GCE

Chemistry A

H432/02: Synthesis and analytical techniques

A Level

Mark Scheme for June 2022

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. Award No Response (NR) if:

- there is nothing written in the answer space.

Award Zero '0' if:

- anything is written in the answer space and is not worthy of credit (this includes text and symbols).

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 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(e)** and **21**

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.

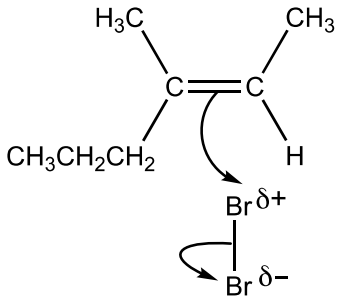
You should ensure also that you are familiar with the administrative procedures related to the marking process. These are set out in the OCR booklet **Instructions for Examiners**. If you are examining for the first time, please read carefully **Appendix 5 Introduction to Script Marking: Notes for New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

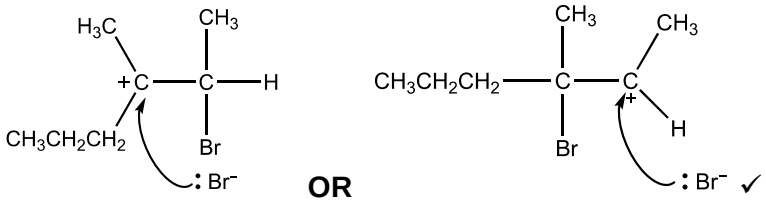
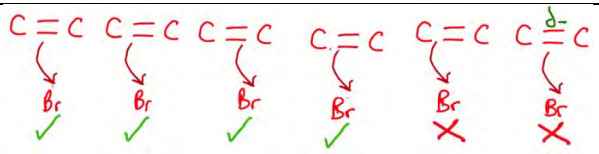
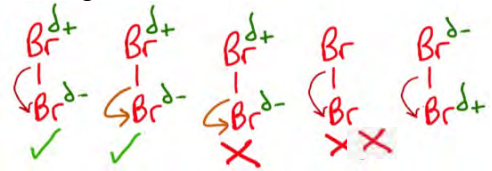
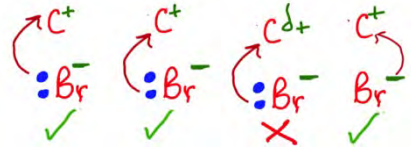
Please ask for help or guidance whenever you need it. Your first point of contact is your Team Leader.

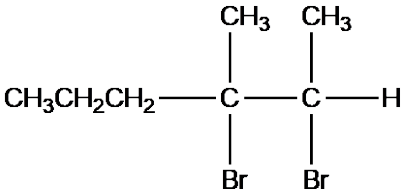
SECTION A

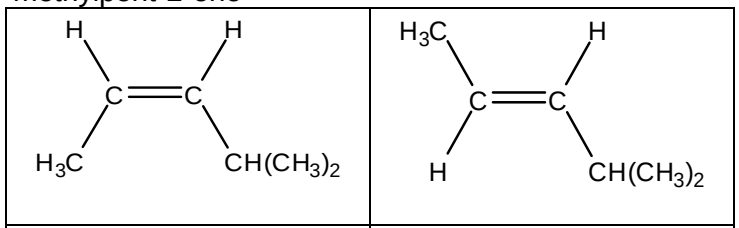
Question	Answer	Marks	AO element	Guidance
1	B	1	AO1.1	
2	B	1	AO1.1	
3	D	1	AO1.2	**ALLOW** 15 (correct number of sigma bonds)
4	A	1	AO1.1	
5	D	1	AO1.2	**ALLOW** 8 (correct number of chiral centres)
6	B	1	AO1.2	
7	D	1	AO1.2	
8	C	1	AO2.2	**ALLOW** 500 (This is the correct mass)
9	C	1	AO2.6	**ALLOW** 4.8 (This is the correct volume)
10	B	1	AO1.2	
11	B	1	AO2.5	
12	A	1	AO2.1	
13	D	1	AO1.1	
14	A	1	AO1.1	
15	B	1	AO2.1	
	Total	**15**		

SECTION B

Question			Answer	Marks	AO element	Guidance
16	(a)	(i)	3-methylhex-2-ene ✓	1	AO1.2	**IGNORE** lack of hyphens, or addition of commas **DO NOT ALLOW** 3-methyhex-2-ene OR 3-methhex-2-ene OR 3-methlyhex-2-ene OR 3-methylhexan-2-ene **IGNORE** references to *E/Z or cis/trans*
16	(a)	(ii)	**ANNOTATE ANSWER WITH TICKS AND CROSSES**  Curly arrow from C=C bond to $Br^{\delta+}$ of Br–Br **AND** Correct dipole on Br–Br **AND** curly arrow for breaking of Br–Br bond ✓	3	AO1.2 ×1 AO2.5 ×2	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** connectivity of $CH_3CH_2CH_2$ and CH_3 groups in carbocation and product **ALLOW** C_3H_7 for $CH_3CH_2CH_2$ **DO NOT ALLOW** half headed or double headed arrows but allow **ECF** if seen more than once **DO NOT ALLOW** use of HBr but ECF for subsequent use **For curly arrows, ALLOW straight or snake-like arrows and small gaps (see examples):** **----------** **DO NOT ALLOW** partial charge on C=C **1st curly arrow** must • go to a Br atom of Br–Br **AND** start from, **OR** be traced back to **any point across width** of C=C

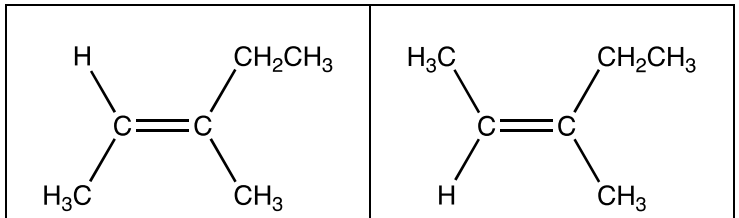
Question	Answer	Marks	AO element	Guidance
	Correct carbocation to match mechanism **AND** curly arrow from Br^- to C^+ of carbocation  **OR** *i.e.* ***ALLOW*** *carbonium + on either C atom* ----------			 **2nd curly arrow** must • start from, **OR** be traced back to, **any part of** $^{\delta+}Br–Br^{\delta-}$ bond • **AND** go to Br $^{\delta-}$  **3rd curly arrow** must • go to the C^+ of carbocation **AND** • start from, **OR** be traced back to **any point across width** of lone pair on $:Br^-$ • **OR** start from – charge on Br^- ion  *(Lone pair* ***NOT*** *needed if curly arrow shown from – charge on* Br^-*)* **ALLOW** bromonium ion (Contact TL)

Question			Answer	Marks	AO element	Guidance
			Correct product to match mechanism ✓ 			
16	**(b)**	**(i)**	Same **molecular** formula **AND** Different **structural** formulae ✓ **OR** Both have the **molecular** formula C_6H_{12} **AND** Different **structural** formulae ✓	**1**	AO1.1	Same formula is **not** sufficient *(no reference to molecular)* Different arrangement of atoms is **not** sufficient *(no reference to structure/structural)* For 'structural formulae', **ALLOW** structure/displayed/skeletal formulae/ functional groups **DO NOT ALLOW** any reference to spatial/space
16	**(b)**	**(ii)**	Same structural formula **AND** Different arrangement (of atoms) **in space** **OR** different **spatial** arrangement (of atoms) ✓	**1**	AO1.1	**ALLOW** structure/displayed/skeletal formula **DO NOT ALLOW** same empirical formula **OR** same general formula **IGNORE** same molecular formula Reference to *E*/*Z* isomerism or optical isomerism is **not** sufficient

<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>AO element</th><th>Guidance</th></tr>
<tr><td>16</td><td>(b)</td><td>(iii)</td><td>Correct identification of cis AND trans isomers of 4-methylpent-2-ene ✓✓
 

cis isomer | trans isomer

OR

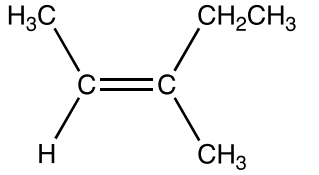
Identification of 3-methylpent-2-ene as cis AND trans isomers ✓✓
 

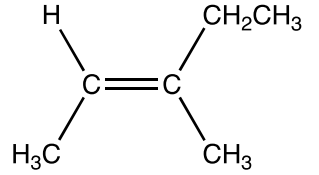
cis isomer | trans isomer</td><td>2</td><td>AO1.2

AO2.5</td><td>ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous

C_3H_7 is not sufficient (could be unbranched)

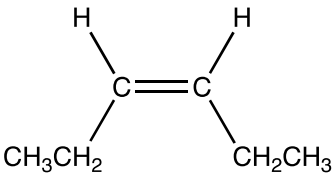
ALLOW one mark if cis AND trans isomers of 4-methylpent-2-ene are in the wrong boxes

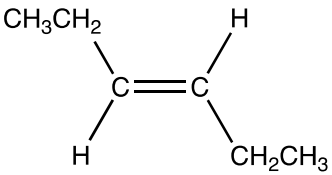
ALLOW the isomers of 3-methylpent-2-ene in either box
 

cis isomer
 

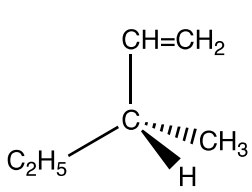
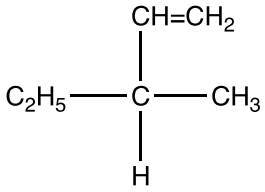
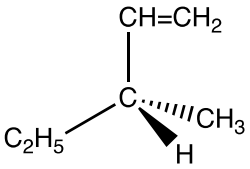
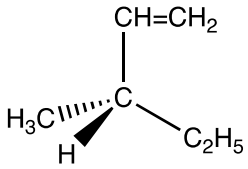
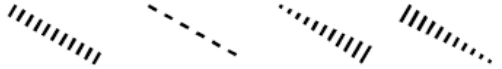
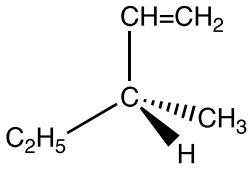
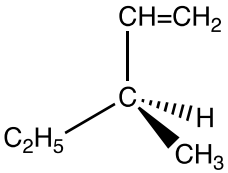
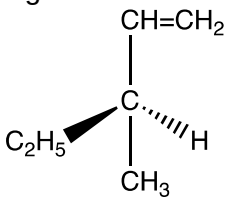
trans isomer

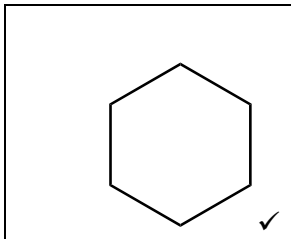
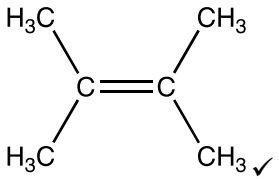
Ambiguity with cis/trans identification system

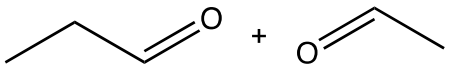
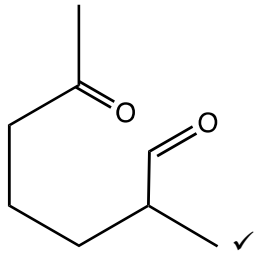
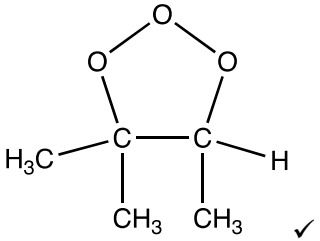
ALLOW one mark for correct identification of cis AND trans isomers of unbranched C_6H_{12} e.g.
 

cis isomer
 

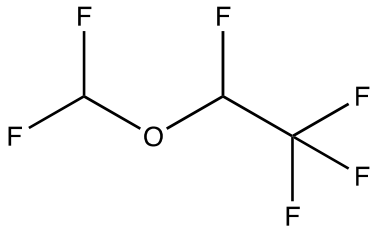
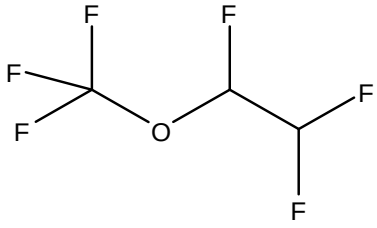
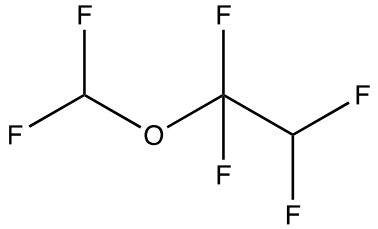
trans isomer</td></tr>
</table>

Question			Answer	Marks	AO element	Guidance
16	(b)	(iv)	Correct groups attached to chiral carbon of compound C seen **once** e.g.  **OR**  ✓ Two **3D structures** of compound C that are mirror images with correct connectivity in both  **OR**  ✓	**2**	AO2.5 ×2	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous For C_2H_5–, **ALLOW** CH_3CH_2– For –$CH=CH_2$, **ALLOW** –C_2H_3 **OR** –$CHCH_2$ For bond into paper accept:  **ALLOW** two 3D structures with 2 groups swapped e.g.   **DO NOT ALLOW** a bond angle of 180° e.g. 

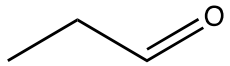
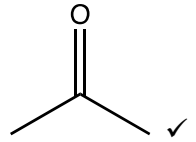
Question			Answer	Marks	AO element	Guidance
16	(b)	(v)	 ✓  ✓ **D** **E** Two of the following for **D** ✓ • All H are equivalent/in the same chemical environment/ the same type • All C are equivalent/ in the same chemical environment/ the same type • No C=C present Two of the following for **E** ✓ • All H are equivalent/ in the same chemical environment/ the same type • 2 C environments • C=C present	4	AO2.5 ×2 AO2.2 ×2	**ALLOW** 1 mark for structures if shown in wrong boxes. **CHECK** table 16.1 for annotations that may be worthy of credit

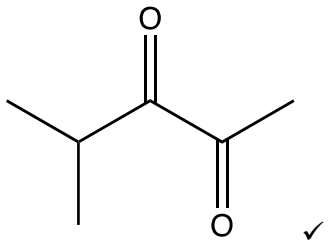
Question			Answer	Marks	AO element	Guidance
16	(c)	(i)	 **BOTH** structures required for ✓  ✓	2	AO3.1 ×1 AO3.2 ×1	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous
16	(c)	(ii)	 ✓	1	**AO3.2**	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous
			Total	17		

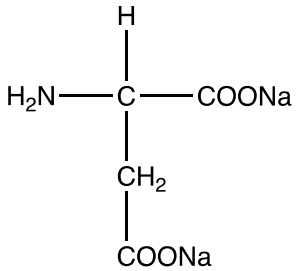
Question			Answer	Marks	AO element	Guidance
17			**FIRST CHECK ANSWER LINES** **If M=168(.0) Award 4 marks for calculation providing unit conversions are correct** **----------** ***Use of ideal gas equation*** $pV = nRT$ ***OR*** $n = \frac{pV}{RT}$ ✓ ***SI Unit conversions AND substitution into*** $n = \frac{pV}{RT}$ **:** • *R = 8.314* ***OR*** *8.31* • *V* = 186×10^{-6} • *T in K: 303 K* *e.g.* $\frac{1.07 \times 10^5 \times 186 \times 10^{-6}}{8.314 \times 303}$ ✓ ***Calculation of n*** $n = 7.90 \times 10^{-3}$ (mol) ✓ ***Calculation of M*** $M = \frac{1.327}{7.90 \times 10^{-3}} = 168(.0)$ ✓ ***Molecular formula*** $C_3H_2F_6O$ ✓	**6**	AO1.2 ×1 AO2.4 ×3 AO2.5 ×2	**ALLOW ECF throughout** **ALLOW** calculator value of 167.968115 (using 8.314) for M **ALLOW** calculator value of 167.8873033 (using 8.31) for M Calculator value of *n*: from 8.314 = $7.900308915 \times 10^{-3}$ from 8.31 = $7.904111711 \times 10^{-3}$ **ALLOW** ECF that matches M but the formula MUST contain F_6O **----------** **Use of 24 dm^3**: e.g. $n = \frac{186.0}{24000} = 7.75 \times 10^{-3}$ **No mark** (*calculation much simpler*) $M = \frac{1.327}{7.75 \times 10^{-3}} = 171(.2)$ ✓ **ECF** $C_3H_5F_6O$ ✓ **ECF**

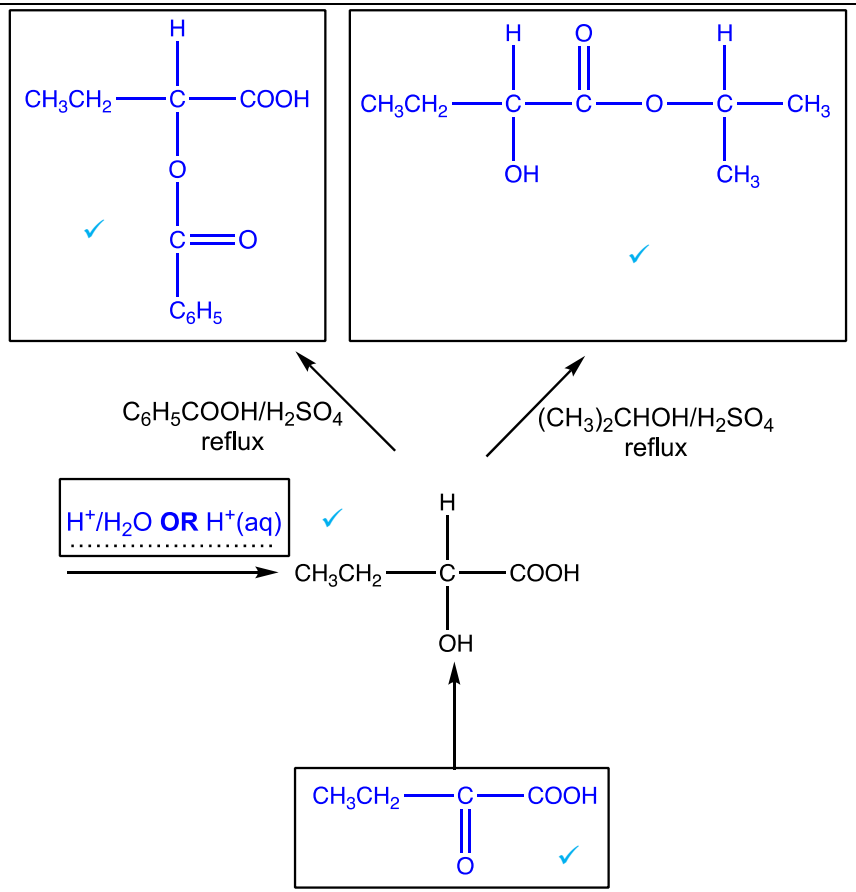
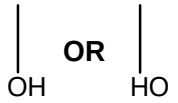
Question			Answer	Marks	AO element	Guidance
			Structure  **OR**  ✓			**ALLOW** ECF for a feasibile chemical structure that matches M **AND** contains F_6O **AND** has a chiral carbon **DO NOT ALLOW**  *no chiral carbon*
			Total	**6**		

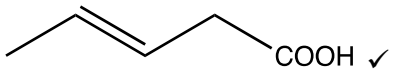
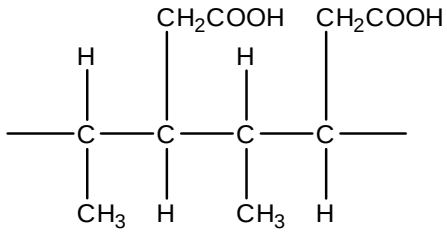
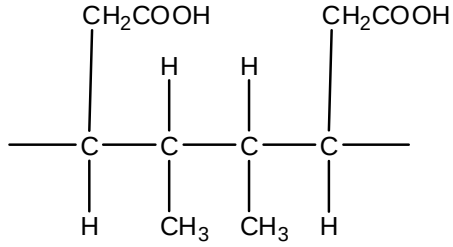
Question			Answer	Marks	AO element	Guidance
18	(a)	(i)	(Add) 2,4-dinitrophenylhydrazine **AND** orange/yellow/red precipitate ✓ Take melting point (of crystals) ✓ Compare to known values/database ✓	3	AO1.2 × 3	**ALLOW** errors in spelling **ALLOW** 2,4(-)DNP **OR** 2,4(-)DNPH **ALLOW** Brady's reagent or Brady's Test **ALLOW** solid **OR** crystals **OR** ppt as alternatives for precipitate **Mark second and third points independently of response for first marking point** **DO NOT ALLOW** 2nd and 3rd marks for taking and comparing boiling points **OR** chromatograms
18	(a)	(ii)	Tollens' (reagent) **AND** Silver (mirror/precipitate/ppt/solid) ✓	1	AO1.2	**ALLOW** ammoniacal silver nitrate **OR** Ag^+/NH_3 **ALLOW** black ppt **OR** grey ppt **ALLOW** $Cr_2O_7^{2-}/H^+$ **AND** Turns green ✓ **IGNORE** reference to conditions, e.g. Heat or reflux --- **IF** other reagents are seen e.g. Fehling's or Benedict's, contact your Team Leader

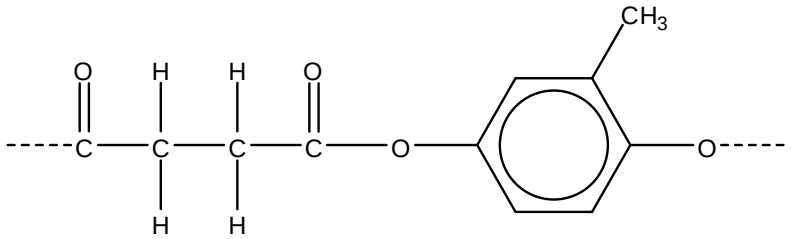
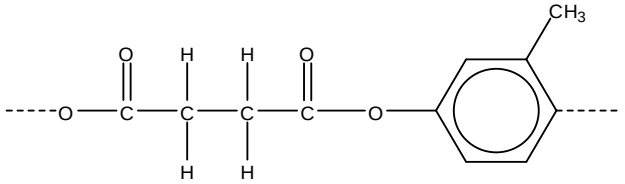
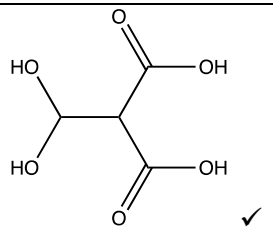
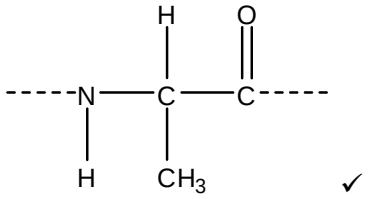
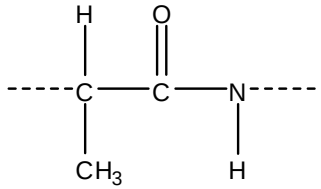
Question			Answer	Marks	AO element	Guidance
18	(b)		***Initial ratios*** C, $\frac{62.07}{12.0}$: H, $\frac{10.34}{1.0}$: O, $\frac{27.59}{16.0}$ **OR** C, 5.1725 : H, 10.34 : O, 1.724 **OR** C, 3 : H, 6 : O, 1 ✓	**4**	AO1.2	**CHECK** spectra for annotations that may be worthy of credit Mark can be awarded from a correct molecular formula
			(Molecular formula =) C_3H_6O **AND** Evidence of **58** in working or from labelled peak in one of the spectra✓		AO2.5 AO3.2	
			For F evidence for fragment ion m/z=29 linked to $CH_3CH_2(^+)$ **OR** $CHO(^+)$ ✓		AO3.2	**IGNORE** m/z=15 (as this is not unique) **IGNORE** m/z=43 **IGNORE** incorrect fragments **IGNORE** charges on fragment ions
			F =  **AND** **G** =  ✓			**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous

Question			Answer	Marks	AO element	Guidance
18	(c)		**^{1}H NMR** δ = 1.1 ppm/doublet linked to 2 x C**H$_3$** ✓ δ = 2.2 ppm/singlet linked to C**H$_3$**–C=O **OR** δ = 2.9 ppm/multiplet linked to C**H**$(CH_3)_2$ **OR H**C–C=O ✓ **Structure** Any structure with molecular formula $C_6H_{10}O_2$ and has 2 carbonyl groups ✓  ✓	**4**	AO3.1 ×3 AO3.2 ×1	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **CHECK** spectra for annotations that may be worthy of credit **ALLOW** δ values ± 0.2 ppm, as a range or a value within the range **IGNORE H**C–C=O linked to δ = 2.2 ppm **IGNORE** additional chemical environments (taken from the data sheet) that align with the given chemical shifts
			Total	**12**		

Question			Answer	Marks	AO element	Guidance
19	(a)		$C_2H_5COOH + KOH \rightarrow C_2H_5COOK + H_2O$ ✓	4	AO2.6 ×4	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** state symbols and use of equilibrium sign **ALLOW** KC_2H_5COO **DO NOT ALLOW** a missing charge (e.g. $C_2H_5COO^-K$) the 1st time seen but **IGNORE** for next equations.
			$2HCOOH + Mg \rightarrow (HCOO)_2Mg + H_2$ ✓			For salts, **ALLOW** $C_2H_5COO^-K^+$ **OR** $C_2H_5COO^- + K^+$ **DO NOT ALLOW** –COO–K (covalent bond) the 1st time seen but **IGNORE** for next equations.
			H_2O **AND** CO_2 ✓			**FOR** $CO_2 + H_2O$ **ALLOW** H_2CO_3
			Correct formula of salt:  ✓			

Question			Answer	Marks	AO element	Guidance
19	(b)			4	AO2.5 ×4	**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**  **IGNORE** connectivity of CH_3CH_2 group **IGNORE** inorganic by-products **ALLOW** HCl/H_2O, H_2SO_4/H_2O **IGNORE** dilute

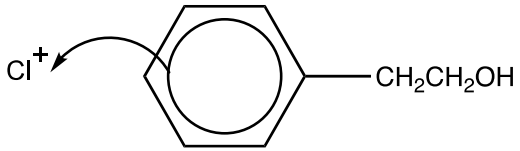
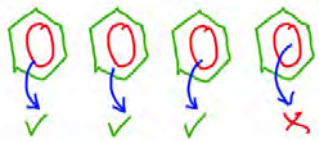
Question			Answer	Marks	AO element	Guidance
19	(c)	(i)	**Pent-3-enoic acid**  ✓ **2 repeat units of polymer**  ✓	2	AO1.2 AO2.5	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** either the *E* or *Z* isomer **ALLOW ECF** from pent-2-enoic acid **OR** pent-4-enoic acid **ONLY** **For repeat unit,** • 'side bonds' required on either side of repeat unit from C atoms • **2** repeat units required **IGNORE** connectivity of CH_2COOH in polymer **IGNORE** brackets **IGNORE** *n* --- **ALLOW** any consistent repeat unit: CH_2COOH and CH_3 groups can alternate or be on opposite sides of chain e.g. 

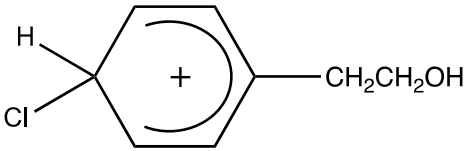
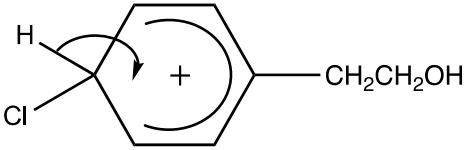
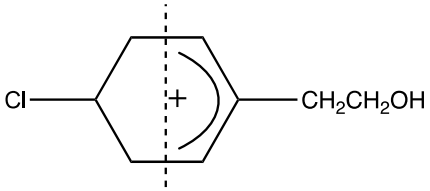
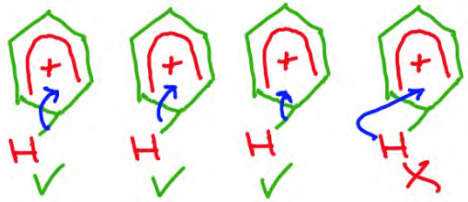
Question			Answer	Marks	AO element	Guidance
19	(c)	(ii)	 ester link ✓ **ONE** repeat units of correct polymer ✓	2	AO1.2 AO2.5	end –O– may be at either side e.g.  **ALLOW** CH_3 to be on position 2 or 3 of the aromatic ring 'End bonds' **MUST** be shown (do not have to be dotted) **IGNORE** brackets **IGNORE** *n*
19	(c)	(iii)	 ✓	1	AO3.2	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous
19	(d)	(i)	 ✓ **ONE** repeat unit **ONLY**	1	AO2.5	end –N– may be at either side e.g.  'End bonds' **MUST** be shown (do not have to be dotted) **IGNORE** brackets **IGNORE** *n*

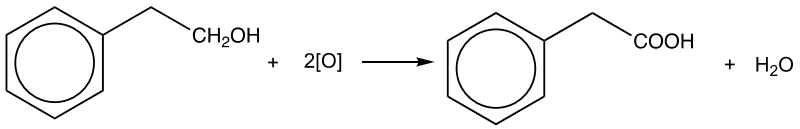
Question			Answer	Marks	AO element	Guidance
19	(d)	(ii)	**IF** answer on answer line = 28418, **AWARD** 2 marks **IF** answer on answer line = 28400, **AWARD** 1 mark --- M_r of 400 molecules = 400 × 89 = 35600 ✓ M_r of polymer = 35600 – (399 × 18) = 28418 ✓	**2**	AO2.2 ×2	**ALLOW ECF** from incorrect repeat unit in 19di **ALLOW ECF** from incorrect M_r of 400 repeat units Alternative method based on repeat unit: M_r of 400 repeat units = 400 × 71 = 28400 ✓ M_r of polymer = 28400 + 1 + 17 = 28418 ✓
19	(e)*		*Refer to marking instructions on page 5 of mark scheme for guidance on marking this question.* **Level 3 (5-6 marks**) Correct calculation of mass of $CH_3CHClCOOH$. **AND** Planned synthesis includes substitution of –Cl and formation of compound **I** (or its corresponding ammonium salt) with the correct reagents and some conditions identified and equations are mostly correct. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.*	**6**	AO3.3 ×6	**Indicative scientific points may include:** **<u>Calculation of mass of $CH_3CHClCOOCH_3$</u>** **Using moles** • $n(\mathbf{I}) = \frac{9.36}{117.0}$ = 0.08(00) (mol) • $n(CH_3CHClCOOC_2H_5) = 0.0800 \times \frac{100}{64}$ = 0.125 (mol) • Mass of $CH_3CHClCOOH$ = 108.5 × 0.125 = 13.5625 g

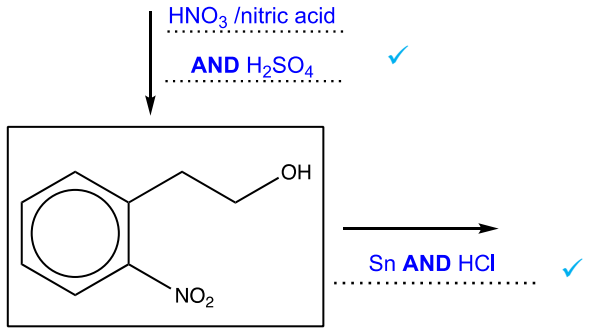
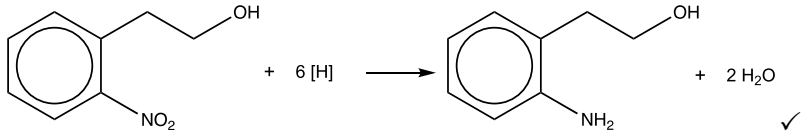
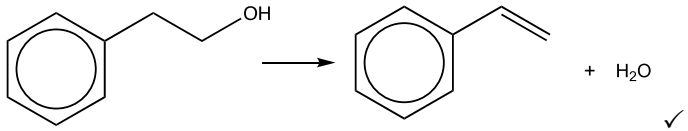
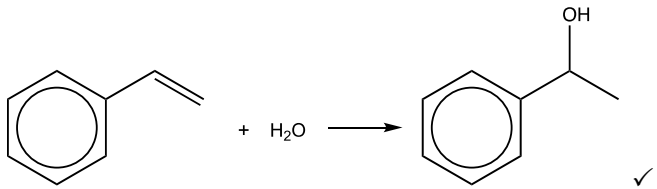
Question			Answer	Marks	AO element	Guidance
			Level 2 (3-4 marks) Calculation of mass of $CH_3CHClCOOH$ is correct **AND** Planned synthesis includes one step of the synthesis with the correct reagent and some conditions identified and equation is mostly correct **OR** Calculation of mass of $CH_3CHClCOOH$ is partly correct **AND** Planned synthesis includes substitution of –Cl and formation of compound **I** (or its corresponding ammonium salt) with the correct reagents **OR** Attempts to calculate mass of $CH_3CHClCOOC_2H_5$ but makes little progress **AND** Planned synthesis includes substitution of –Cl and formation of compound **I** (or its corresponding ammonium salt) with the correct reagents and some conditions identified and equations are mostly correct *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.*			**Using mass** • Theoretical mass of **I** = $9.36 \times \frac{100}{64}$ = 14.625 (g) • Theoretical $n(CH_3CHClCOOH) = \frac{14.625}{117.0}$ = 0.125 (mol) • Mass of $CH_3CHClCOOH = 108.5 \times 0.125$ = 13.5625 g **ALLOW** slip/rounding errors such as errors in M_r, e.g. use of 107.5 instead of 108.5 for $CH_3CHClCOOH \rightarrow 13.4375$ --- ***Examples of partly correct calculations*** Mass = 5.5552 g from $0.0800 \times \frac{64}{100} \times 108.5$ (*% yield inverted*) Mass = 8.68 g from 0.0800×108.5 (*% yield omitted*) **Synthesis: *Either order for 2 stages*** **Substitution of –Cl → amine:** • Reagents: (excess) NH_3 • Condition: ethanol • Equation: $CH_3CHClCOOH + 2NH_3 \rightarrow CH_3CHNH_2COOH + NH_4Cl$ **OR** $CH_3CHClCOOH + NH_3 \rightarrow CH_3CHNH_2COOH + HCl$

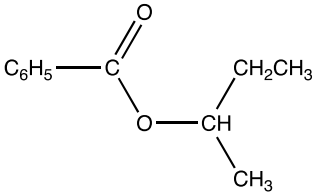
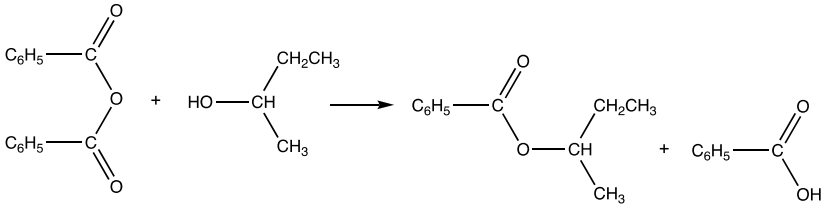
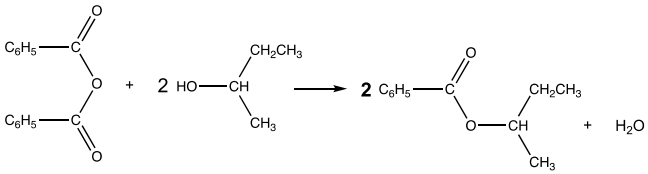
Question			Answer	Marks	AO element	Guidance
			Level 1 (1-2 marks) Calculation of mass of $CH_3CHClCOOH$ is partly correct **OR** Planned synthesis includes both steps with some of the reagents and conditions identified **OR** Attempts equations for both steps but these may contain errors **OR** Describes one step of the synthesis with reagents, conditions 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.* **0 marks** No response or no response worthy of credit.			**Esterification of amine → compound I** • Reagents**:** CH_3CH_2OH • Conditions: acid (catalyst), e.g. H_2SO_4 (reflux/heat) • Equation: $CH_3CHNH_2COOH + CH_3CH_2OH \rightarrow CH_3CHNH_2COOCH_2CH_3 + H_2O$ **OR ----------** **Esterification of carboxylic acid → ester** • Reagents**:** CH_3CH_2OH • Conditions: acid (catalyst), e.g. H_2SO_4 (reflux/heat) • Equation: $CH_3CHClCOOH + CH_3CH_2OH \rightarrow CH_3CHClCOOCH_2CH_3 + H_2O$ **Substitution of –Cl → amine:** • Reagents: (excess) NH_3 • Condition: ethanol • Equation: e.g $CH_3CHClCOOCH_2CH_3 + 2NH_3 \rightarrow CH_3CHNH_2COOCH_2CH_3 + NH_4Cl$ **OR** $CH_3CHClCOOCH_2CH_3 + NH_3 \rightarrow CH_3CHNH_2COOCH_2CH_3 + HCl$ **OR** $CH_3CHClCOOCH_2CH_3 + NH_3 \rightarrow CH_3CHNH_3ClCOOCH_2CH_3$ *(ammonium salt)*
			Total	**22**		

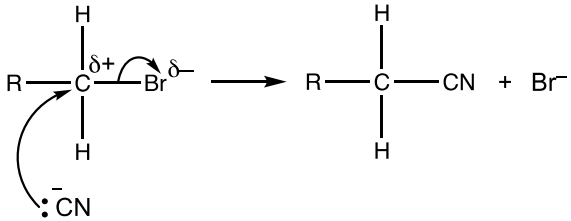
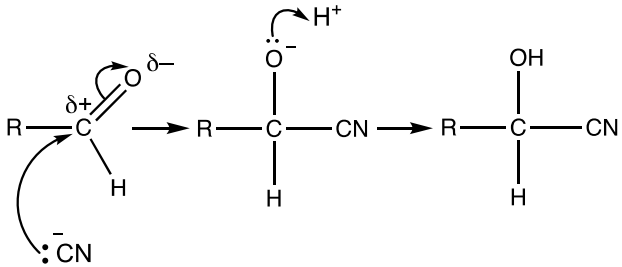
Question			Answer	Marks	AO element	Guidance
20	(a)	(i)	Indicator **AND** observation of acidity **AND** No reaction with carbonate ✓	1	AO1.2 ×1	**ALLOW** (Add) bromine **AND** white precipitate ✓ **ALLOW** (Add) $FeCl_3$ **AND** violet/purple colour ✓
20	(a)	(ii)	Compound **J** has **6** peaks/environments/types of carbon ✓ Compound **K** has **5** peaks/environments/types of carbon ✓ Compound **L** has **8** peaks/environments/types of carbon ✓	3	AO3.2 ×3	**IGNORE** any numbers shown on structures **IGNORE** chemical shifts
20	(a)	(iii)	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **Action of catalyst** **1 mark** Formation of electrophile: $Cl_2 + AlCl_3 \rightarrow Cl^+ + AlCl_4^-$ **AND** Regeneration of catalyst: $H^+ + AlCl_4^- \rightarrow AlCl_3 + HCl$ ✓ **----------** **Electrophilic attack** **1 mark** Curly arrow from π-bond to Cl^+ ✓  	4	AO1.2 ×2 AO2.5 ×2	**ALLOW** use of $FeCl_3$ or other halogen carriers ($AlBr_3$) **----------** **For curly arrows, ALLOW straight or snake-like arrows and small gaps (see examples):** **----------** **1st curly arrow** must • start from, **OR** close to **circle of benzene ring** **AND** • go to Cl^+ 

Question	Answer	Marks	AO element	Guidance
	Correct intermediate only **1 mark**  ✓ --- **Reforming benzene ring** **1 mark** Curly arrow from C–H bond to reform π-ring ✓  			**DO NOT ALLOW** the following intermediate:  π-ring must cover more than half of benzene ring **AND** correct orientation, *i.e.* gap towards C with Cl **ALLOW** + sign anywhere inside the 'hexagon' of intermediate **DO NOT ALLOW** intermediates substituted at positions 3 or 5 **IGNORE** intermediates substituted at position 2 **OR** di-substituted at positions 2,4 --- **Curly arrow** must start from, **OR** be traced back to, **any part of** C–H bond and go inside the 'hexagon' 

Question			Answer	Marks	AO element	Guidance
20	(b)		(In phenols) a (lone) pair of electrons on O is (partially) **delocalised/donated** into the ring / π-system ✓ Electron density increases/is higher (than benzene) ✓ **ORA** (phenols) are more susceptible to electrophilic attack **OR** (phenols) attract/accept electrophile/Cl_2 more **OR** (phenols) polarise electrophile/Cl_2 more ✓ **ORA**	**3**	AO1.1 × 3	**ALLOW** the electron pair in the p-orbitals of the 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 delocalised/donated into the ring / π-system **IGNORE** activating **IGNORE** charge density **IGNORE** electronegativity **IGNORE** phenols react more readily with electrophiles/Cl_2 *(given in question)* **ALLOW** Cl^+ for electrophile **IGNORE** Cl for electrophile
20	(c)		 organic product ✓ Correct balanced equation ✓	**2**	AO2.5 AO2.6	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** C_6H_5 for phenyl group

20	**(d)**	**(i)**		**2**	AO1.2 ×2	**IGNORE** references to concentration **IGNORE** 'dilute' for HC*l* **IGNORE H_2** **IGNORE** NaOH if seen as a reagent to convert nitro group into amine e.g 'Sn/(concentrated) HC*l* then NaOH' scores the mark
20	**(d)**	**(ii)**		**1**	AO2.6	
20	**(e)**		**Stage 1** *Reagents*: H_2SO_4 ✓  **Stage 2** *Reagents*: Steam/H_2O(g) **AND** acid/H^+ (catalyst) ✓ 	**4**	AO3.1 AO2.6 AO3.1 AO2.6	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** H^+ **OR** HCl **OR** H_3PO_4 **DO NOT ALLOW** other named acids **IGNORE** concentration/pressure **IGNORE** water/steam For steam, **ALLOW** H_2O with temperature ≥100ºC **ALLOW** use of H_3PO_4/H_2SO_4 as catalyst **DO NOT ALLOW** HCl **IGNORE** pressure

20	**(f)**		Structure of ester product ✓  Correct balanced equation ✓ 	**2**	AO3.1 AO3.2	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** 
			Total	**22**		

Question	Answer	Marks	AO element	Guidance
21	*Refer to marking instructions on page 5 of mark scheme for guidance on marking this question*. **Level 3 (5–6 marks)** Describes, in detail, reactions of **two** aliphatic compounds that form a C–C bond **AND** mechanisms for the **two** aliphatic reactions. *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)** Describes a reaction of **one** aliphatic compound that forms a C–C bond with few omissions/errors. **AND** mechanism for **one** aliphatic reaction. **OR** Describes reactions of **two** compounds that forms a C–C bond **AND** attempts a mechanism for **one** of the reactions *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)** Selects suitable reagents for reactions of **two** compounds that form a C–C bond. **OR** Attempts to describe a reaction and mechanism of **one** compound that forms a C–C bond, with omissions/errors. *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 ×4 AO2.5 ×2	**Indicative scientific points may include:** **<u>Reactions of aliphatic compounds and mechanisms</u>** • Haloalkane, RX and $CN^- \rightarrow RCN + X^-$ Reagents: NaCN and ethanol Reaction: Nucleophilic substitution Mechanism:  • Aldehyde or ketone and HCN e.g. RCHO + HCN → RCH(OH)CN Reagents: NaCN and H^+ Reaction: Nucleophilic addition Mechanism:  OR H_2O instead of H^+ for 2nd stage **If alternative reactions are shown contact your TL e.g. radical substitution, polymerisation**
	Total	**6**		

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