OCR
Oxford Cambridge and RSA

GCE

Chemistry A

H432/02: Synthesis and analytical techniques

A Level

Mark Scheme for June 2023

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.

MARKING INSTRUCTIONS

PREPARATION FOR MARKING

RM ASSESSOR

1. Make sure that you have accessed and completed the relevant training packages for on-screen marking: *RM Assessor Online Training*; *OCR Essential Guide to Marking*.

2. Make sure that you have read and understood the mark scheme and the question paper for this unit.

3. Log-in to RM Assessor and mark the **required number** of practice responses ("scripts") and the **required number** of standardisation responses.

MARKING

1. Mark strictly to the mark scheme.

2. Marks awarded must relate directly to the marking criteria.

3. The schedule of dates is very important. It is essential that you meet the RM Assessor 50% and 100% (traditional 50% Batch 1 and 100% Batch 2) deadlines. If you experience problems, you must contact your Team Leader (Supervisor) without delay.

4. If you are in any doubt about applying the mark scheme, consult your Team Leader by telephone, email or via the RM Assessor messaging system.

5. Work crossed out:

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

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

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

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

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

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

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

6. Always check the pages (and additional objects if present) at the end of the response in case any answers have been continued there. If the candidate has continued an answer there then add a tick to confirm that the work has been seen.

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

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

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

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

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

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

10. For answers marked by levels of response:

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

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

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

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

In summary:

The skills and science content determines the level.

The communication statement determines the mark within a level.

Level of response questions on this paper are **19** and **23**

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

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

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

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

No marks (0) should have a cross: 

Place the annotations alongside the mark for the question.

On additional pages, annotate using 

11. Annotations available in RM Assessor

Annotation	Meaning
	Correct response
	Incorrect response
	Omission mark
	Benefit of doubt given
	Contradiction
	Rounding error
	Error in number of significant figures
	Error carried forward
	Level 1
	Level 2
	Level 3
	Benefit of doubt not given
	Noted but no credit given
	Ignore
	Blank page

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

Annotation	Meaning
DO NOT ALLOW	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
( )	Words which are not essential to gain credit
__	Underlined words must be present in answer to score a mark
ECF	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

13. **Subject-specific Marking Instructions**

INTRODUCTION

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

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

You should ensure that you have copies of these materials.

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

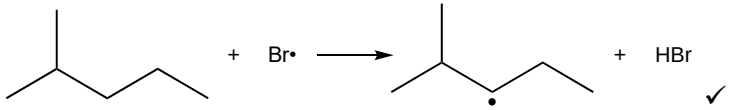
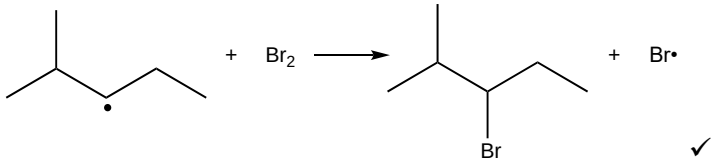
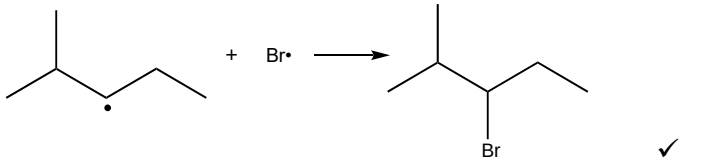
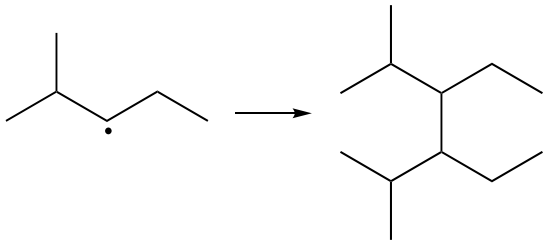
Please ask for help or guidance whenever you need it. Your first point of contact is your Team Leader.

SECTION A

Question	Answer	Marks	AO element	Guidance
1	C	1	AO1.1	
2	A	1	AO1.2	
3	B	1	AO2.1	
4	C	1	AO1.2	
5	B	1	AO1.2	**ALLOW** 24
6	B	1	AO1.1	
7	A	1	AO1.2	
8	B	1	AO2.2	
9	C	1	AO2.1	
10	B	1	AO2.1	
11	C	1	AO2.1	
12	D	1	AO1.2	
13	B	1	AO1.2	
14	D	1	AO1.2	
15	A	1	AO1.2	
	Total	**15**		

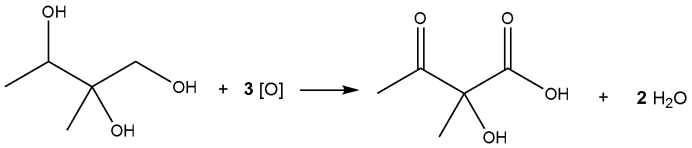
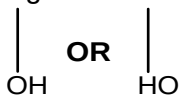
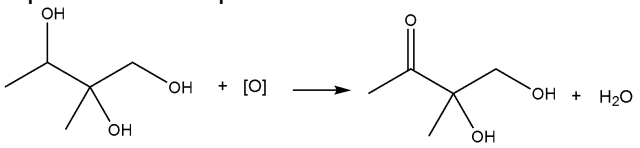
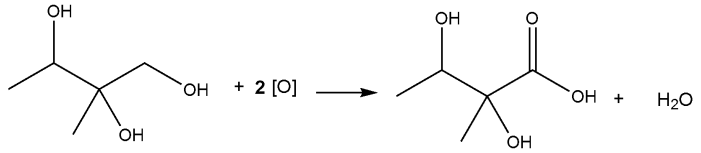
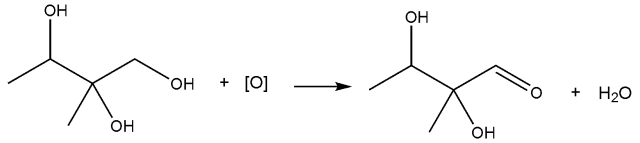
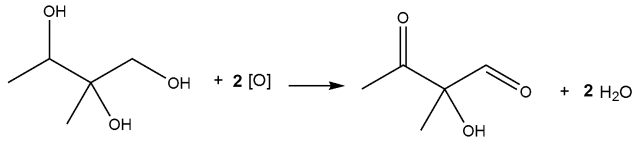
SECTION B

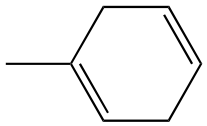
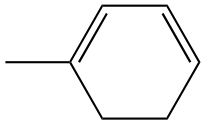
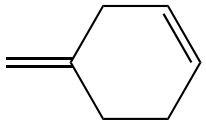
Question			Answer	Marks	AO element	Guidance
16	(a)			4		**ANNOTATE WITH TICKS AND CROSSES** **Comparisons** needed throughout **ORA** throughout
			Trend for all 3 hydrocarbons (1 mark): Boiling point increases with less branching **OR** less methyl/alkyl groups/side chains ✓		AO1.1	Must have link between rank order of branching and boiling point for all 3. **ALLOW** Hexane is least branched/straight chain and has highest bp **AND** 2,2-dimethylbutane is most branched and has lowest bp. **IGNORE** Chain length
			Explanation with comparison (3 marks): **Branching and surface contact** (Less branching gives) more (surface) contact / interaction (between molecules) ✓		AO1.2 X3	Surface area alone is **not** sufficient, must have idea of contact. **DO NOT ALLOW** arguments comparing different numbers of electrons (as all have the same number).
			Surface contact and London forces (More surface contact) gives more /stronger induced dipole(–dipole) interactions/ London forces ✓ **Energy and intermolecular forces** More energy to break induced dipole(–dipole) interactions/ London forces/intermolecular forces/intermolecular bonds (with less branching) ✓			**IGNORE** van der Waals'/vdW forces **OR** IDID **OR** IDD **ALLOW** 'more energy to break intermolecular forces' if intermolecular forces are not identified or incorrect. **IGNORE** harder to overcome/break intermolecular forces (no reference to energy) **IGNORE** just 'bonds' intermolecular/London forces required

Question			Answer	Marks	AO element	Guidance
16	(b)	(i)	**Initiation** $Br_2 \rightarrow 2Br\bullet$ **AND** ultraviolet / UV ✓ **Propagation**  ✓  ✓ **Termination** $2Br\bullet \rightarrow Br_2$ ✓  ✓ --- 2  ✓	6	AO1.1 AO2.5 AO2.5 AO2.5 AO3.1	**DOT REQUIRED** throughout **IGNORE** temperature and pressure **ALLOW ECF** for use of Cl• (from Cl_2) in subsequent propagation and termination steps **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** 1 mark for propagation for 2 'correct' equations but with dot omitted or in wrong position **DO NOT ALLOW ECF** from incorrect radical intermediate for termination steps

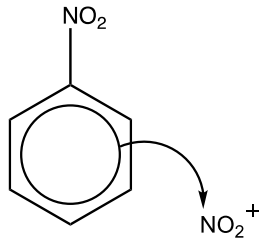
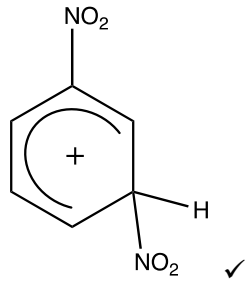
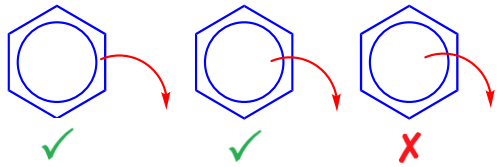
Question			Answer	Marks	AO element	Guidance
16	(b)	(ii)	C_6Br_{14} ✓ Correct balanced equation $C_6H_{14} + 14\,Br_2 \rightarrow C_6Br_{14} + 14\,HBr$ ✓	2	AO2.6 ×2	**ALLOW** 1 mark for correct balanced equation using any combination of skeletal **OR** structural **OR** displayed formula
	(b)	(iii)	$n(\mathbf{B}) = \frac{72.0}{40000}$ **OR** $\frac{0.072}{40}$ **OR** $1.8(0) \times 10^{-3}$ (mol) ✓ $M(\mathbf{B}) = \frac{0.8649}{1.8(0) \times 10^{-3}} = 480.5$ ✓ Molecular formula = $C_6H_9Br_5$ ✓	3	AO2.2 ×2 AO3.2	**ALLOW 2SF** up to calculator value **ALLOW ECF** from incorrect $n(\mathbf{B})$ **ALLOW ECF** from incorrect $M(\mathbf{B})$ from $n(\mathbf{B})$ **COMMON ERROR** $n(\mathbf{B}) = \frac{72.0}{24000} = 3 \times 10^{-3}$ (mol) ✗ $M(\mathbf{B}) = \frac{0.8649}{3 \times 10^{-3}} = 288.3$ ……✓ Molecular formula = $C_6H_{12}Br_2$ **OR** $C_6H_{11}Br_3$ ✓ **ALLOW ECF** for viable molecular formula with C_6 but must be derived from a calculated value for $M(\mathbf{B})$

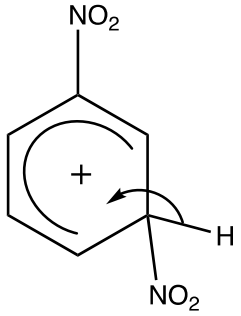
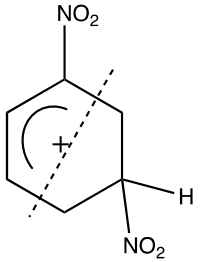
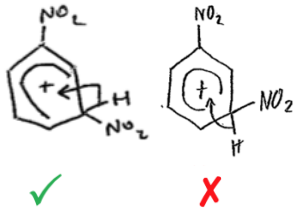
Question			Answer	Marks	AO element	Guidance
17	(a)		$C_6H_{11}OH$ ✓ Correct balanced equation $C_6H_{11}OH + 8½\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$ ✓	2	AO2.6 ×2	For $C_6H_{11}OH$, **ALLOW** $C_6H_{12}O$ **OR** any combination of skeletal **OR** structural **OR** displayed formula **ALLOW** multiples **IGNORE** state symbols **ALLOW** multiple OH groups in structure for both marks e.g. $C_6H_{12}O_2$ ✓ $C_6H_{12}O_2 + 8\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$ ✓

Question			Answer	Marks	AO element	Guidance
17	(b)		 Compound C Correct organic product ✓✓ Correct balanced equation ✓	3	AO2.5 ×2 AO2.6	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** any vertical bond to the OH group e.g. **ALLOW**  **OR** **ALLOW** 1 mark for partially oxidised organic product and an additional mark for ECF for correct balanced equation for this product. i.e.  Organic product ✓ Correct balanced equation ✓ **OR**  **OR**  **OR** 

Question			Answer	Marks	AO element	Guidance
17	(c)	(i)	 ✓  ✓  ✓	3	AO2.5 ×3	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous
	(c)	(ii)	NaI / KI **AND** H_2SO_4 ✓	1	AO1.2	**ALLOW** HI **ALLOW** NaI / KI **AND** H_3PO_4 **OR** HNO_3 **IGNORE** Conc or dilute

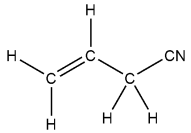
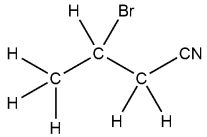
Question			Answer	Marks	AO element	Guidance
17	(d)		**Structures 1 mark** $CH_3CH_2CH_2CH_2OH$ **AND** $CH_3CH_2CHOHCH_3$ **AND** $(CH_3)_2CHCH_2OH$ **AND** $(CH_3)_3COH$ ✓	5	AO2.1	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **Note:** all 4 structures are needed for the mark. Additional incorrect structures prevent this mark being awarded.
			Number of peaks 3 marks $CH_3CH_2CH_2CH_2OH$/ butan-1-ol **OR** $CH_3CH_2CHOHCH_3$ / Butan-2-ol have 4 peaks/environments/types of carbon ✓ $(CH_3)_2CHCH_2OH$/ (2-)methylpropan-1-ol has 3 peaks/environments/types of carbon ✓ $(CH_3)_3COH$/(2-)methylpropan-2-ol has 2 peaks/environments/types of carbon ✓		AO3.1 ×3	**IGNORE** chemical shifts **IGNORE** incorrect name if structure given **ALLOW** correct number of peaks linked to an incomplete structure e.g. C-C-C-C-OH has 4 peaks (no hydrogens shown)
			Statement 1 mark $(CH_3)_2CHCH_2OH$/(2-)methylpropan-1-ol can be distinguished (from any other isomer) **OR** $(CH_3)_3COH$/(2-)methylpropan-2-ol can be distinguished (from any other isomer) **OR** $CH_3CH_2CH_2CH_2OH$/ butan-1-ol **AND** $CH_3CH_2CHOHCH_3$/ butan-2-ol cannot be distinguished ✓		AO3.2 ×1	**Statement mark can only be awarded if candidate compares at least two isomers and determines correct number of peaks for the isomers referred to.** **DO NOT ALLOW ECF** from an incorrect number of peaks/environments/types of carbon

Question			Answer	Marks	AO element	Guidance
18	(a)		**Role of H_2SO_4 catalyst** **2 marks** *Forming electrophile* $HNO_3 + H_2SO_4 \longrightarrow H_2O + HSO_4^- + NO_2^+$ ✓ *Reforming catalyst* $H^+ + HSO_4^- \longrightarrow H_2SO_4$ ✓ **Electrophilic attack** **1 mark** Curly arrow from π-bond to NO_2^+ ✓  --- **Correct intermediate** **1 mark**  ✓	5	AO1.2 AO1.2 AO1.2 AO2.5	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **ALLOW** $HNO_3 + 2H_2SO_4 \rightarrow H_3O^+ + 2HSO_4^- + NO_2^+$ **ALLOW** $HNO_3 + H_2SO_4 \rightarrow H_2NO_3^+ + HSO_4^-$ then $H_2NO_3^+ \rightarrow H_2O + NO_2^+$ **ALLOW** $^+NO_2$ **OR** NO_2^+ **NOTE**: curly arrows can be straight, snake-like, etc. but **NOT** double headed or half headed arrows **1st curly arrow** must • start from, **OR** close to **circle of benzene ring** **AND** • go to anywhere on NO_2^+  **DO NOT ALLOW** mark for intermediate if additional NO_2 is missing

Question	Answer	Marks	AO element	Guidance
	--- **Reforming benzene ring** **1 mark** Curly arrow from C–H bond to reform π-ring ✓  **Curly arrow** must start from, **OR** be traced back to, **any part of** C–H bond and go inside the 'hexagon'		AO1.2	**IGNORE** connectivity to NO_2 groups *(mark is for correct substitution position and position of* π-ring*)* **DO NOT ALLOW** the following intermediate:  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

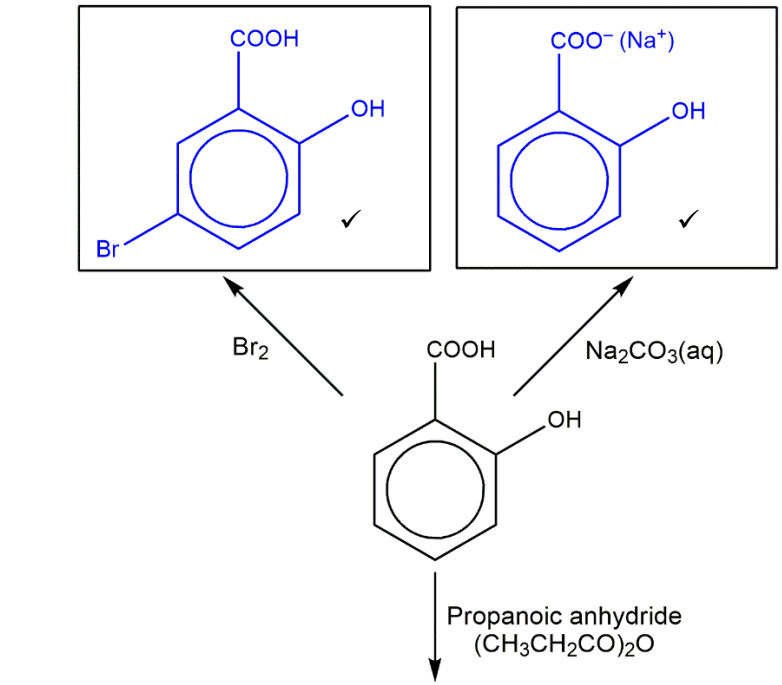
Question			Answer	Marks	AO element	Guidance
18	(b)		**FIRST CHECK ANSWER ON ANSWER LINE** **If answer = 73.2 award 3 marks** --- **Theoretical moles** $n(C_6H_5NO_2)$ **OR** $n(C_6H_4(NO_2)_2)$ $= \frac{12.5 \times 1.20}{123.0}$ **OR** 0.12195... (mol) ✓ **Actual moles** $n(C_6H_4(NO_2)_2) = \frac{15.0}{168.0}$ **OR** 0.0892857(mol) ✓ % yield = $\frac{0.0892857\ldots}{0.12195\ldots} \times 100$ = 73.2 % to **3SF** ✓	3	AO2.8 AO2.8 AO1.2	**ALLOW 3SF** up to calculator value throughout working **IGNORE** rounding errors past **3SF** **TAKE CARE** as value written down may be truncated but with value stored in calculator, depending on rounding, either can be credited. Calculator = 0.1219512195 Calculator = 0.08928571429 **ALLOW ECF** except for final mark if value is ≥100% --- **Alternative method using mass** 1. Theoretical moles = 0.12195…. mol 2. Mass = 0.12195… × 168.0 **OR** 20.4878... g 3. % yield = $\frac{15}{20.4878\ldots} \times 100 = 73.2\%$ --- **Common errors** 87.9% → 2 marks • From $\frac{12.5}{123}$ = 0.101626…..*(no density)*

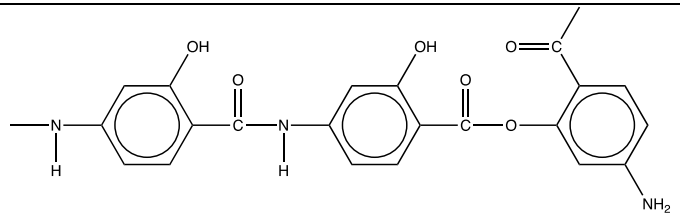
Question			Answer	Marks	AO element	Guidance
18	(c)		Dissolve in the minimum quantity of hot water/solvent ✓ Cool (to allow crystals form) **AND** Then filter (under reduced pressure) ✓ (Leave to) dry ✓	3	AO3.3 ×3	**ALLOW** any solvent **IGNORE** • Initial filtering • Filtration between dissolving and cooling (implies hot filtration) • Washing with cold solvent **DO NOT ALLOW** use of drying agent (e.g. $MgSO_4$)

Question	Answer	Marks	AO element	Guidance
19*	*Refer to marking instructions on page 4 of mark scheme for guidance on marking this question.* **Level 3 (5-6 marks**) A **three** stage synthesis in the **correct** order **AND** Equations for each stage are mostly correct **AND** Most reagents 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)** Synthesis includes at least **two** stages in **any** order **OR** uses NH_3 and HBr in the **correct** order (without chain extension) **AND** some of the reagents and some equations correct *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)** Planned synthesis includes reagents for **any** two stages **OR** Describes one stage with reagents and equation mostly correct *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.*	**6**	AO3.3 ×6	**Mark second page as SEEN** **Indicative scientific points may include:** **IGNORE conditions** ***Stage 1: Reaction with CN^-*** • Reagents: CN^- (in ethanol) • Equation: $H_2C{=}CHCH_2Br + CN^- \rightarrow H_2C{=}CHCH_2CN + Br^-$ **Intermediate 1**  ***Stage 2: Addition of HBr to C=C*** • Reagents**:** HBr • Equation: $H_2C{=}CHCH_2CN + HBr \rightarrow CH_3CHBrCH_2CN$ **Intermediate 2**  ***Stage 3: Reduction of CN*** • Reagents: H_2 (with Ni) • Equation: $H_3CCHBrCH_2CN + 2H_2 \rightarrow CH_3CHBrCH_2CH_2NH_2$ ***Needs CN^- before HBr*** ***– CN^- would react with both Br atoms*** ***Needs HBr before H_2*** ***– H_2 would react with C=C***

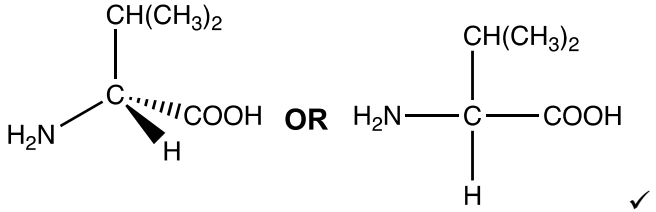
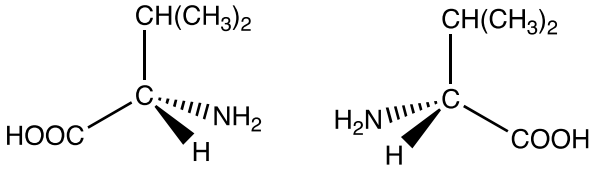
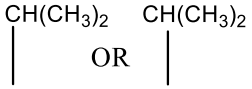
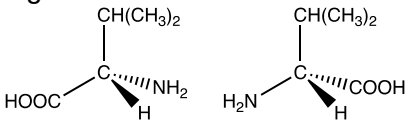
Question	Answer	Marks	AO element	Guidance
	0 marks No response or no response worthy of credit.			**Alternative three stage syntheses:** ***Alternative using $LiAlH_4$*** ***Caution - Can be done as stage 2 or 3*** • Reagents: $LiAlH_4$ • Equation: $H_2C=CHCH_2CN + 4[H] \rightarrow H_2C=CHCH_2CH_2NH_2$ **OR** $H_3CCHBrCH_2CN + 4[H] \rightarrow CH_3CHBrCH_2CH_2NH_2$ ***Needs CN^- before HBr and $LiAlH_4$*** ***Can have HBr and $LiAlH_4$ in any order*** ***Alternative using radical substitution:*** ***Stage 1: Reaction with CN^-*** • Reagents: CN^- (in ethanol) • Equation: $H_2C=CHCH_2Br + CN^- \rightarrow H_2C=CHCH_2CN + Br^-$ ***Stage 2: Reduction of CN and C=C*** • Reagents: H_2 (with Ni) • Equation: $H_2C=CHCH_2CN + 3H_2 \rightarrow CH_3CH_2CH_2CH_2NH_2$ **Stage 3: Reaction with Br_2** • Reagents: Br_2 (with UV) • Equation: $CH_3CH_2CH_2CH_2NH_2 + Br_2 \rightarrow$ $CH_3CHBrCH_2CH_2NH_2 + HBr$ ***Needs CN^- before H_2*** ***Needs H_2 before Br_2***

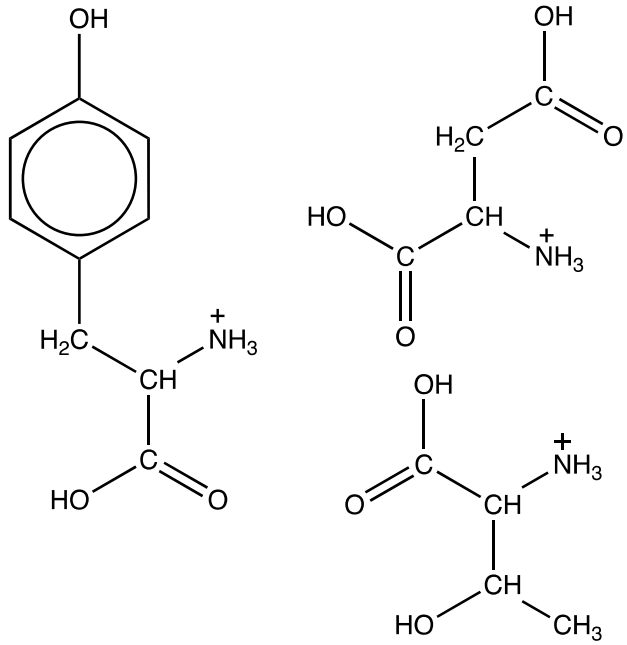
Question			Answer	Marks	AO element	Guidance
						Two stage synthesis using NH_3 and HBr forming product with no lengthening of carbon chain ***Stage 1: Reaction of NH_3*** • Reagents: NH_3 (in ethanol) • Equation: $H_2C=CHCH_2Br + NH_3 \rightarrow H_2C=CHCH_2NH_2 + HBr$ ***OR*** *$2\ NH_3 \rightarrow NH_4Br$* ***Stage 2: Addition of HBr to C=C*** • Reagents**:** HBr • Equation: $H_2C=CHCH_2NH_2 + HBr \rightarrow CH_3CHBrCH_2NH_2$ ***Needs NH_3 before HBr*** ***– HBr would react with C=C***

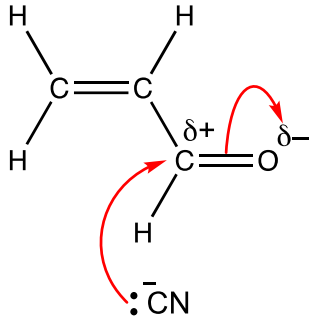
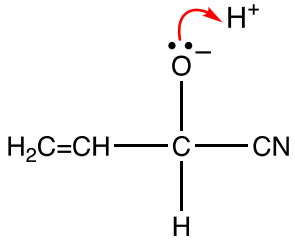
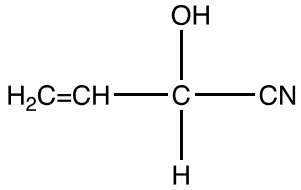
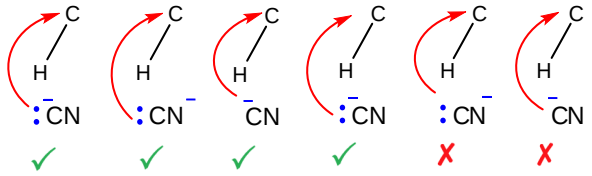
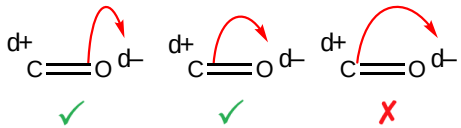
Question			Answer	Marks	AO element	Guidance
20	(a)			4	AO2.5 ×4	**IGNORE** connectivity of phenol OH group and COOH group throughout *(marks are for correct conversions)* **Br_2** **ALLOW** Br substitution at any position on ring **ALLOW** up to 4 Br atoms onto ring **Na_2CO_3** **ALLOW** COO^- **OR** COONa **$(CH_3CH_2CO)_2O$** **IGNORE** reaction of COOH to form an acid anhydride **ALLOW** structures in bottom 2 boxes in either order

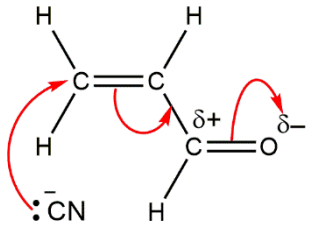
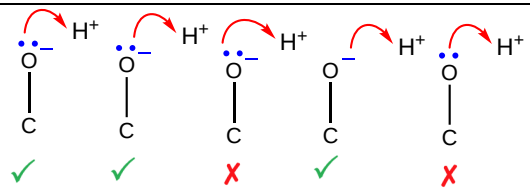
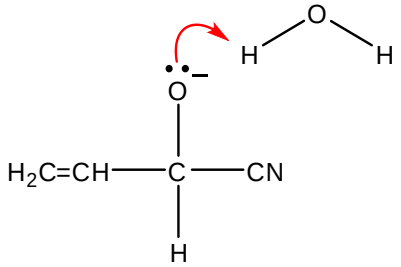
Question			Answer	Marks	AO element	Guidance
20	(b)	(i)	 Section contains A displayed amide linkage between 2 benzene rings ✓ A displayed ester linkage between 2 benzene rings ✓ Section with at least **one** 'end bond' and correct positioning of all 3 groups on **each** benzene ✓	**3**	AO1.2 ×2 AO3.2	**Marking point 3 is dependent on first 2 marks** Check bonding around **each** benzene so C=O position 1, C-O position 2 and C-NH position 4. **ALLOW** 'end bonds' (with either a solid or dashed line') **OR** terminal ends e.g. -O- or -OH **ALLOW** any combination of 'end bonds' as showing a section not a repeat unit **IGNORE** connectivity of OH and NH_2 groups to benzene

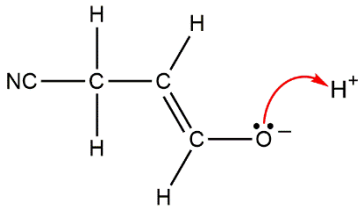
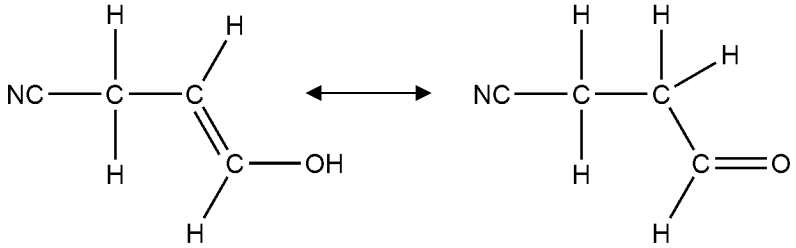
Question			Answer	Marks	AO element	Guidance
20	(b)	(ii)	**FIRST CHECK ANSWER ON THE ANSWER LINE** **If answer = 2.36×10^{22} award 3 marks** **Calculate moles of PAS:** 300 mg of PAS contains $\frac{300 \times 10^{-3}}{153}$ **OR** $1.96\ldots. \times 10^{-3}$ (mol) ✓ **Daily dose of PAS:** *n*(PAS) for 20.0 kg child = $20 \times 1.96\ldots. \times 10^{-3}$ (mol) **OR** 0.0392……. (mol) ✓ **Use of Avogadro's constant:** Number of PAS molecules = $0.0392\ldots\ldots \times 6.02 \times 10^{23}$ $= 2.36 \times 10^{22}$ ✓	3	AO3.1 ×2 AO3.2 ×1	**ALLOW 3SF** up to calculator value throughout **IGNORE** rounding errors past **3SF** **If there is an alternative answer, apply ECF throughout. Steps can be carried out in any order.** **Calculator values:** $1.960784314 \times 10^{-3}$ 0.03921568627 **Common alternative method:** m(PAS) for 20.0 kg child = 0.3 x 20 **OR** 6.0 (g) ✓ n(PAS) for 20.0 kg child = 6/153 **OR** 0.0392…(mol**)** ✓

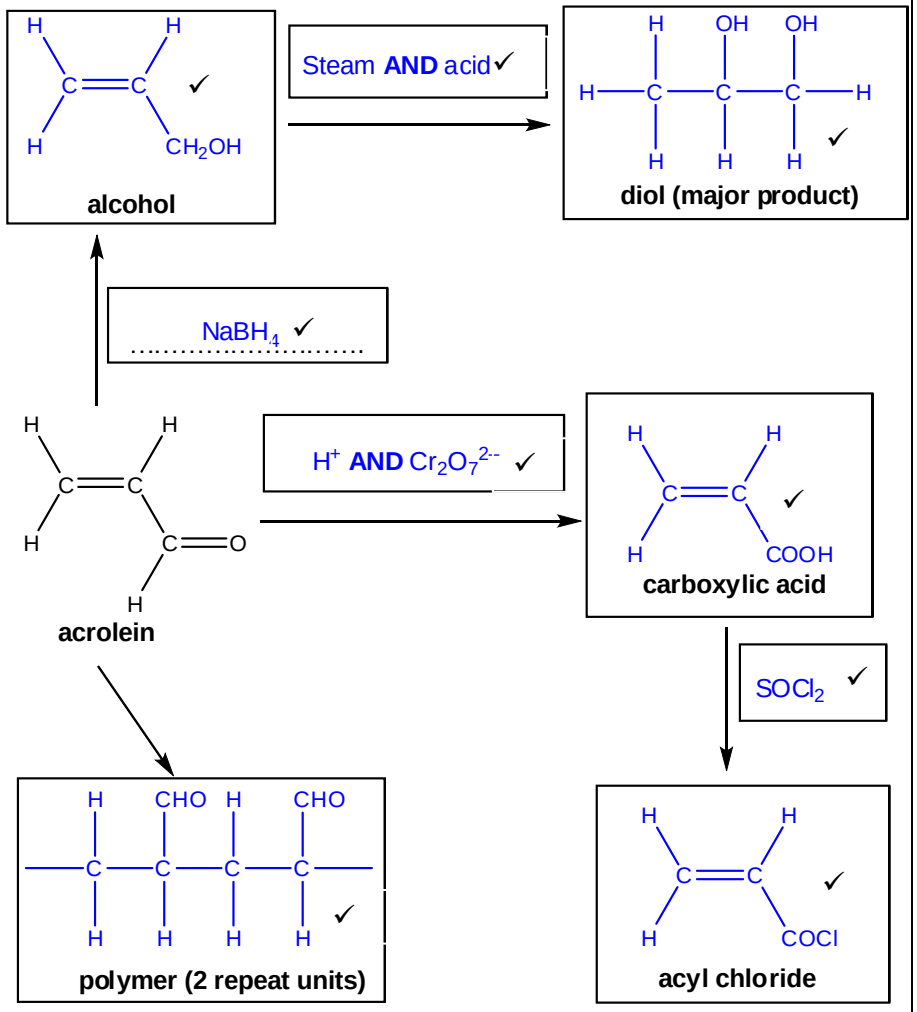
Question			Answer	Marks	AO element	Guidance
21	(a)		Non-superimposable mirror images (about a chiral centre) ✓	1	AO1.1	**IGNORE** definition of stereoisomers
	(b)	(i)	2-amino-3-methylbutanoic acid **OR** 3-methyl-2-aminobutanoic acid ✓	1	AO1.2	**IGNORE** lack of hyphens, extra hyphens, or addition of commas **DO NOT ALLOW** the following for methyl: methy, meth, methly **DO NOT ALLOW** the following for amino: amine, amin
	(b)	(ii)	Correct groups attached to chiral C of valine seen **once** e.g.  ✓ Two **3D structures** of valine that are mirror images with correct connectivity in both ✓  	2	AO1.1 AO1.2	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** connectivity for the first marking point but must be correct for the second mark. **ALLOW** bond to any part of the CH of the $CH(CH_3)_2$ group e.g. **ALLOW**  Each structure must have four central bonds with **at least two wedges.** For bond into paper accept:  **ALLOW** two 3D structures with 2 groups swapped e.g.  **ALLOW** R or C_3H_7 to be shown for $CH(CH_3)_2$ for second mark only. **ALLOW ECF** for second mark for small slips such as missing H e.g. $C(CH_3)_2$

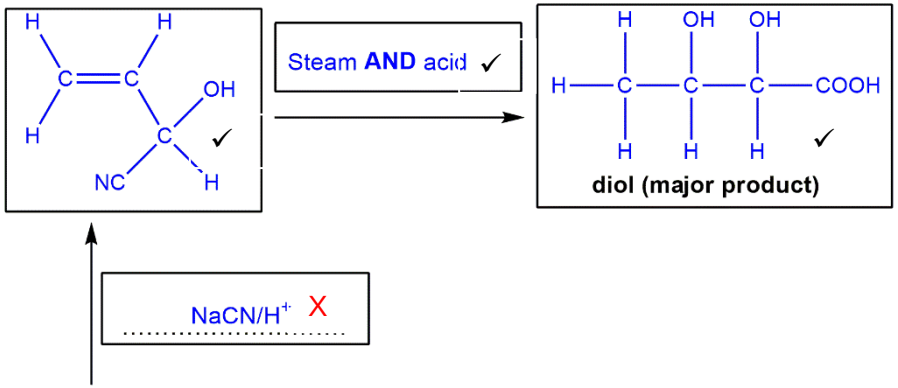
Question			Answer	Marks	AO element	Guidance
21	(c)	(i)	16 ✓	1	AO2.6	
	(c)	(ii)	 **1 mark** for each **correct** structure with • **Either** NH_3^+ **OR** NH_2 ✓✓✓ **1 mark** for • **all 3 correct** structures with NH_3^+ ✓	4	AO2.5 ×4	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** connectivity **ALLOW** + charge on H of NH_3 group, i.e. NH_3^+ If structures are shown with NH_3 groups (without the + charge) **OR** as NH_2^+ groups allow **ECF** for subsequent use. **ALLOW** structures shown as correctly balanced salts, e.g NH_3Cl **OR** $NH_3^+Cl^-$ all marks can be awarded.

Question			Answer	Marks	AO	Guidance
22	(a)	(i)	**NOTE**: curly arrows can be straight, snake-like, etc. but **NOT** double headed or half headed arrows --- **Nucleophilic attack** *2 marks*  Curly arrow from ⁻CN 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^+ ✓ **DO NOT ALLOW** δ– on O of intermediate **IGNORE** connectivity of $H_2C{=}CH–$ --- **Product** *1 mark*  Correct product ✓	4	AO1.2 ×2 AO2.5 ×2	**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 C of ⁻:CN **OR** :CN⁻ • **OR** start from – charge on C of ⁻CN (then lone pair on CN^- does not need to be shown)  **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 $O^{\delta-}$)  **3rd curly arrow must** • go to H^+ **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 (then lone pair on O^- does not need to be shown)

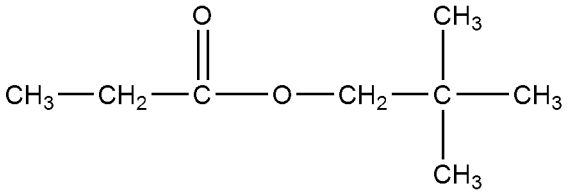
Question	Answer	Marks	AO	Guidance
	Possible alternative 1,4 (conjugate) addition can be credited as follows (not in specification): --- **Nucleophilic attack** *2 marks*  Curly arrow from ^{-}CN to C of CH_2 of C=C ✓ Curly arrow from C=C to C-C **AND** curly arrow showing breaking of C=O ✓ ---  **NOTE: For arrow to H^+** **ALLOW** arrow to H of H_2O i.e.  **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 *Otherwise this more difficult mechanism could cost 2 marks*			

Question			Answer	Marks	AO	Guidance
			Intermediate *1 mark*  Correct intermediate **AND** curly arrow from O^- to H^+ ✓ **DO NOT ALLOW** δ– on O of intermediate --- **Product** *1 mark* Either tautomer as correct product ✓ 			**Product mark can only be given here if clear from mechanism that there is nucleophilic attack of CH_2 in C=C.** Same product could be seen with an attempt at electrophilic addition across C=C.
22	**(a)**	**(ii)**	Nucleophilic addition ✓	**1**	AO1.1	**IGNORE** just 'addition'

Question			Answer	Marks	AO	Guidance
22	(b)			9	AO1.2 ×4 AO2.5 ×5	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** Correct names instead of formula for all reagents throughout e.g. For H^+ and $Cr_2O_7^{2-}$, **ALLOW** acidified dichromate For Steam and acid • For steam, **ALLOW** $H_2O(g)$ **OR** H_2O with $T \geq 100^oC$ • For acid, **ALLOW** H^+ **OR** H_2SO_4 **OR** H_3PO_4 • Note both needed for 1 mark. **ALLOW** either way round. For $NaBH_4$ • **IGNORE** water / aqueous /acid • **ALLOW** $LiAlH_4$ For $SOCl_2$, **ALLOW** PCl_5 **OR** $COCl_2$ • **IGNORE** H^+ **OR** HCl For H^+ and $Cr_2O_7^{2-}$, **ALLOW** H_2SO_4 **AND** $K_2Cr_2O_7$ **OR** $Na_2Cr_2O_7$ **ALLOW** Tollens' reagent **IGNORE** connectivity except **DO NOT ALLOW** -COH for aldehyde For polymer **ALLOW** alternating side chains. **IGNORE** brackets and use of 'n' 'End bonds' **MUST** be shown (solid or dotted)

Question			Answer	Marks	AO	Guidance
			Only possible alternative that can gain credit: Reaction with $NaCN/H^+$  			**IF** $NaCN/H^+$ reacted with acrolein instead of $NaBH_4$ • No mark for $NaCN/H^+$ **OR** HCN • Unsaturated alcohol award mark for product as shown • Final product must have CN hydrolysed as shown

Question	Answer	Marks	AO element	Guidance
23	*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 $CH_3CH_2COOCH_2C(CH_3)_3$ **OR** $(CH_3)_3CCH_2COOCH_2CH_3$ **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 is an ester of $C_8H_{16}O_2$ with **some** key features present **AND** Analyses some of the data from at least 3 of the scientific points. *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	AO1.2 × 2 AO3.1 × 2 AO3.2 × 2	**Mark spectra page as SEEN** **Indicative scientific points:** **1. Empirical Formulae** • C : H : O = $\frac{66.63}{12.0} : \frac{11.18}{1.0} : \frac{22.19}{16.0}$ = 5.55 : 11.18 : 1.39 = 4 : 8 : 1 • Empirical formula = C_4H_8O **2. Molecular Formulae** • uses *m/z* = 144.0 to determine molecular formula as $C_8H_{16}O_2$ **3. Functional group** From IR, • → C=O from ~1740 cm^{-1} **IGNORE** references to C–O peaks No reaction with 2,4-DNP • → no carbonyl/no ketone and aldehyde • Likely to be an ester **4. ^{1}H NMR analysis** • δ = 0.9 ppm, singlet, 9H –C(**CH_3**)$_3$ • δ = 1.2 ppm, triplet, 3H **CH_3**CH_2– • δ = 2.2 ppm, quartet, 2H CH_3**CH_2**CO • δ = 4.1 ppm, singlet, 2H –**OCH_2**– **ALLOW** approximate values for chemical shifts.

Question	Answer	Marks	AO element	Guidance
				Structure **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **Key features consistent with chemical shift data and relative peak areas** • O-CH_2 • $C(CH_3)_3$ • $CH_3CH_2C{=}O$ **Correct Structure** • $CH_3CH_2COOCH_2C(CH_3)_3$ 

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