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EDEXCEL A LEVEL CHEMISTRY: QUESTIONS BY TOPIC

Modern Analytical Techniques II (19)

A Level Chemistry Topic 19

6 questions · 62 marks · Mark schemes included

Pearson Edexcel A Level Chemistry (9CH0), June 2017 - June 2025

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HOW TO USE THIS BOOKLET

Questions are grouped by specification sub-topic; within each sub-topic they run from the lowest mark tariff to the highest.

Click any sub-topic heading or question row below to jump straight to it.

On every question page, click ANSWER in the top-right corner to jump to its mark scheme.

Diagrams, graphs, tables and data are printed exactly as they appeared in the original papers.

QUESTION	SOURCE	MARKS	PAGE
19(b) NMR SPECTROSCOPY		6 questions · 62 marks	3
1. Q6	A Level Paper 2 June 2024	7	4
2. Q6	A Level Paper 3 June 2024	9	6
3. Q6	A Level Paper 3 June 2025	9	8
4. Q6	A Level Paper 3 June 2022	11	10
5. Q4	A Level Paper 3 June 2018	13	12
6. Q4	A Level Paper 2 June 2019	13	15



QUESTIONS

6 questions · 62 marks · grouped by sub-topic



SUB-TOPIC 19(b)

NMR SPECTROSCOPY

6 questions in this sub-topic · 62 marks · lowest tariff first



6 This question is about nuclear magnetic resonance (NMR) spectroscopy.

(a) Which part of the electromagnetic spectrum is used in NMR?

(1)

- ☐ A infrared
- ☐ B radio waves
- ☐ C ultraviolet
- ☐ D X-ray

(b) Explain why tetramethylsilane, TMS, is used in NMR spectroscopy.

(2)

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(c) A secondary amine, **Q**, has the molecular formula $C_6H_{15}N$.
The low resolution ^1H NMR spectrum of **Q** has three peaks.

(i) State what is meant by the term 'secondary amine'.

(1)

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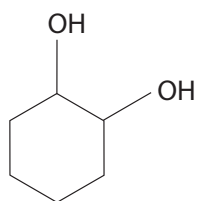
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(ii) Deduce the structure of **Q**.

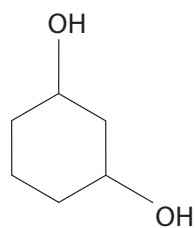
(1)



(d) Two cyclic alcohols have the structures shown.



cyclohexane-1,2-diol



cyclohexane-1,3-diol

Show that the ^{13}C NMR spectra of these compounds can be used to distinguish between the two alcohols, labelling the diagrams to justify your answer.

(2)

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(Total for Question 6 = 7 marks)



6 An ester **Q** has the molecular formula $C_8H_{16}O_2$.

- (a) When hydrolysed, 2.07 g of **Q** formed a carboxylic acid with a 78 % yield. Once separated, the carboxylic acid was neutralised using excess sodium hydrogencarbonate solution.



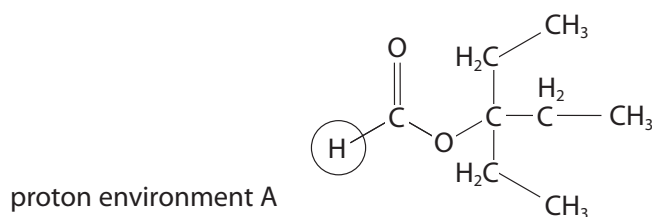
In this reaction, 269 cm^3 of carbon dioxide gas was produced at room temperature and pressure.

Show that these data confirm that the relative molecular mass of **Q** is 144.

(3)



- (b) The high resolution proton NMR spectrum of ester **Q** was obtained.
The structure of the ester **Q** is shown.



- (i) Explain the expected splitting pattern for the peak due to proton environment A circled in the structure.

(2)

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- (ii) Label the structure to indicate the remaining equivalent proton environments in ester **Q**.

(1)

- (iii) Predict the chemical shifts, relative peak areas and splitting patterns in the high resolution proton NMR spectrum, due to the proton environments you have labelled.

Do not consider proton environment A.

(3)

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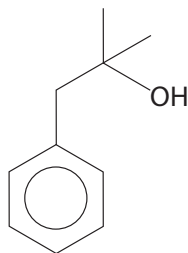
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(Total for Question 6 = 9 marks)

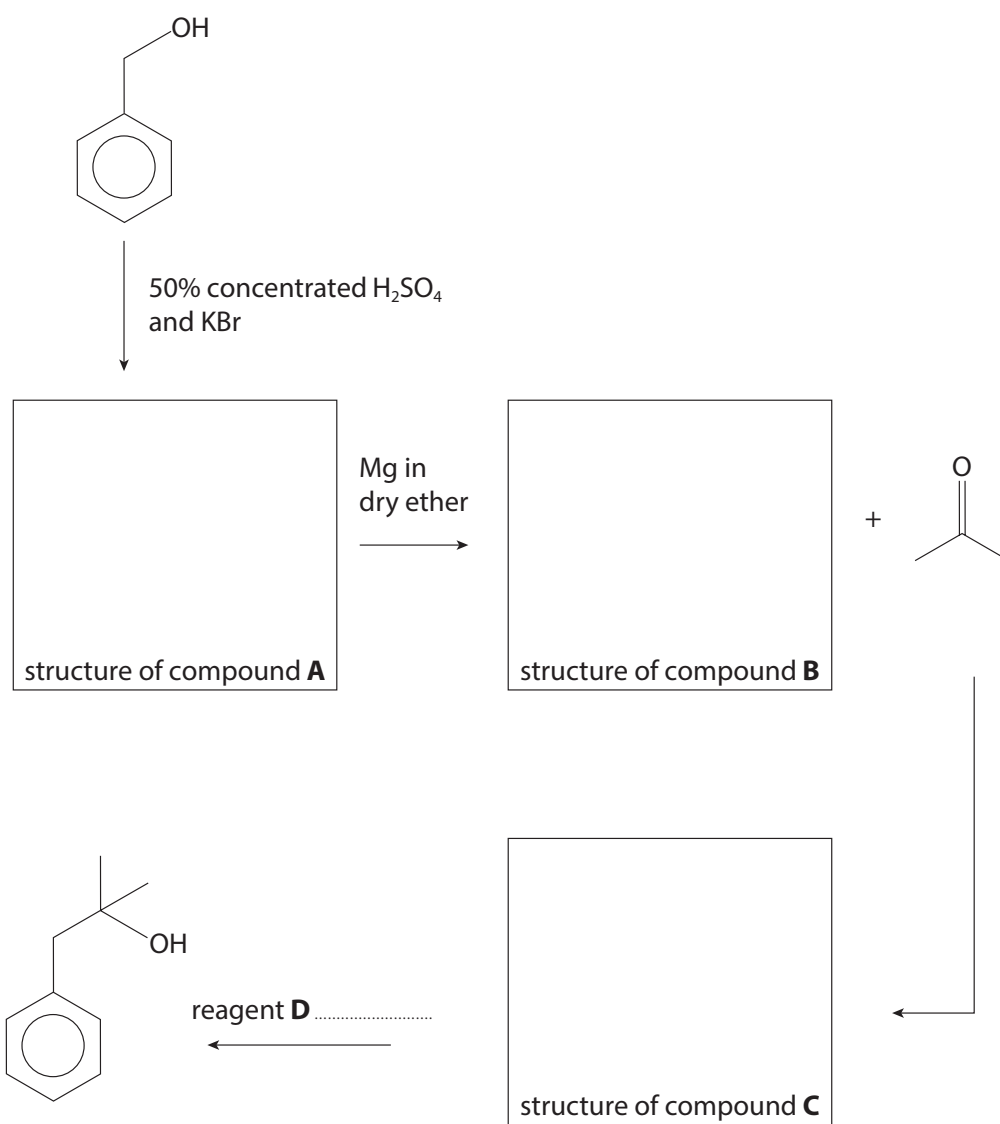
- 6 The compound 2-methyl-1-phenylpropan-2-ol is found in small amounts in cocoa beans and has the structure shown.



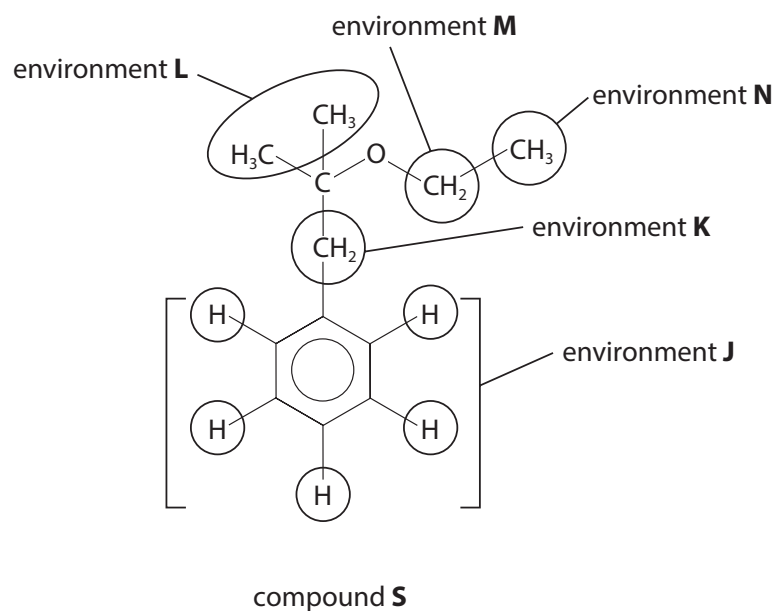
- (a) A proposed synthesis of 2-methyl-1-phenylpropan-2-ol from phenylmethanol and propanone is shown.

Complete the diagram to show the structures of compounds **A**, **B** and **C** and the formula of reagent **D**.

(4)



- (b) 2-Methyl-1-phenylpropan-2-ol can be converted to compound **S**.
 When considering the ^1H NMR spectrum of **S**, the hydrogen atoms of the benzene have been assumed to be a single environment, labelled **J**.
 The other hydrogen environments have been labelled **K**, **L**, **M** and **N**.



Complete the table for each of the environments **K** to **N** in the high resolution ^1H NMR spectrum of **S**.

(5)

	Chemical shift / ppm	Relative peak area	Splitting pattern
Environment J	6.8 – 8.2	5	complex
Environment K			
Environment L			
Environment M			
Environment N			

(Total for Question 6 = 9 marks)



6 An ester **Q** has the molecular formula $C_8H_{16}O_2$.

- (a) When burned in excess oxygen, 1.879 g of **Q** formed 4.594 g of carbon dioxide and 1.879 g of water.

Show that the empirical formula of **Q** is C_4H_8O .

(4)

- (b) Data from the high resolution ^1H (proton) NMR spectrum of the ester **Q** are shown in the table.

Chemical shift (δ) / ppm	Splitting pattern of peak	Relative peak area
2.50	singlet	3
1.56	quartet	4
1.43	singlet	3
0.92	triplet	6

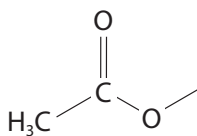


Part of the structure of **Q** is shown.

Complete the structure of **Q**.

Justify your answer by linking the proton environments in your structure to the relative peak areas and the splitting pattern of the peaks.

(7)



(Total for Question 6 = 11 marks)



4 This question is about the use of NMR spectroscopy to distinguish between isomers of $C_6H_{12}O_2$.

(a) Tetramethylsilane (TMS) is a compound used as a standard when recording both ^1H and ^{13}C NMR spectra.

(i) Give the structural formula of TMS.

(1)

(ii) TMS is an inert and non-toxic compound. State **two** other reasons why TMS is suitable for use as a standard when recording NMR spectra.

(2)

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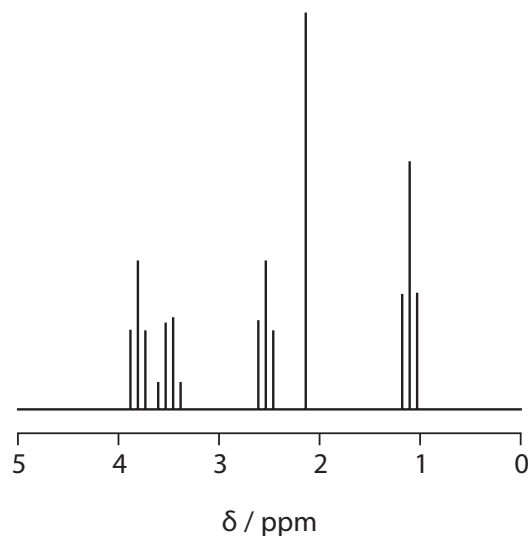
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(b) (i) Draw the structural formulae of the **two** esters with formula $C_6H_{12}O_2$ that each have only **two** peaks, both singlets, in their high resolution **proton** NMR spectra. The relative peak areas are 3:1 for both esters.

(2)



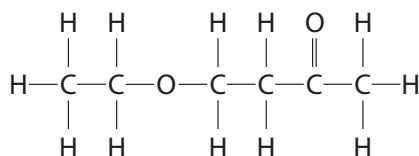
(ii) The high resolution **proton** NMR spectrum of another isomer of $C_6H_{12}O_2$ is shown.



The ratios of the number of protons for the five sets peaks in the spectrum are given in the table.

δ / ppm	3.8	3.5	2.6	2.2	1.2
Ratio of the number of protons	2	2	2	3	3

Show that **all** these data are consistent with the displayed formula shown. Refer to the five chemical shifts and explain **two** of the splitting patterns.



(5)

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- (c) (i) There are three other isomers of $C_6H_{12}O_2$ which are carboxylic acids with **five** peaks in their **carbon-13** NMR spectra.

Draw the structural formula of **two** of these isomers.

(2)

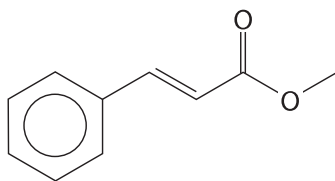
- (ii) Draw the **skeletal** formula of a cyclic diol isomer of $C_6H_{12}O_2$ that has only **two** peaks in its **carbon-13** NMR spectrum.

(1)

(Total for Question 4 = 13 marks)



4 Methyl cinnamate, $C_{10}H_{10}O_2$, is a white crystalline solid used in the perfume industry.



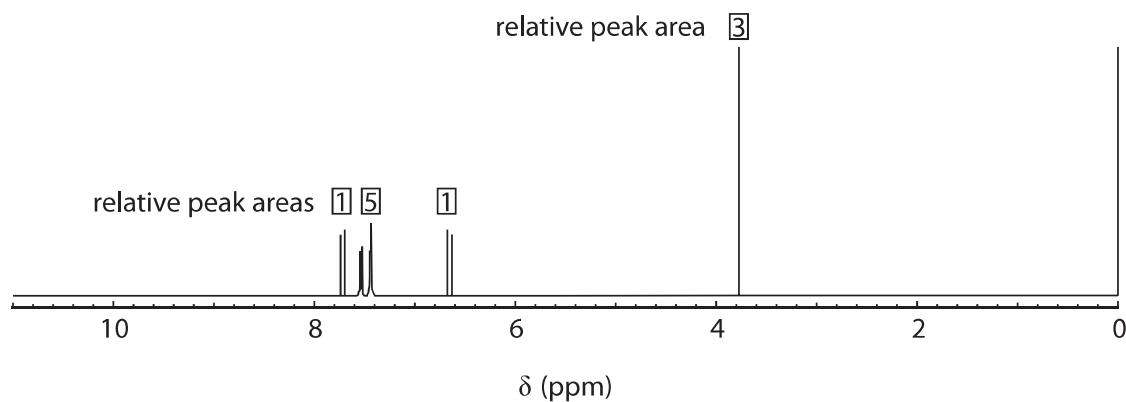
methyl cinnamate

(a) Calculate the mass of carbon in 2.34 g of methyl cinnamate.

(2)

(b) A sample of methyl cinnamate was analysed by high resolution proton NMR spectroscopy.

A simplified spectrum is shown.



(i) Name the compound responsible for the peak at a chemical shift of 0 ppm, stating its purpose.

(2)

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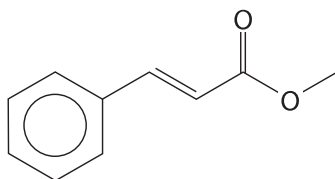
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- (ii) Identify the proton environment that causes the peak at a chemical shift of 3.8 ppm by circling it on the diagram shown. Fully justify your answer.

(3)



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- (c) Methyl cinnamate undergoes an addition reaction in the dark with bromine.

- (i) Draw the mechanism for the reaction between methyl cinnamate and bromine, Br₂.
Include curly arrows, and relevant lone pairs and dipoles.

(4)

- (ii) Deduce the number of optical isomers of the addition product that can exist.

(1)

- ☐ A 2
- ☐ B 3
- ☐ C 4
- ☐ D 8

- (iii) When plane-polarised light is passed through an optical isomer, the plane of polarisation is

(1)

- ☐ A diffracted
- ☐ B reflected
- ☐ C refracted
- ☐ D rotated

(Total for Question 4 = 13 marks)



MARK SCHEMES

official Pearson Edexcel mark schemes



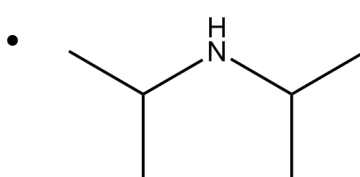
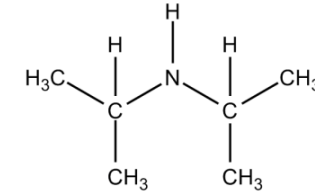
Question Number	Answer	Mark
6(a)	The only correct answer is B (radio waves) <i>A is not correct because IR interacts with bonds</i> <i>C is not correct because UV interacts with electrons</i> <i>D is not correct because X-rays are diffracted by crystals in the solid state</i>	(1)

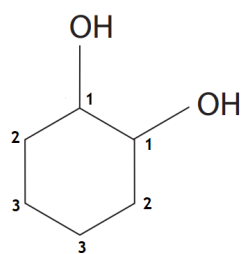
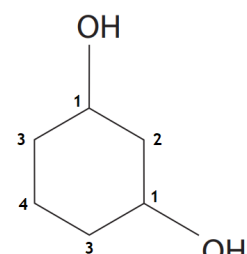
Question Number	Answer	Additional Guidance	Mark
6(b)	An explanation that makes reference to the following points: - TMS acts as a standard / reference (at 0 ppm) - as it has (12 equivalent) hydrogens that produce a single / strong peak or - as it has (4 equivalent) carbons that produce a single / strong peak	(1) Allow acts as a control / comparison point / baseline / to calibrate / to mark 0 ppm (1) Ignore just 'has a shift at 0 ppm' Allow produces a peak (well) away from those caused by other hydrogens / carbons Allow (most organic) compounds result in shift values (much) greater than TMS Allow easy to separate from sample (after spectrum is obtained) Allow unreactive (so will not react with sample)	(2)



Question Number	Answer	Additional Guidance	Mark
6(c)(i)	An answer that makes reference to the following point: the nitrogen (in the amine group) is attached to two carbon atoms / the nitrogen (in the amine group) is attached to two carbons (atoms)	Allow contains an NH group / two alkyl groups attached to the N / two R groups attached to the N / N is adjacent to two carbons Ignore amine group is attached to two carbons	(1)



Question Number	Answer	Additional Guidance	Mark
6(c)(ii)		Note – take care to check H is present on N in skeletal formula Allow structural, displayed or hybrid formulae, e.g. 	(1)

Question Number	Answer	Additional Guidance	Mark
6(d)	An answer that makes reference to the following points: - cyclohexane-1,2-diol has 3 peaks (in its ^{13}C spectra) (1) and 3 environments shown on diagram (1) - cyclohexane-1,3-diol has 4 peaks (in its ^{13}C spectra) (1) and 4 environments shown on diagram	If no marks scored allow 1 mark for idea that the spectrum of cyclohexane-1,2-diol has fewer peaks / fewer environments than cyclohexane-1,3-diol (even if any numbers quoted are incorrect)  cyclohexane-1,2-diol  cyclohexane-1,3-diol Allow alternative labelling systems on diagrams e.g. use of letter Ignore comments related to size of peaks / position of shift values / splitting	(2)

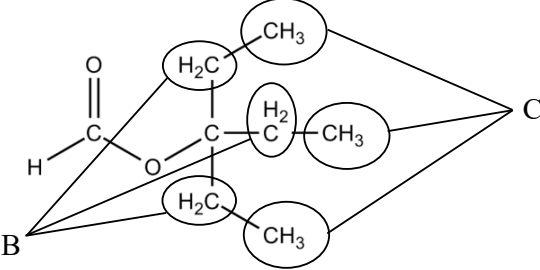
(Total for Question 6 = 7 marks)



Question Number	Answer	Additional Guidance	Mark
6(a)	(method 1) (M1) calculation of moles of carbon dioxide (1) (M2) calculation of moles of Q based on 100% yield (1) (method 2) (M1) calculation of volume at 100% yield (1) (M2) calculation of moles at 100% yield (1) (method 1 and method 2) (M3) show how to calculate M_r of Q (1)	<u>Example of calculation</u> $n(\text{CO}_2) = 269 \div 24000 = 0.011208 / 1.1208 \times 10^{-2} \text{ (mol)}$ $n(\text{ester}) = 0.011208 \times (100 \div 78) = 0.014370 / 1.4370 \times 10^{-2} \text{ (mol)}$ $V(\text{CO}_2) = 269 \times (100 \div 78) = 344.87 \text{ (cm}^3\text{)}$ $n(\text{CO}_2) = 344.87 \div 24000 = 0.01437 / 1.437 \times 10^{-2} \text{ (mol)} = n(\text{ester})$ $M_r \text{ of ester} = 2.07 \div 0.014370 = 144.05 / 144$ or Justification $2.07 \div 144 = 1.4375 \times 10^{-2}$ which is ca. 1.4370×10^{-2} Accept calculation variations which involve the 78% conversion, the molar volume of gas and the starting mass of 2.07 Ignore SF except 1 SF in M1 and M2 Ignore intermediate units even if incorrect Note: Use of the formula $pV=nRT$ with $T=298$ and $P=1 \times 10^5$ gives a $RMM=148$ and scores (3)	(3)



Question Number	Answer	Additional Guidance	Mark
6(b)(i)	An explanation that makes reference to the following points: (peak due to A) is a singlet - as there are no adjacent carbon atoms with hydrogen atoms/ as the carbon is (only) bonded to oxygen atoms	Ignore any comments about chemical shifts Allow no splitting Use of n+1 rule Do not award if it is clear that the methanoate carbon is being referred to as the adjacent carbon	(2)

Question Number	Answer	Additional Guidance	Mark
6(b)(ii)	An answer that makes reference to the following points: 	Accept any clear means of labelling of the two different hydrogen environments Ignore labelling of just one CH₃ and one CH₂ unless it is clearly stated that the other groups (of each sort) are equivalent	(1)

Question Number	Answer	Additional Guidance	Mark												
6(b)(iii)	- chemical shifts - splitting patterns - relative peak areas	<table border="1"> <thead> <tr> <th></th><th>Chemical shift (δ) / ppm</th><th>Splitting pattern of peak</th><th>Relative peak area</th></tr> </thead> <tbody> <tr> <td>B</td><td>0 – 1.9</td><td>quartet</td><td>6 Allow 2</td></tr> <tr> <td>C</td><td>0 – 1.9</td><td>triplet</td><td>9 Allow 3</td></tr> </tbody> </table> Allow any single chemical shift value or range within the MS range Allow four splits for quartet and three splits for triplet Ignore reference to proton environment A Additional proton environments max 1 for chemical shifts If no other mark awarded then allow (1) for either B or C given correctly for chemical shift and splitting and peak area (row)		Chemical shift (δ) / ppm	Splitting pattern of peak	Relative peak area	B	0 – 1.9	quartet	6 Allow 2	C	0 – 1.9	triplet	9 Allow 3	(3)
	Chemical shift (δ) / ppm	Splitting pattern of peak	Relative peak area												
B	0 – 1.9	quartet	6 Allow 2												
C	0 – 1.9	triplet	9 Allow 3												

(Total for Question 6 = 9 marks)



Question Number	Answer	Additional Guidance	Mark
6(a)	An answer that makes reference to the following points: • structure of compound A (1) • structure of compound B (1) • structure of compound C (1) • identify reagent D (1)	Allow Kekulé structures Allow O⁻ for OMgBr Allow any dilute (aq) strong acid for reagent D Ignore H⁺, H₃O⁺ Ignore partial charges on Mg and Br even if incorrect Penalise missing delocalised ring once only. Do not award full charges on Mg and Br	(4)

Question Number	Answer	Additional Guidance	Mark
6(b)	An answer that makes reference to the following points: - all 12 correct scores 5 marks 10-11 correct scores 4 marks 7-9 correct scores 3 marks 4-6 correct scores 2 marks 2-3 correct scores 1 mark 0-1 correct scores 0	See table below	(5)

	Chemical shift / ppm	Area under curve	Splitting pattern
Environment J	6.8 – 8.2	5	complex
Environment K	1.6–3(.0)	2	singlet
Environment L	–0.2 – 2(.0)	6	singlet
Environment M	2.8 – 4.4	2	quartet / quadruplet
Environment N	–0.2 – 2(.0)	3	triplet

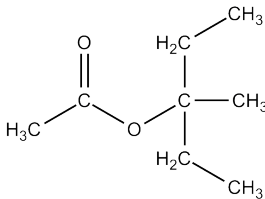
For chemical shifts allow any single value or range within the stated range
 Allow ranges reversed (e.g. 1.9-0.0)
 Do not award quaternary
 Ignore splitting patterns even if incorrect (e.g. 1,2,1)
 Penalise numbers for the splitting pattern (e.g. for K, 1, for L, 1, for M, 4 and for N, 3) up to a maximum of 2 points
 Ignore ‘no splitting’ for singlet

(Total for Question 6 = 9 marks)



Question Number	Answer	Additional Guidance	Mark																				
6(a)	- calculation of masses of carbon and hydrogen (1) - calculation of mass of oxygen (1) - calculation of moles of carbon, hydrogen and oxygen (1) - calculation of ratio (and matched to empirical formula) (1)	<u>Example of calculation</u> <table border="1"> <thead> <tr> <th></th><th>C</th><th>H</th><th>O</th></tr> </thead> <tbody> <tr> <td>mass =</td><td>$4.594 \times \frac{12}{44}$ $= 1.253(\text{g})$</td><td>$1.879 \times \frac{2}{18}$ $= 0.209(\text{g})$</td><td>$1.879 - (1.253 + 0.209)$ $= 0.417(\text{g})$</td></tr> <tr> <td>Moles =</td><td>$= \frac{1.253}{12}$ $= 0.1044$</td><td>$= \frac{0.209}{1}$ $= 0.209$</td><td>$= \frac{0.417}{16}$ 0.0261</td></tr> <tr> <td>Ratio</td><td>4</td><td>8</td><td>1</td></tr> <tr> <td>(Formula =</td><td colspan="3">$\text{C}_4\text{H}_8\text{O}$)</td></tr> </tbody> </table> Note – no mark for $\text{C}_4\text{H}_8\text{O}$ as this is given in the question so no TE Ignore SF except 1 SF in M1 and M2 Allow alternative methods, for example: $\text{mol CO}_2 = 4.954/44 = 0.1044(\text{mol})$ and $\text{mol H}_2\text{O} = 1.879/18 = 0.1044(\text{mol})$ (1) $\text{mol C}_8\text{H}_{16}\text{O}_2 = 1.879/144 = 0.013(\text{mol})$ (1) ratio $\text{C}_8\text{H}_{16}\text{O}_2 : \text{CO}_2 : \text{H}_2\text{O}$ – conditional on moles of $\text{C}_8\text{H}_{16}\text{O}_2$ $= 1 : 8 : 8$ or $0.5 : 4 : 4$ (1) this matches the balanced equation $\text{C}_8\text{H}_{16}\text{O}_2 + 11\text{O}_2 \rightarrow 8\text{CO}_2 + 8\text{H}_2\text{O}$ / $\text{C}_4\text{H}_8\text{O} + 11/2\text{O}_2 \rightarrow 4\text{CO}_2 + 4\text{H}_2\text{O}$ (1)		C	H	O	mass =	$4.594 \times \frac{12}{44}$ $= 1.253(\text{g})$	$1.879 \times \frac{2}{18}$ $= 0.209(\text{g})$	$1.879 - (1.253 + 0.209)$ $= 0.417(\text{g})$	Moles =	$= \frac{1.253}{12}$ $= 0.1044$	$= \frac{0.209}{1}$ $= 0.209$	$= \frac{0.417}{16}$ 0.0261	Ratio	4	8	1	(Formula =	$\text{C}_4\text{H}_8\text{O}$)			(4)
	C	H	O																				
mass =	$4.594 \times \frac{12}{44}$ $= 1.253(\text{g})$	$1.879 \times \frac{2}{18}$ $= 0.209(\text{g})$	$1.879 - (1.253 + 0.209)$ $= 0.417(\text{g})$																				
Moles =	$= \frac{1.253}{12}$ $= 0.1044$	$= \frac{0.209}{1}$ $= 0.209$	$= \frac{0.417}{16}$ 0.0261																				
Ratio	4	8	1																				
(Formula =	$\text{C}_4\text{H}_8\text{O}$)																						



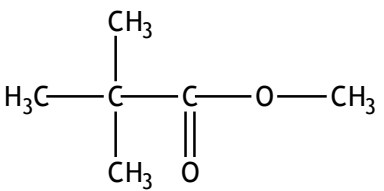
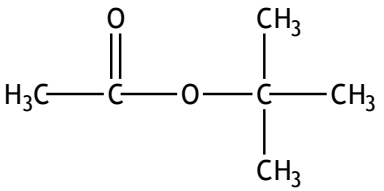
Question Number	Answer	Additional Guidance	Mark
6(b)	An answer that makes reference to the following points: Peak at 2.50 ppm - identified as CH_3CO (as relative peak area = 3 / singlet so no protons on adjacent C) (1) Peak at 1.56 ppm 2 CH_2 groups as relative peak area = 4 (1) (the 2 CH_2 groups / hydrogen environment) next to CH_3 groups as peak is a quartet (1) Peak at 0.92 ppm 2 CH_3 groups as relative peak area = 6 (1) (the 2 CH_3 groups / hydrogen environment) next to CH_2 groups as peak is a triplet (1) Peak at 1.43 ppm CH_3 group with no protons on adjacent carbon atoms as (relative peak area = 3 and) singlet (1) - structure of Q (1)	Allow credit for annotations on table in p14 and on labelled structures Allow adjacent protons / hydrogens for protons on adjacent C Penalise H^+ for protons once only Allow ester group / $\text{H}-\text{C}-\text{C}=\text{O}$ / CH_3 on left of structure given is indicated Do not award if aldehyde / ketone mentioned Allow 4 protons / hydrogens Allow 6 protons / hydrogens Allow just CH_3 identified in M6 if singlet explained in M1 	(7)

(Total for Question 6 = 11 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
4(a)(i)	(CH ₃) ₄ Si	Allow partially or fully displayed formula Ignore connectivity $ \begin{array}{c} \text{CH}_3 \\ \\ \text{H}_3\text{C} - \text{Si} - \text{CH}_3 \\ \\ \text{CH}_3 \end{array} $	(1)

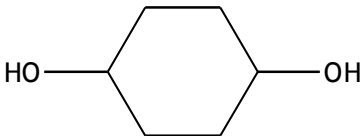
Question Number	Acceptable Answers	Additional Guidance	Mark
4(a)(ii)	An answer that makes reference to any two of the following: - single peak / all H or all C in same environment / no splitting pattern (1) (TMS) peak to the right / upfield / out of the way of other peaks / peak doesn't overlap with other peaks (1) (TMS) low boiling temperature / volatile / can be easily removed (1) - gives a strong signal so only a small amount needed (1)	Allow 12 H or 4 C in the same environment Ignore references to inertness / non-toxicity / cost / non-polar(ity) Ignore chemical shift = 0 12 H / 4 C are equivalent so gives a strong signal scores 2 marks	(2)



Question Number	Acceptable Answers	Additional Guidance	Mark
4(b)(i)	$\text{C}(\text{CH}_3)_3\text{COOCH}_3$ or  (1) $\text{CH}_3\text{COOC}(\text{CH}_3)_3$ or  (1)	Allow displayed or skeletal formulae	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
4(b)(ii)	An answer that makes reference to the following points: - the chemical shift δ 2.2 identified - four remaining chemical shifts identified - two splitting patterns given and explained	(1) $\text{CH}_3\text{C}=\text{O}$ / methyl attached to $\text{C}=\text{O}$ (2) Identifies 2 or 3 chemical shifts correctly scores 1 δ 1.2 3.5 3.8 2.6 (2.2) <pre> H H H H O H H — C — C — O — C — C — C — C — H H H H H H H </pre> (2) 1 specific splitting patterns explained scores 1	(5)

Question Number	Acceptable Answers	Additional Guidance	Mark
4(c)(i)	Any two of the following $(\text{CH}_3)_2\text{CHCH}(\text{CH}_3)\text{COOH}$ / $ \begin{array}{ccccccc} & \text{CH}_3 & & \text{CH}_3 & & & \\ & & & & & & \\ \text{H}_3\text{C} & -\text{C} & - & \text{C} & - & \text{C} & -\text{OH} \\ & & & & & & \\ & \text{H} & & \text{H} & & \text{O} & \end{array} $ (1) $\text{CH}_3\text{CH}_2\text{C}(\text{CH}_3)_2\text{COOH}$ / $ \begin{array}{ccccccc} & \text{H} & & \text{CH}_3 & & & \\ & & & & & & \\ \text{H}_3\text{C} & -\text{C} & - & \text{C} & - & \text{C} & -\text{OH} \\ & & & & & & \\ & \text{H} & & \text{CH}_3 & & \text{O} & \end{array} $ (1) $(\text{CH}_3)_2\text{CHCH}_2\text{CH}_2\text{COOH}$ / $ \begin{array}{ccccccc} & \text{CH}_3 & & \text{H} & & \text{H} & & \text{O} \\ & & & & & & & \\ \text{H}_3\text{C} & -\text{C} & - & \text{C} & - & \text{C} & - & \text{C} & -\text{OH} \\ & & & & & & & \\ & \text{H} & & \text{H} & & \text{H} & & \end{array} $ (1)	Allow displayed or skeletal formulae	(2)

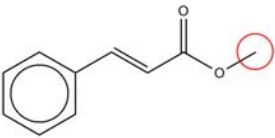
Question Number	Acceptable Answers	Additional Guidance	Mark
4(c)(ii)		Do not award other types of structure	(1)

(Total for Question 4 = 13 marks)



Question Number	Answer	Additional Guidance	Mark
4(a)	- calculation of molar mass of methyl cinnamate (1) - calculation of mass of carbon (1)	Example of calculation molar mass = 162 (g mol⁻¹) 2.34 x (120/162) = 1.73333 = 1.73 (g) TE on incorrect molar mass for M2 Correct answer with no working scores 2 marks Ignore SF except 1	(2)

Question Number	Answer	Additional Guidance	Mark
4(b)(i)	An answer that makes reference to the following points: - peak due to tetramethylsilane (1) - so (chemical) shifts (due to other hydrogen atoms) can be compared (1)	Allow TMS / Si(CH₃)₄ Name must be correct if given Allow "a reference" / "a standard" "calibration" Ignore "to allow other molecules to be compared"	(2)

Question Number	Answer	Additional Guidance	Mark
4(b)(ii)	An answer that makes reference to the following points: M1 circle around -CH_3 group in -OCH_3 (1) M2 singlet as no neighbouring hydrogen atoms (1) M3 peak area of 3 means there are 3 hydrogen atoms in this environment (1)	Allow 'protons' for hydrogen atoms  Award whole -OCH_3 circled Do not award if C=O included in circle M1 is a stand alone mark Award "has no adjacent hydrogen atoms" Award "no hydrogens on adjacent carbon" Ignore "there is no adjacent C atom" Award "(relative) peak area of three for a -CH_3 group" For M3 must relate to (relative) peak area / integral Ignore references to chemical shift value for ester $\delta = 3.0$ to 4.0 (ppm) Ignore references to relative heights of peaks Comment M2 and / or M3 dependent on -CH_3 group being included in the circled group	(3)

Question Number	Answer	Additional Guidance	Mark
4(c)(i)	M1 arrow from double bond to (δ^+)Br in Br₂ (1) M2 arrow from bond in Br₂ to Brδ^- (1) M3 structure of carbocation (1) M4 arrow from lone pair on Br$^-$ to C$^+$ in carbocation and final product (1)	<u>Example of mechanism</u> See below Penalise lack of dipole only once in M1 and M2 Award C$^+$ in intermediate on either C from the double bond Do not award M3 if four bonds are shown on carbocation Br atoms can be shown either upwards or downwards in final product Award (0) if just electrophilic substitution mechanism given. If both electrophilic substitution and addition shown allow 2 max Penalise errors in structure of methyl cinnamate once only in either M3 or M4 Do not award M4 if the two Br atoms have been added to the same carbon atom in the addition product Penalise use of half arrows once only	(4)



Question Number	Answer	Mark
4(c)(ii)	The only correct answer is C (4) <i>A is not correct because 2 chiral centres form in reaction, so 4 possible combinations of +/- forms</i> <i>B is not correct because 2 chiral centres form in reaction, so 4 possible combinations of +/- forms</i> <i>D is not correct because 2 chiral centres form in reaction, so 4 possible combinations of +/- forms</i>	(1)

Question Number	Answer	Mark
4(c)(iii)	The only correct answer is D (rotated) <i>A is not correct because diffracted is the wrong term</i> <i>B is not correct because reflected is the wrong term</i> <i>C is not correct because refracted is the wrong term</i>	(1)

(Total Question 4 = 13 marks)

