GCE

Chemistry A

H432/02: Synthesis and analytical techniques

A Level

Mark Scheme for June 2025

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. 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 SEEN

11. **Annotations**

Annotation	Meaning
✓	Correct response
✗	Incorrect response
^	Omission mark
BOD	Benefit of doubt given
CON	Contradiction
RE	Rounding error
SF	Error in number of significant figures
ECF	Error carried forward
L1	Level 1
L2	Level 2
L3	Level 3
NBOD	Benefit of doubt not given
SEEN	Noted but no credit given

Annotation	Meaning
I	Ignore
BP	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.

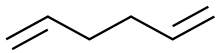
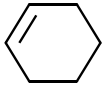
SECTION A

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	

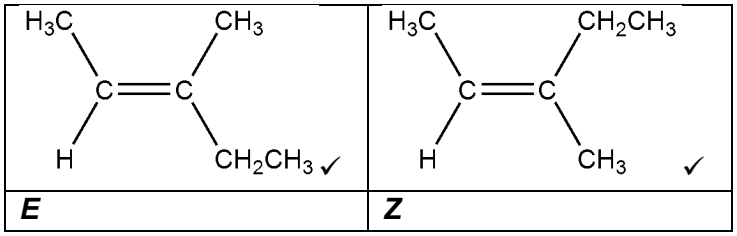
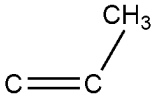
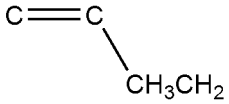
SECTION B

<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Mark</th><th>Guidance</th></tr>
<tr><td>16</td><td>(a)</td><td></td><td>2-methylpent-2-ene ✓</td><td>1</td><td>IGNORE lack of hyphens, or addition of commas

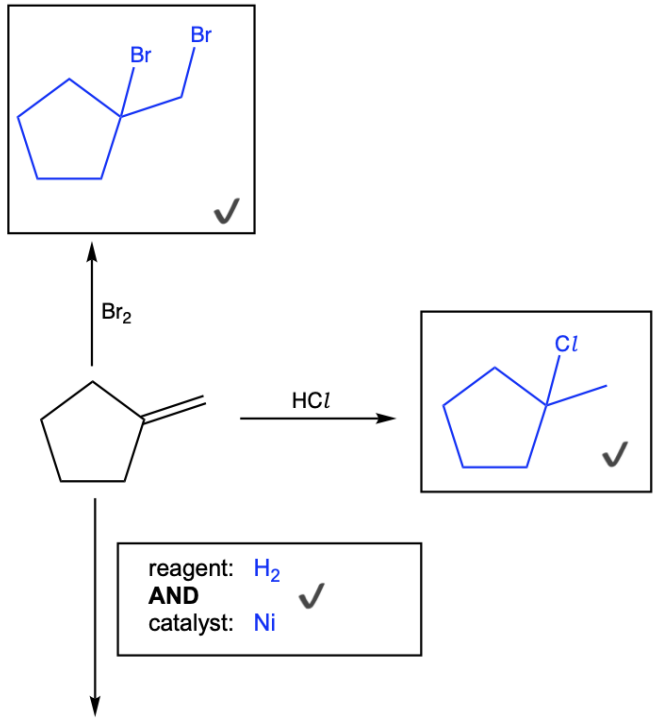
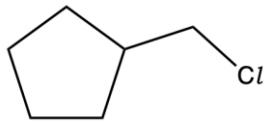
DO NOT ALLOW the following for methyl: methy, meth, methly, methyle, methanyl

DO NOT ALLOW 2-methylpentan-2-ene</td></tr>
<tr><td>16</td><td>(b)</td><td></td><td>
<table>
<tr><td></td><td>  </td><td>  </td></tr>
<tr><td>Molecular formula</td><td>C_6H_{10}</td><td>C_6H_{10}</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 ✓✓✓
</td><td>3</td><td>One mark per row

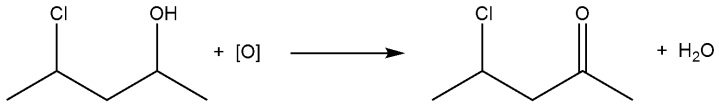
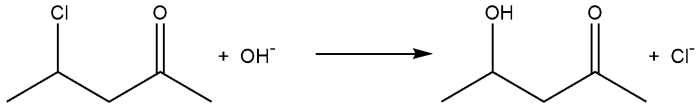
If no other marks awarded, ALLOW 1 mark for a correct column</td></tr>
</table>

Question			Answer	Mark	Guidance
16	(c)	(i)		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** $–C_2H_5$ for ethyl group **ALLOW** connectivity to any part of methyl or CH_2 in ethyl e.g.  **BUT DO NOT ALLOW** ethyl group bonded via CH_3 e.g. $-CH_3CH_2$ 

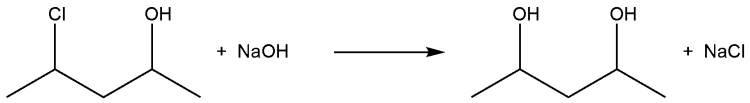
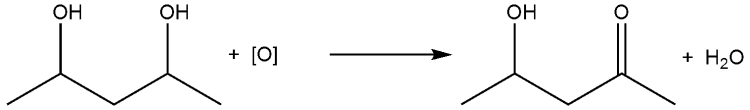
Question			Answer	Mark	Guidance
16	(c)	(ii)	C=C / double bond does not rotate **OR** restricted rotation of the C=C/double bond ✓ **Each** carbon atom in **C=C/double bond** has (two) different groups/atoms (bonded) ✓	2	**ALLOW** π/pi bond does not rotate **ALLOW** C=C / double bond does not twist **IGNORE** 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 *(could be above or below must be clear it is on each C)* **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)		$C_6H_{14} + 6O_2 \rightarrow 5CO + C + 7H_2O$ ✓	1	**DO NOT ALLOW** any equations which show H_2 as a product **ALLOW** $C_6H_{14} + 6O_2 \rightarrow 2CO_2 + CO + 3C + 7H_2O$ **ALLOW** $C_6H_{14} + 6O_2 \rightarrow CO_2 + 3CO + 2C + 7H_2O$ **ALLOW** multiples that show a 1:6 ratio e.g. $2C_6H_{14} + 12O_2 \rightarrow 10CO + 2C + 14H_2O$ **OR** $2C_6H_{14} + 12O_2 \rightarrow 5CO_2 + 7C + 14H_2O$

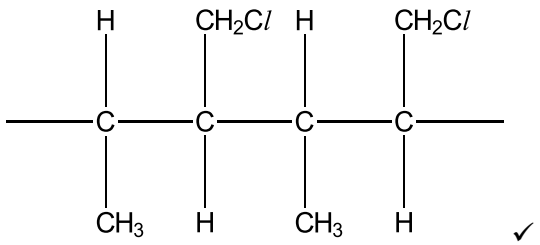
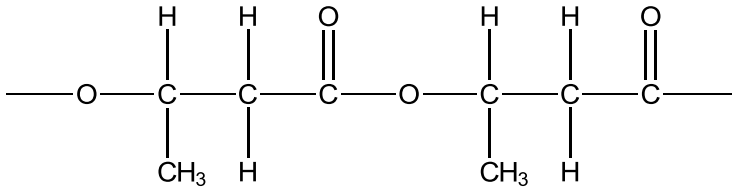
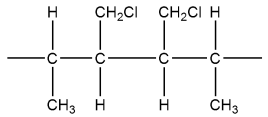
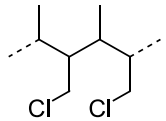
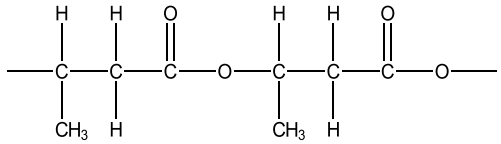
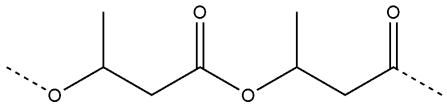
Question			Answer	Mark	Guidance
16	(e)			3	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** names for reagents e.g. hydrogen, if no formulae given **DO NOT ALLOW** minor product, i.e.  **ALLOW** reagent and catalyst on either answer line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

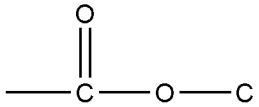
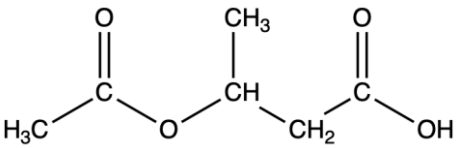
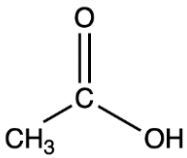
Question			Answer	Mark	Guidance
17*			**Level 3 (5–6 marks)** Correct calculation of mass of **D** required **AND** Gives correct reagents for both stages of the synthesis in the **correct order** with both equations mostly correct *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** 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 *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.*	6	**Mark additional answer space P15 as SEEN** **Indicative scientific points may include:** **<u>Calculation of mass of D</u>** **Using moles:** • $n(\mathbf{F}) = \frac{2.50}{102} = 0.0245\ldots$ (mol) • $n(\mathbf{D}) = 0.0245\ldots \times \frac{100}{31.5} = 0.0778\ldots$ (mol) • $m(\mathbf{D}) = 0.0778\ldots \times 122.5 = 9.53$ (g) **Using mass:** • Theoretical $m(\mathbf{F}) = 2.50 \times \frac{100}{31.5} = 7.94$ (g) • Theoretical $n(\mathbf{D}) = \frac{7.94}{102} = 0.0778\ldots$ (mol) • $m(\mathbf{D}) = 0.0778\ldots \times 122.5 = 9.53$ (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

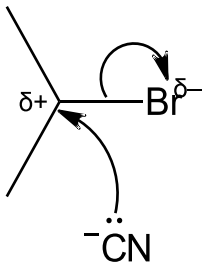
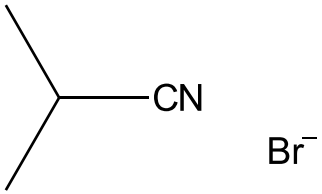
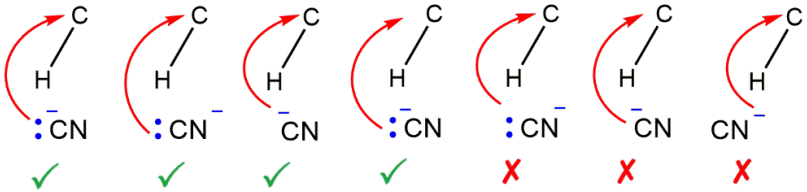
Question			Answer	Mark	Guidance
			Level 1 (1–2 marks) Calculation of mass of **D** is partly correct **OR** Gives correct reagents for both stages of the synthesis **OR** Describes one stage of the synthesis with reagents and equation mostly correct **OR** Attempts to calculate the mass of **D** but makes little progress **AND** Correct reagent for one stage of the synthesis *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*		<u>**Synthesis**</u> **In equations, ALLOW** any unambiguous formulae **IGNORE** conditions or solvents **Stage 1 (oxidation of 2º alcohol)** Reagents: $H^+/Cr_2O_7^{2-}$ **ALLOW** $K_2Cr_2O_7$ **OR** $Na_2Cr_2O_7$ **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 C*l*)** Reagents: NaOH **OR** KOH **OR** OH^- **ALLOW** H_2O Equation: **ALLOW** correct ionic equation/mechanism showing OH^- and Cl^- 

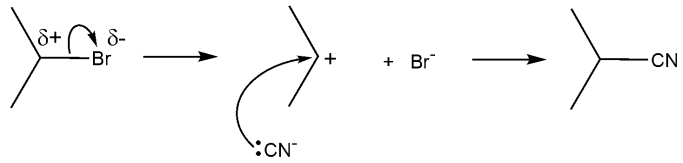
Question			Answer	Mark	Guidance

					IF stage 2 (substitution of C*l*) 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:
					  ○ no additional incorrect reagents e.g. NaOH and H_2SO_4 for substitution
					  ○ 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 *n* 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'

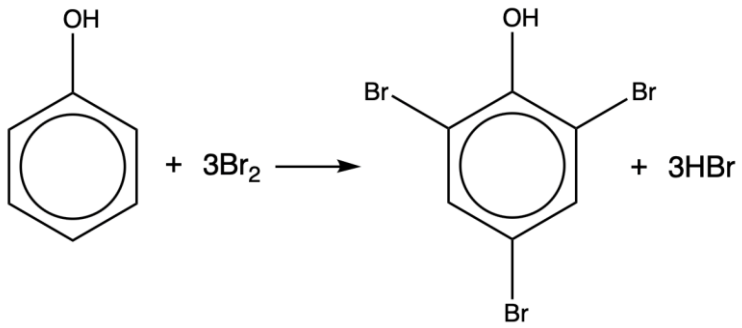
Question			Answer	Mark	Guidance
18	(b)	(i)	(Chlorine containing polymers) **produces toxic** (products when incinerated) ✓	1	**ALLOW** suitable alternatives for 'produces' e.g. forms, releases *(must be clear that it is a product)* **ALLOW** produces HCl /hydrogen chloride/ hydrochloric acid **ALLOW** '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 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. $CH_3COOCH(CH_3)CH_2COOH$ CH_3COOH **ALLOW** products in either box **IGNORE** Connectivity **BUT DO NOT ALLOW** -HO

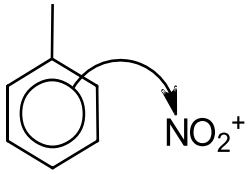
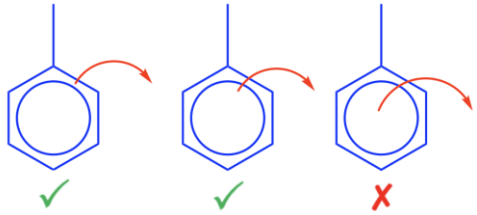
Question			Answer	Mark	Guidance
19	(a)	(i)	Curly arrow from CN^- to $C^{(\delta+)}$ of C–Br bond ✓ Dipole shown on C–Br bond, $C^{\delta+}$ and $Br^{\delta-}$ **AND** curly arrow from C–Br bond to Br atom ✓  Correct organic product **AND** Br^- ✓  	3	**ANNOTATIONS MUST BE USED** **ALLOW** any combination 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** S_N1 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^- ✓

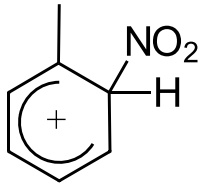
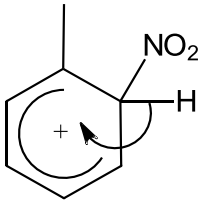
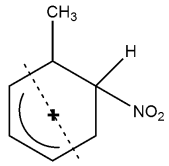
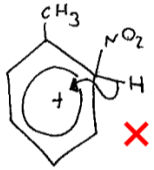
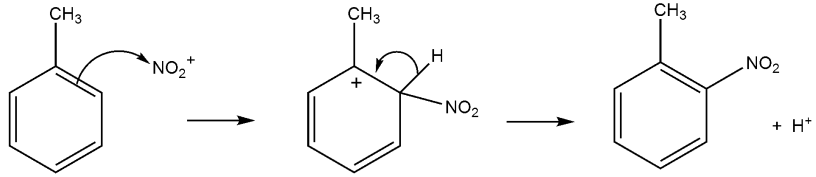
Question			Answer	Mark	Guidance
					
19	**(a)**	**(ii)**	Nucleophilic substitution ✓	**1**	
19	**(b)**	**(i)**	NaBr **AND** H_2SO_4 ✓	**1**	**ALLOW** HBr (**IGNORE** additional acid if given e.g HBr and H_2SO_4) **ALLOW** KBr instead of NaBr **ALLOW** H_3PO_4 **OR** HNO_3 in place of H_2SO_4 **BUT NOT** HCl **ALLOW** PBr_3 **ALLOW** names if no formulae given **IGNORE** conc **OR** dilute **OR** (aq) **IGNORE** H^+/Acid (*must be clear which acid should be used)*

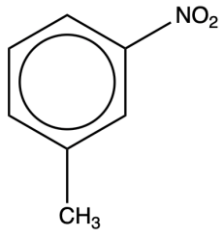
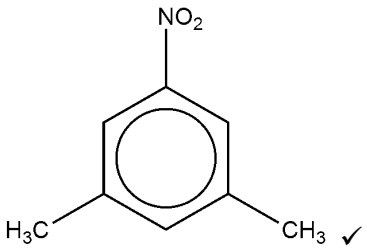
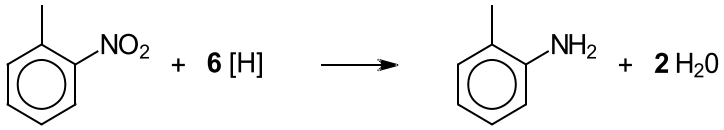
Question			Answer	Mark	Guidance
19	(b)	(ii)		4	**ANNOTATIONS MUST BE USED** **Mark each step in order but then don't mark any further if response refers to purification of a solid** e.g. dissolve in minimum amount of hot solvent, evaporate off water to allow solid to crystalise
			Step 1 (Add to) separating funnel ✓ (Use of) bottom layer (containing 1-bromopropane / organic) ✓		**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**
			Step 2 **Dry** with (one of the following) • an anhydrous salt • $MgSO_4$ /magnesium sulfate • $CaCl_2$ /calcium chloride ✓		**ALLOW** 'to remove water' instead of 'dry' **IGNORE** any other salt **IGNORE** filtration to remove anhydrous salt after **step 2**
			Step 3 (Re)Distil (and collect the fraction) at 71°C ✓		**ALLOW** temperature range of 70 – 72°C for distillation **DO NOT ALLOW** if forms a solid product

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** $\Delta_{hyd}H$ **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 pair**s** 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

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

Question			Answer	Mark	Guidance
20	(c)	(ii)	**Role of H_2SO_4 catalyst** **2 marks** *Forming electrophile* $HNO_3 + H_2SO_4 \rightarrow NO_2^+ + HSO_4^- + H_2O$ ✓ *Reforming catalyst* $H^+ + HSO_4^- \rightarrow H_2SO_4$ ✓ **Electrophilic attack** **1 mark** Curly arrow from π-bond to NO_2^+ ✓ 	5	**ANNOTATIONS MUST BE USED** **ALLOW** for forming an electrophile $HNO_3 + 2H_2SO_4 \rightarrow NO_2^+ + 2HSO_4^- + H_3O^+$ **ALLOW** for forming an electrophile $HNO_3 + H_2SO_4 \rightarrow H_2NO_3^+ + HSO_4^-$ **AND** then $H_2NO_3^+ \rightarrow NO_2^+ + H_2O$ **NOTE:** curly arrows can be straight, snake-like etc. but **NOT** double headed or half headed arrows **ALLOW** use of $^+NO_2$ **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 ✓  + H^+		**DO NOT ALLOW** mark for intermediate if methyl group is missing, or substitution is in wrong position **IGNORE** connectivity (*mark is for correct substitution position and position of π-ring*) **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 

Question			Answer	Mark	Guidance
20	(c)	(iii)	(Synthesis 1 shows that the) $–CH_3$ is 2, (4)-directing **AND** (Synthesis 2 is not successful because) $–NO_2$ / nitro group is **3**-directing ✓  **OR** 	2	**ALLOW** CH_3 is 2, (4)-directing **AND** $–NO_2$ / nitro group is **not** (2, 4-directing) **ALLOW** $–NO_2$ / nitro group is **3**-directing AND $-CH_3$ 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** $–NO_2$ / nitro group is meta directing **ALLOW** $-CH_3$ is ortho, (para) directing **IGNORE** 5-directing for $-NO_2$ **IGNORE** 6-directing for $-CH_3$ **ALLOW** Kekulé structure
20	(c)	(iv)	**Reagents** Sn **AND** HC*l* ✓ **Equation**  H_2O product **AND** balancing ✓	2	**ALLOW** names if no formulae given **IGNORE** dilute for HC*l* **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** HC*l* **OR** H_2 **AND** Ni

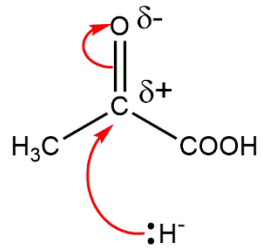
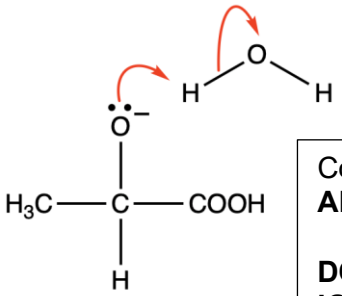
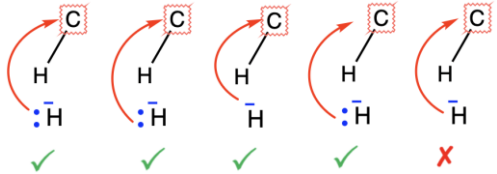
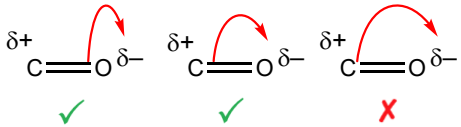
Question			Answer	Mark	Guidance
21	(a)		An atom/ group of atoms/part of molecule responsible for the characteristic reactions (of a compound) ✓	1	**ALLOW** 'part of an organic compound' for 'part of molecule' **ALLOW** 'chemical properties' **OR** 'reactions **OR** 'reactivity' for 'characteristic reactions' **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**

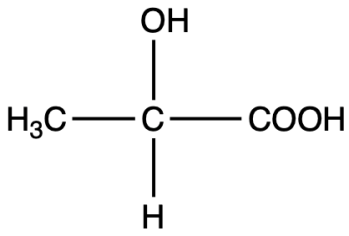
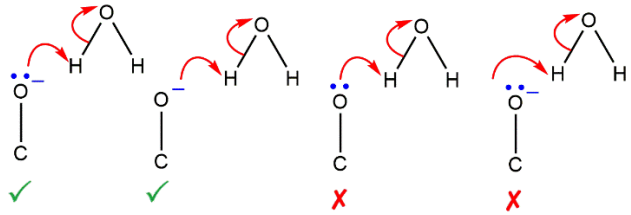
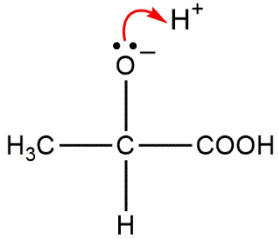
<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Mark</th><th>Guidance</th></tr>
<tr><td>21</td><td>(c)</td><td></td><td>
<table>
<tr><td rowspan="2">Chemical test</td><td colspan="3">Expected observations</td></tr>
<tr><td>Pyruvic acid</td><td>Methylglyoxal</td><td>Acetol</td></tr>
<tr><td>Tollens' reagent</td><td>no change</td><td>Silver mirror</td><td>no change
OR
Silver mirror</td></tr>
<tr><td>Na_2CO_3(aq)</td><td>Effervescence
OR
Bubbles
OR
Fizzing</td><td>no change</td><td>no change</td></tr>
<tr><td>$Cr_2O_7^{2-}$(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 ✓✓✓
</td><td>3</td><td>
ALLOW alternatives for 'no change' such as 'no observation', 'no reaction', 'nothing' or 'X'

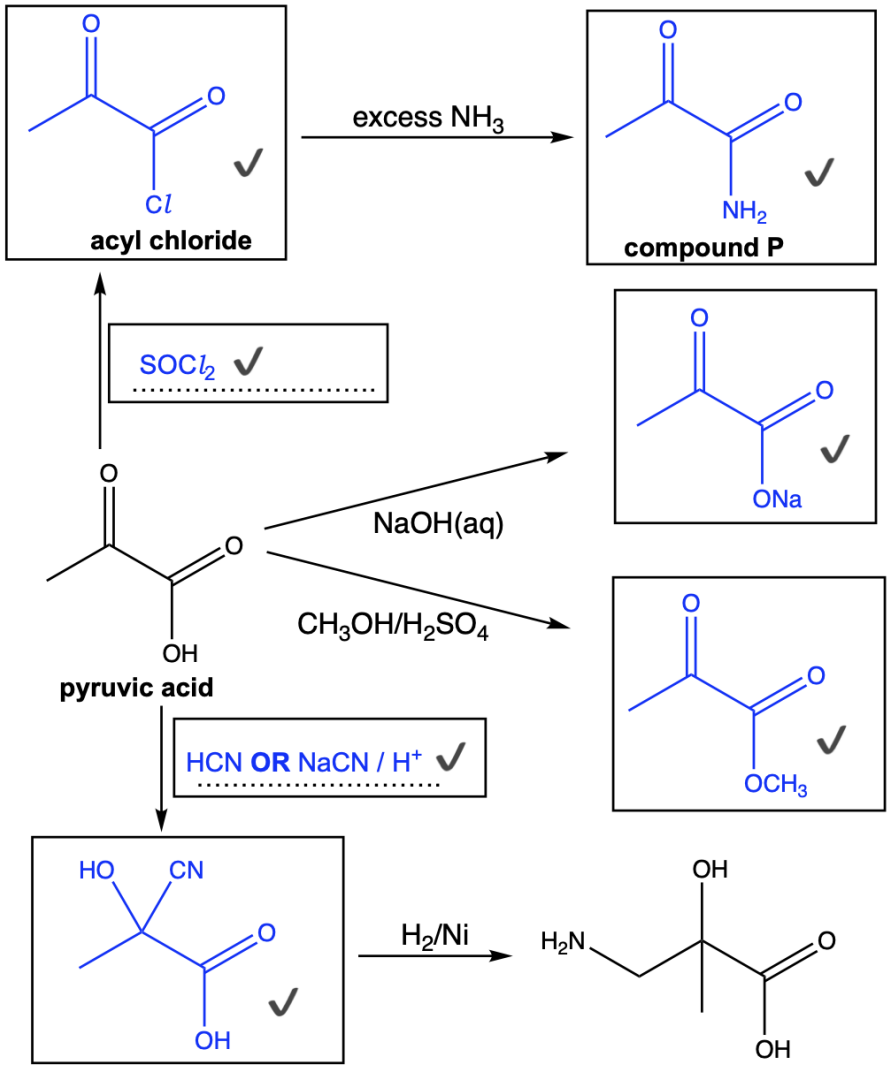
For Tollen's
ALLOW Silver/Grey/Black AND precipitate/ppt/solid
ALLOW acetol to give a positive result (it is an alpha hydroxy ketone so can tautomerize to give an aldehyde, not covered in the specification)

For Na_2CO_3
IGNORE gas / CO_2 formed i.e. must be an observable change
IGNORE test with limewater BUT DO NOT ALLOW other gas tests

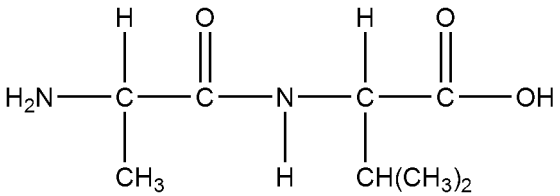
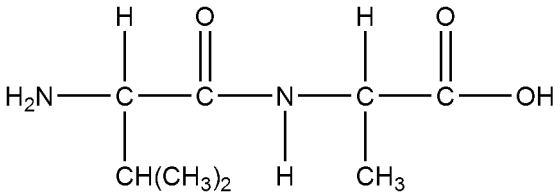
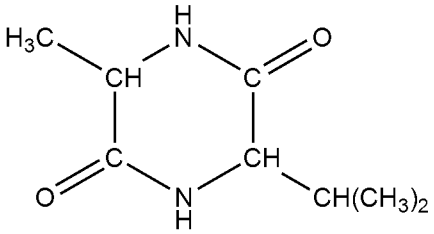
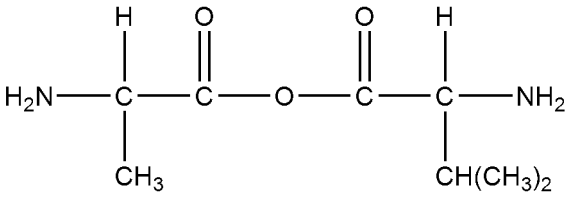
If no other marks awarded, ALLOW 1 mark for a correct column
</td></tr>
</table>

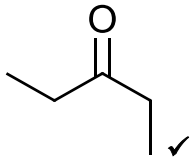
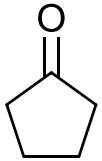
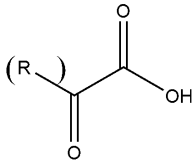
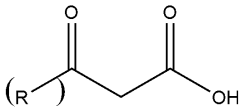
Question			Answer	Mark	Guidance
21	(d)		**NOTE**: curly arrows can be straight, snake-like, etc. but **NOT** double headed or half headed arrows ---------- **Nucleophilic attack** *2 marks*  Curly arrow from H^- to C of C=O ✓ Correct dipole shown on C=O **AND** curly arrow showing breaking of C=O ✓ ---------- **Intermediate** *1 mark*  Correct intermediate **AND** curly arrow from O^- to H in H_2O ✓ **DO NOT ALLOW** δ– on O of intermediate **IGNORE** attempt to draw curly arrow showing breaking of H–O in H_2O **IGNORE** lack of dipole on H_2O **IGNORE** absence of OH^- as 2nd product **IGNORE** connectivity of H_3C–	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 $O^{\delta-}$) 

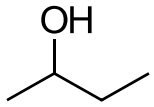
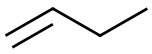
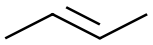
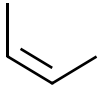
Question			Answer	Mark	Guidance
			Product *1 mark*  Correct product ✓		**3rd curly arrow must** • go to H of H_2O **AND** • start from, **OR** be traced back to any point across width of lone pair on $:O^-$ • **OR** start from $^-$ charge of O^- of intermediate  **NOTE: For arrow to** H of H_2O **ALLOW** curly arrow from O^- of intermediate to H^+  **IGNORE** Connectivity

Question			Answer	Mark	Guidance
21	(e)			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** $–CONH_3^+$ 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 *Acid is required for mark* **IGNORE** solvent **OR** (aq) **ALLOW** any vertical bond to the OH or CN e.g. **ALLOW** OH **OR** OH CN **OR** CN **BUT DO NOT ALLOW** -HO **OR** -NC

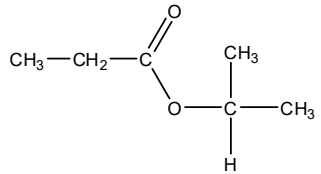
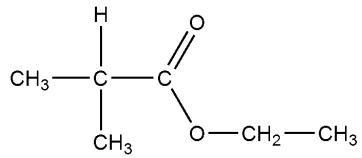
Question			Answer	Mark	Guidance
22	(a)	(i)	**Calculation of R_f values** $R_f = \frac{34.5}{46} = 0.75$ **AND** $R_f = \frac{11.5}{46} = 0.25$ ✓	1	**ALLOW** ±1 mm on each measurement, i.e. $R_f = 0.71 – 0.79$ $R_f = 0.22 – 0.28$ **ALLOW** values that round to 2dp to give a value in the acceptable range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

Question			Answer	Mark	Guidance
22	(a)	(ii)	**Any 2 from the following:** ✓✓    	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 Rf 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

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. CO_2, O=C=O, H_2O 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 *(matches alpha amino acid description)* **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}) ✓	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}) *(consistent with spectrum provided)* **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)**
			Possible structures of K, L and M **K** =  ✓ **L** =  ✓ **M** =  **OR**  ✓		**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)*		*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 either $CH_3CH_2COOCH(CH_3)_2$ **OR** $(CH_3)_2CHCOOCH_2CH_3$ **AND** Most of the data analysed *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Structure has a molecular formula of $C_6H_{12}O_2$ with **at least two** key features present **AND** Analyses some of the data from the NMR *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** Attempts analysis from at least 2 of the scientific points. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** No response or no response worthy of credit.	6	**Mark spectra page as SEEN** **Indicative scientific points:** **1. Empirical Formula** • C : H : 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 = C_3H_6O • **ALLOW** Alternative method using Mr of 116 e.g (0.6270 x116) ÷12 = 6 **2. Molecular Formula and Mass Spectrum** • uses *m/z* = 116.0 to determine molecular formula as $C_6H_{12}O_2$ • Any possible fragments, for example: - m/z = 43 $(CH_3)_2CH^+$ - m/z = 29 $CH_3CH_2^+$ **3. ^{1}H NMR analysis** • δ = 1.1 ppm, triplet, 3H **CH_3**CH_2– • δ = 1.4 ppm, doublet, 6 H –CH**$(CH_3)_2$** • δ = 2.4 ppm, quartet, 2H CH_3**CH_2CO** • δ = 4.4 ppm, heptet, 1H –**OCH**$(CH_3)_2$ **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 $-CH_2CH_3$ • Dimethyl group $-C(\mathbf{CH_3})_2$ **Correct structure**  Justified from NMR chemical shift analysis **OR**  Justified from MS fragment as $(CH_3)_2CHCO^+$ 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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