4$ ppm, quartet, 2H $\text{CH}_3\text{CH}_2\text{CO}$ $\delta = 4.4$ ppm, heptet, 1H $-\text{OCH}(\text{CH}_3)_2$ ALLOW approximate values for chemical shifts. ALLOW multiplet for heptet 4. Structure ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous

Question	Answer	Mark	Guidance
			Key Features • Carbonyl -C=O • C-O bond • Ethyl group -CH₂CH₃ • Dimethyl group -C(CH₃)₂ Correct structure $\begin{array}{c} \text{CH}_3-\text{CH}_2-\text{C}=\text{O} \\ \quad \quad \quad \diagdown \\ \quad \quad \quad \text{O}-\text{C}-\text{CH}_3 \\ \quad \quad \quad \\ \quad \quad \quad \text{H} \end{array}$ Justified from NMR chemical shift analysis OR $\begin{array}{c} \text{H} \\ \\ \text{CH}_3-\text{C}-\text{C}=\text{O} \\ \quad \quad \diagdown \\ \text{CH}_3 \quad \quad \text{O}-\text{CH}_2-\text{CH}_3 \end{array}$ Justified from MS fragment as (CH₃)₂CHCO⁺ at 71 Aspects of the communication statement being met might typically includes; • Structures given are feasible and unambiguous • Justifying the correct structure from the evidence • Easy to follow layout on empirical formula calculation • Plausible MS fragments (ideally with a positive charge shown) • Clear information for each NMR peak, including use of correct terminology for splitting patterns • No additional irrelevant/incorrect information given

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