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A LEVEL

Examiners' report

CHEMISTRY A

H432
For first teaching in 2015

H432/02 Summer 2018 series

Version 1

Contents

Introduction

Our examiners' reports are produced to offer constructive feedback on candidates' performance in the examinations. They provide useful guidance for future candidates. The reports will include a general commentary on candidates' performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. The reports will also explain aspects which caused difficulty and why the difficulties arose, whether through a lack of knowledge, poor examination technique, or any other identifiable and explainable reason.

Where overall performance on a question/question part was considered good, with no particular areas to highlight, these questions have not been included in the report. A full copy of the question paper can be downloaded from OCR.

Subject information update

Candidates sitting their A Level Chemistry examinations this summer may have noticed they had additional line space to write their answers to level of response questions. We made this change having noticed in previous examination series that some candidates were writing answers that were longer than could fit in the space provided. The extra line space was clearly labelled as additional, and was only there should candidates have required it. There is not an expectation that candidates will necessarily need to use the extra space and we would encourage teachers to continue reminding candidates about the importance of writing concise answers to questions. We will continue to make the extra line space available for level of response questions in future examination series too.

Paper H432/02 series overview

H432/02 is the second of the three examination components for GCE Chemistry A. This component is focused on organic chemistry and brings together topics from modules 4 and 6 of the specification, including relevant practical techniques. There is a synoptic element to all of the three of the A Level examinations and as such this paper also contains some content of modules 1 and 2 set in the context of organic chemistry.

The paper consists of two sections comprised of multiple choice and a mixture of short and long response questions respectively.

Candidate performance overview

Candidates who did well on this paper generally:

- Demonstrated knowledge of reagents and techniques used in organic chemistry: 19(c)(i), 20(b)(i)-(iii), 20(c), 21(b).
- Applied knowledge of reactions to unfamiliar compounds, including those with more than one functional group: 16(c), 20(c), 21(a) and 21(b).
- Drew clear diagrams to show reaction mechanisms: 18(b), 19(b) and 20(d).
- Solved problems with logical and clear working: 19(c)(ii), 21(c)(i)(ii), 22(c)(i) and 22(d).

Candidates who did less well on this paper generally:

- Produced written responses that lacked accuracy and precision: 18(a)(i)(ii), 19(a), 20(a) and 22(b).
- Found it difficult to apply what they had learnt to unfamiliar compounds: 16(a)(iv), 16(b), 17(c) and 20(d).
- Showed poor presentation of organic structures and mechanisms: 16(c), 17(b), 18(b), 19(b) and 21c(ii).
- Showed poor setting out of working in calculations: 19(c)(ii), 21(c)(i), 22(c)(i) and 22(d).

There was no evidence that any time constraints had led to a candidate underperforming and scripts where there was no response to the final question also had large sections of the paper which had not been tackled.

Section A overview

Section A comprises 15 multiple choice questions that assess many different areas of the specification, including practical techniques. This section of the paper is worth 15 marks.

Question 1

1 Which compound is used as a standard for NMR chemical shift measurements?

A $Si(CH_3)_4$

B $CDCl_3$

C D_2O

D CCl_4

Your answer

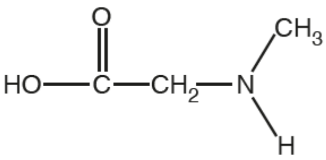
[1]

Candidates found this question more challenging than anticipated. While many correctly chose A, a significant proportion of candidates selected C.

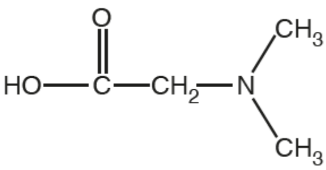
Question 2

2 Which compound is a secondary amide?

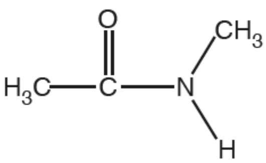
A



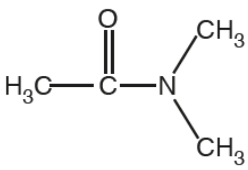
B



C



D



Your answer

[1]

The majority of candidates identified C as the secondary amide.

Question 3

3 Which compound does **not** react with nucleophiles?

A CH_3CH_2CHO

B CH_3CHCH_2

C $CH_3CH_2COCH_3$

D $CH_3CH_2CH_2Cl$

Your answer

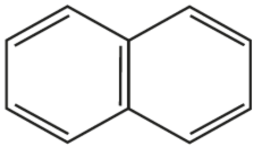
[1]

The majority of candidates identified B (an alkene) as the compound that does not react with nucleophiles.

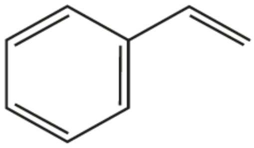
Question 4

4 Which structure represents an alicyclic compound?

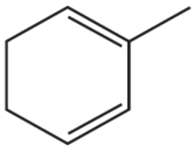
A



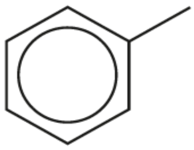
B



C



D



Your answer

[1]

Many candidates correctly identified C as the alicyclic compound. B and D proved good distractors and were seen in approximately equal proportions.

Question 5

5 Which molecule is **not** planar?

A C_2H_4

B C_2H_6

C H_2CO

D HCN

Your answer [ ]

[1]

This question discriminated well, with higher ability candidates correctly identifying B as a non-planar molecule. Common incorrect responses included C and D. Some candidates drew structures alongside each option to aid their choice.

Question 6

6 What is the number of peaks in the ^1H NMR spectrum of $HOOCCH_2CHOHCH_2COOH$?

A 3

B 4

C 5

D 6

Your answer [ ]

[1]

Many candidates correctly identified that the ^1H NMR spectrum would contain 4 peaks and selected B. In most cases candidates arrived at this answer by drawing out the structure and labelling the environments. A common distractor was A (3 peaks) which presumably arose from candidates assuming that the C–H and O–H protons in the centre of the structure were equivalent.

Question 7

7 Ethanol can be prepared by different reactions.

Which reaction has the lowest atom economy?

A $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$

B $C_2H_4 + H_2O \rightarrow C_2H_5OH$

C $C_2H_5Br + H_2O \rightarrow C_2H_5OH + HBr$

D $CH_3COOC_2H_5 + H_2O \rightarrow C_2H_5OH + CH_3COOH$

Your answer [ ]

[1]

A lot of work was required to determine the equation with the lowest atom economy. Some candidates selected C after calculating a value for each equation, while stronger candidates appeared to focus on HBr as a by-product with a relatively high molar mass. Many incorrect responses were seen and candidates appeared to pick A, B and D in roughly equal proportions.

Question 8

8 The breakdown of ozone is catalysed by NO radicals.

Which equation is a propagation step in the mechanism for this process?

A $NO + O_2 \rightarrow N + O_3$

B $NO + O_2 \rightarrow NO_2 + O$

C $N + O_3 \rightarrow NO + O_2$

D $NO_2 + O \rightarrow NO + O_2$

Your answer

[1]

Candidates found this multiple choice question difficult. While some correctly selected D, many candidates chose B.

Question 9

9 Which compound could have produced the IR spectrum below?

Item removed due to third party copyright restrictions

A CH_3CH_2OH

B $CH_3CHOHCN$

C CH_3COOH

D CH_3CONH_2

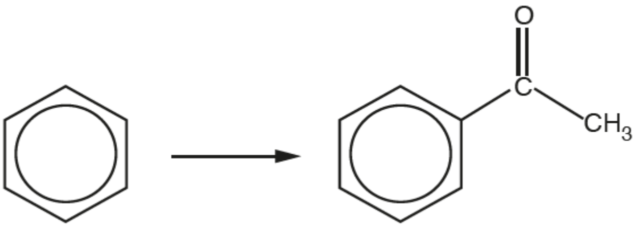
Your answer

[1]

Most candidates correctly identified B as the compound after labelling the O-H and C≡N peaks in the spectrum.

Question 10

10 Benzene reacts with an organic reagent in the presence of a halogen carrier to form phenylethanone.



phenylethanone

Which organic reagent is required?

A CH_3CH_2OH

B CH_3CHO

C CH_3COCl

D CH_3COOH

Your answer ☐

[1]

Almost all candidates identified C (CH_3COCl) as the reagent required for this reaction.

Question 11

11 How many straight-chain structural isomers of $C_7H_{15}Cl$ contain a chiral carbon atom?

A 1

B 2

C 3

D 4

Your answer ☐

[1]

This question proved difficult. Candidates who drew out the different isomers of chloroheptane were able to identify B as the correct response.

Question 12

12 The mass spectrum of $(CH_3)_2CHCH_2OH$ is shown below.

Item removed due to third party copyright restrictions

Which ion is responsible for the peak with the greatest relative intensity?

A $CHCH_2OH^+$

B $CH_3CH_2CH^+$

C $(CH_3)_2CH^+$

D CH_3CO^+

Your answer ☐

[1]

Most candidates were able to identify C as the fragment responsible for the peak at m/z = 43. A number of different approaches were used. Some candidates determined the mass of each fragment shown while others drew the structures to see which were likely to be formed from $(CH_3)_2CHCH_2OH$.

Question 13

13 Which statement(s) support(s) the delocalised model for the structure of benzene?

1 All carbon–carbon bonds have the same length.

2 The enthalpy change of hydrogenation of benzene is less exothermic than expected.

3 Bromine reacts with benzene less readily than with cyclohexene.

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer ☐

[1]

The bonding in benzene is well known by candidates at this level and most correctly selected A as their response.

Question 14

14 A solid organic compound can be purified by recrystallisation.

Which statement(s) about recrystallisation is/are true?

1 The organic compound is more soluble in hot solvent.

2 The hot solution is cooled before the purified organic compound is collected.

3 The melting point of the purified organic compound is lower than the impure compound.

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

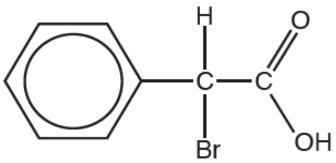
Your answer [ ]

[1]

Many candidates correctly selected B. Option A proved a good distractor, presumably as candidates linked melting point to recrystallisation without fully interpreting statement 3.

Question 15

15 Which of the following could react with the compound below to form a carbon–carbon bond?



1 CH_3Cl and $AlCl_3$

2 KCN in ethanol

3 CH_3OH and H_2SO_4

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer [ ]

[1]

Candidates found this question difficult, presumably as it involved reactions of different functional groups within the same compound. Many candidates identified B as the correct response. The most common incorrect responses were C and D.

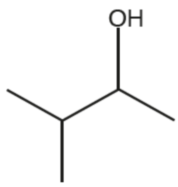
Section B overview

Section B includes a mixture of short answer and extended response questions, including two questions marked using a level of response mark scheme (20d and 22d). This section of the paper is worth 85 marks.

Question 16(a)(i)

16 This question is about reactions of organic compounds containing carbon, hydrogen and oxygen.

(a) A chemist investigates two reactions of alcohol **A**, shown below.



alcohol A

(i) What is the systematic name of alcohol **A**?

.... **[1]**

The majority of candidates were able to correctly name alcohol **A** as 3-methylbutan-2-ol. A significant number of responses used incorrect numbering and suggested 2-methylbutan-3-ol as the name.

Question 16(a)(ii)

(ii) What is the structural formula of alcohol **A**?

.... **[1]**

Most candidates were able to show a correct structural formula of alcohol **A**.

Question 16(a)(iii)

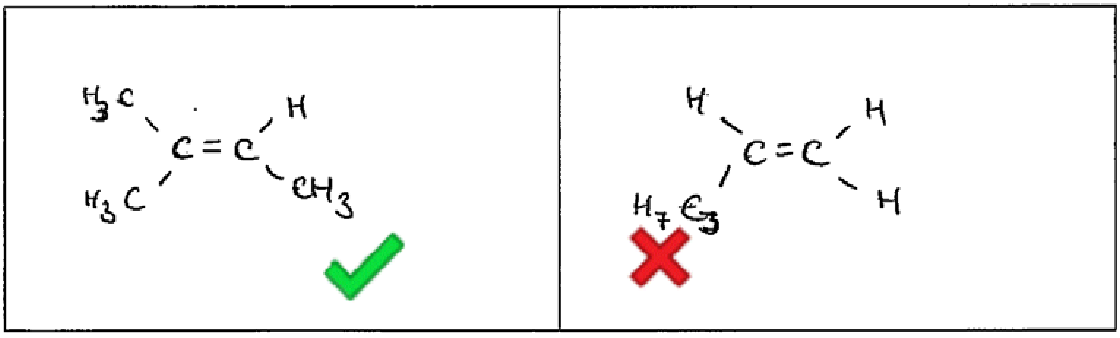
(iii) The chemist heats alcohol **A** with an acid catalyst to form a mixture containing **two** alkenes.

Draw the structures of the **two** alkenes formed in this reaction.

[2]

Many candidates correctly identified the two alkenes formed as 2-methylbut-2-ene and 3-methybut-1-ene. Stronger responses used skeletal formula to show the structures clearly. Some candidates preferred to use chemical symbols to represent the atoms present and although this approach is valid, lower ability responses did not show sufficient detail as demonstrated in Exemplar 1.

Exemplar 1



In this response the alkene 2-methylbut-2-ene has been correctly identified and one mark credited. However, the attempt to show 3-methylbut-1-ene does not score. This is because C_3H_7 has been used instead of $CH(CH_3)_2$. Candidates should be encouraged to show every carbon atom when drawing a structure as the use of ambiguous formulae is not sufficient to gain credit.

Question 16(a)(iv)

(iv) The chemist heats alcohol **A** with sodium chloride and sulfuric acid.

Construct a balanced equation for this reaction.
Show structures for the organic compounds in your equation.

[2]

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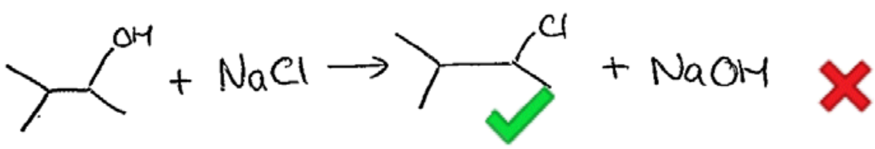
This question proved difficult for candidates. Although many candidates were able to identify the correct organic product, only the higher ability candidates were able to construct an appropriate balanced equation. A common error was to omit the role of the acid; this is shown in Exemplar 2 below. Lower ability candidates appeared not to recognise this reaction and suggested an alkoxide salt, rather than a haloalkane as the organic product.

Exemplar 2

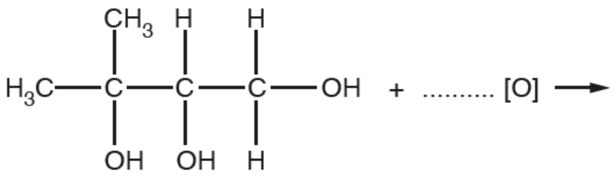


This type of response was seen frequently by examiners. The candidate has drawn the correct structure of the haloalkane formed and scores the first mark. However, the response fails to recognise that the reaction occurs under acidic conditions and omits the sulfuric acid from the equation.

Question 16(b)

(b) Compound **B**, shown below, is refluxed with excess acidified potassium dichromate(VI) to form a single organic product.

Complete the equation for this reaction.



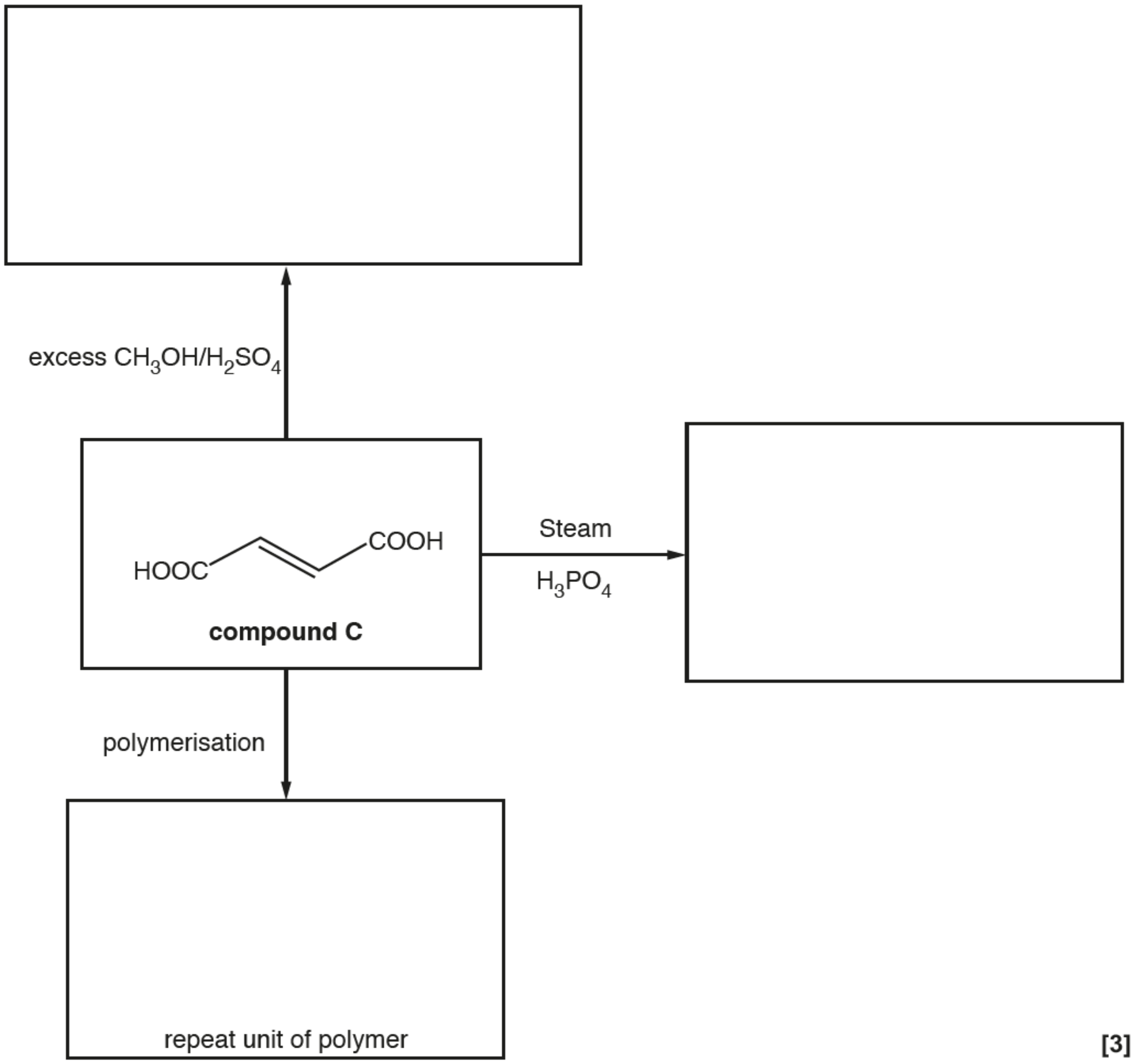
compound B **[2]**

This question required candidates to apply their knowledge of the oxidation of alcohols to complete the equation for the complete oxidation of compound **B**. This question discriminated well. Many candidates correctly identified the organic product but only the higher ability candidates could complete the equation. A common error was to omit water as a product of the reaction.

Question 16(c)

(c) The flowchart below shows some reactions of compound **C**.

In the boxes, draw the organic products of these reactions.



[3]

The majority of candidates were able to identify at least one product from the reactions of compound **C**. The polymerisation reaction appeared to be the most familiar, although some candidates attempted to draw a condensation polymer using the carboxylic acid groups rather than the alkene.

The reaction of **C** with excess methanol was also well attempted. However, a significant number of candidates used chemical symbols to show their product. A proportion of these did not show the H atoms of the alkene group, showing only C=C in the centre of the structure. Candidates are advised to use the type of formulae given in a question as this will reduce the potential for error or omissions.

The product from the hydration of **C** appeared to be the hardest to deduce. Many candidates recognised this reaction would produce an alcohol, but often included two OH groups – one on each C from the double bond – in their structure. Other candidates confused this reaction with hydrogenation and formed a saturated product from **C**.

Question 17(a)

17 The general formula of an α-amino acid is $RCH(NH_2)COOH$.

(a) The α-amino acid cysteine ($R = CH_2SH$) shows optical isomerism.

Draw 3-D diagrams to show the optical isomers of cysteine.

[2]

Candidates were well prepared to tackle this question and consequently most candidates scored both marks.

Question 17(b)

(b) The α-amino acid lysine ($R = (CH_2)_4NH_2$) reacts with an excess of dilute hydrochloric acid to form a salt.

Draw the structure of the salt formed in this reaction.

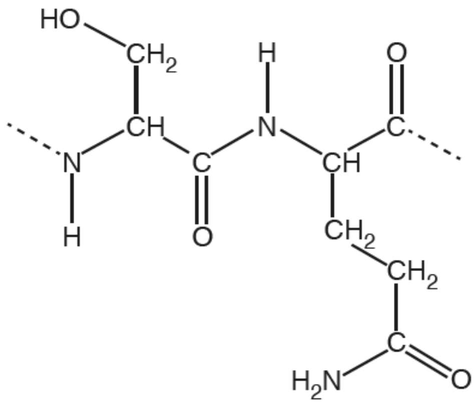
[2]

In contrast to part **(a)** this question proved difficult and discriminated well. The higher ability candidates correctly identified the dichloride salt produced by the reaction of lysine with excess acid. Some candidates formed ammonium ions on both nitrogen atoms but omitted the chloride ions. Others only formed a monochloride salt, leaving the R group unchanged. These two approaches scored one mark.

Question 17(c)

(c) α-Amino acids can react to form proteins.

A short section of a protein chain is shown below.



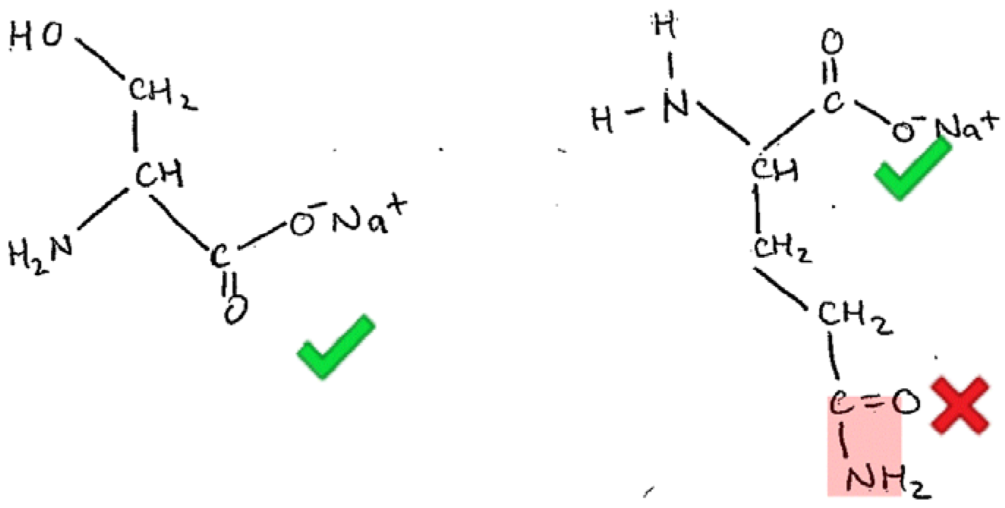
A student hydrolyses the protein with hot NaOH(aq).

Draw the structures of the organic products formed from this section of the protein.

[3]

This question required candidates to apply their knowledge of amide hydrolysis to a section of protein. Many candidates correctly recognised that two amino acids would be produced but not all took account of the alkaline conditions and showed COOH groups rather than carboxylates. Candidates found this question difficult and although many gained some credit only the highest ability candidates, who recognised the amide in the side-chain would also react, scored full marks after. Exemplar 3 shows a good response.

Exemplar 3



This response has correctly identified the amino acid on the left hand side of the amide link and also shown this as a carboxylate. Consequently the first mark has been achieved. The right hand amino acid has also been identified correctly. However, the amide in the R group has not been hydrolysed so this response only scores one of the two marks available for this product. Notice the candidate has presented their structures clearly with the atoms drawn in a similar arrangement to the protein shown in the question. This is a good strategy to avoid errors and omissions when drawing organic structures.

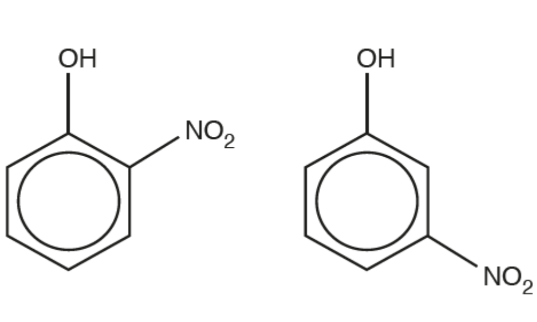
Question 18(a)(i)

18 This question is about aromatic compounds.

(a) Phenol undergoes nitration more readily than benzene.

(i) A student carries out the nitration of phenol with dilute nitric acid to produce 2-nitrophenol and 4-nitrophenol.

A small amount of 3-nitrophenol is also produced.



2-nitrophenol **3-nitrophenol** **4-nitrophenol**

The student thought that ^{13}C NMR spectroscopy could be used to distinguish between these three nitrophenols.

Explain whether the student is correct.

....

....

....

....

....

....

....

....

....

.... **[3]**

This question required candidates to apply their knowledge of ^{13}C NMR spectroscopy to deduce the number of different carbon environments in each of the nitrophenols shown. The best responses were succinct, stating that it is possible to distinguish 4-ntirophenol from the other two after deducing the correct number of carbon environments for each compound. Lower ability candidates' responses did not identify the symmetry in 4-nitrophenol and suggested all three compounds would produce six peaks, therefore making it impossible to distinguish between them.

Question 18(a)(ii)

(ii) Explain why phenol is nitrated more readily than benzene.

....

....

....

....

....

....

....

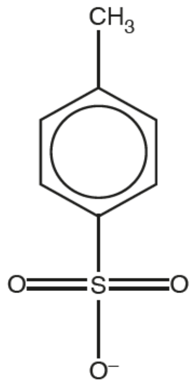
....

.... **[3]**

The relative reactivity of phenol is well known by candidates at this level and the majority scored two or three marks. Candidates who did not score full marks gave imprecise or vague explanations. This included reference to 'higher charge density' or 'higher electronegativity' of the phenol ring, rather than 'higher electron density'.

Question 18(b)

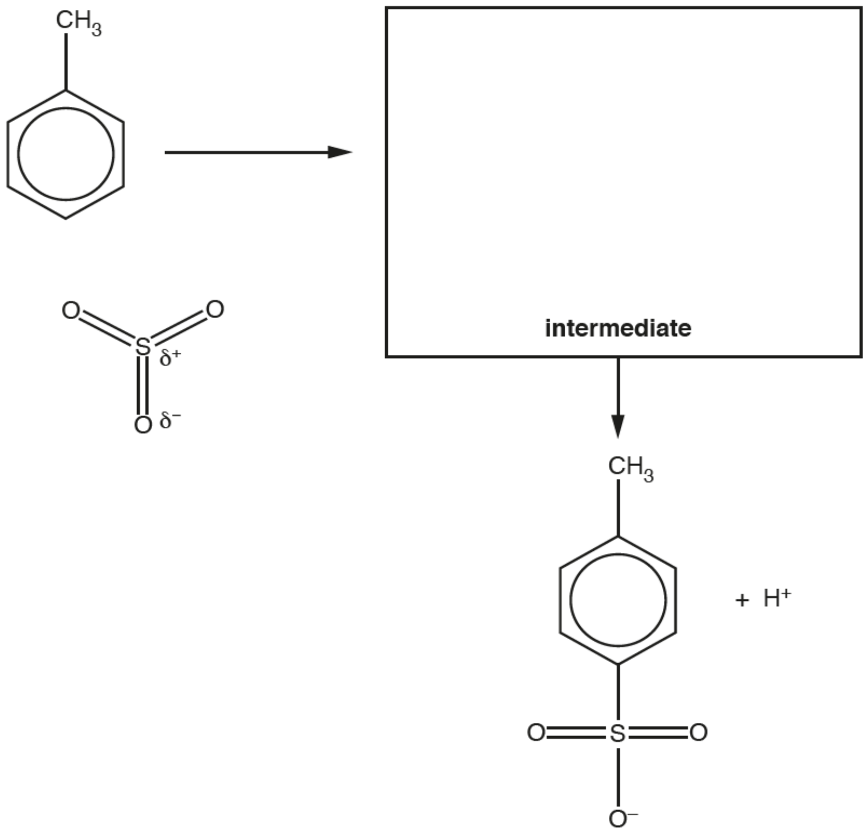
(b) Methylbenzene reacts with sulfur trioxide, SO_3, to form **D**, shown below.



D

The electrophile in this reaction is SO_3.

Complete the mechanism for the formation of **D**.
Show curly arrows and the structure of the intermediate.

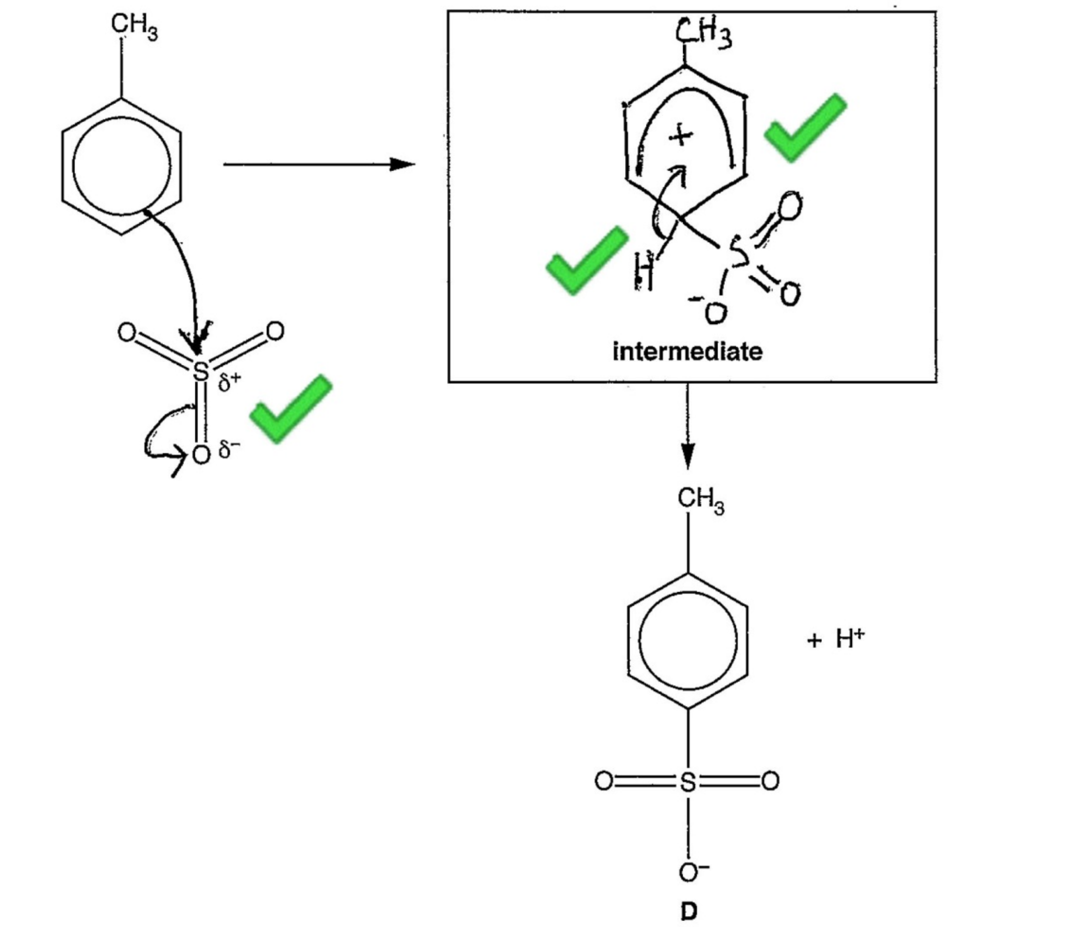


D

[3]

This question required candidates to apply their understanding of electrophilic substitution to the reaction of methylbenzene with sulfur trioxide. Examiners were encouraged by the quality of responses to this question. Most candidates secured full marks in this part. Some candidates did not show the curly arrow for the breaking of the S=O bond, while others omitted the methyl group from the intermediate. Exemplar 4 shows an excellent response.

Exemplar 4



[3]

This response demonstrates an excellent example for candidates to follow. Curly arrows are drawn accurately, with each arrow touching the bond it starts from. The intermediate has been drawn clearly, using all the space provided. The 'horseshoe' has been drawn accurately over five of the carbon atoms with the positive charge shown neatly in the centre.

Question 19(a)

19 This question is about the hydrolysis of haloalkanes.

(a) The rate of hydrolysis of a haloalkane depends on the halogen present.

State and explain how the halogen in the haloalkane affects the rate of hydrolysis.

....

....

....

....

.... **[2]**

This question required candidates to link the rate of hydrolysis with the strength of the carbon-halogen bond present in different haloalkanes. Higher ability candidates were able to do this succinctly, making clear comparisons between different C-X bonds. Exemplar 5 shows a commonly seen one mark response.

Exemplar 5

The bond strength of the carbon-halogen bond affects rate of hydrolysis. The weaker the bond, the faster the rate of hydrolysis. This is because less energy is required to break the bond.

[2]

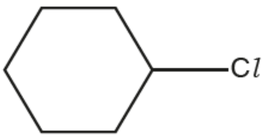
This response correctly describes the effect of bond strength on the rate of hydrolysis and receives one mark. To score the second mark a comparison of two different carbon-halogen bonds is required.

Question 19(b)

(b) Chlorocyclohexane is hydrolysed with aqueous sodium hydroxide.

Outline the mechanism for this reaction.

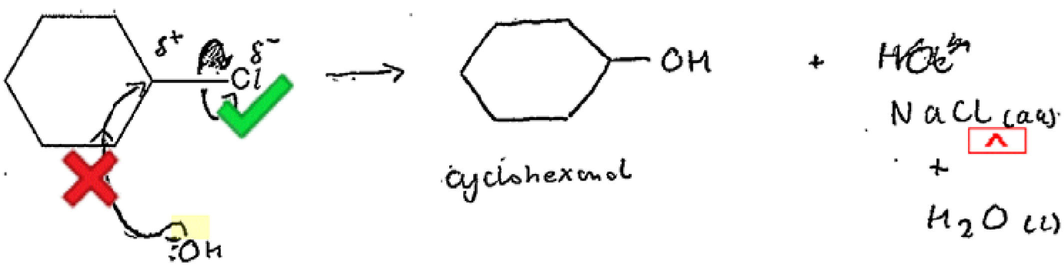
Show curly arrows, relevant dipoles and the products.



[3]

Candidates were very familiar with this nucleophilic substitution mechanism. Consequently the majority of candidates scored two or three marks. Common errors included inaccurate curly arrows from the hydroxide ion and failure to show the chloride ion as a product. Exemplar 6 highlights both of these.

Exemplar 6



This response demonstrates the two most common errors seen in this part. The first marking point cannot be credited as the curly arrow from the hydroxide ion does not involve either the lone pair or minus sign on the O atom. The organic product is correct but the chloride ion produced by the heterolytic fission of the C-C*l* bond is not shown so marking point three cannot be credited. This response only scores one mark for the correct partial charges and curly arrow on the C-C*l* bond. Candidates are encouraged to practice drawing mechanisms so as to avoid costly errors during examinations.

Question 19(c)(i)

(c) A student hydrolyses a haloalkane, **E**, using the following method.

- 0.0100 mol of haloalkane **E** is refluxed with excess NaOH(aq) to form a reaction mixture containing an organic product **F**.
- The reaction mixture is neutralised with dilute nitric acid.
- Excess $AgNO_3$(aq) is added to the reaction mixture. 1.88 g of a precipitate **G** forms.

Organic product, **F**, has a molar mass of 74.0 g mol^{-1} and has a chiral carbon atom.

(i) Draw a **labelled** diagram to show how the student would carry out the hydrolysis of haloalkane **E**.

[2]

Most candidates were able to draw a suitable diagram to show the apparatus required for reflux but some included a stopper on top of the condenser. Many of the diagrams were labelled appropriately but common errors included incorrect direction of water flow or omission of the 'flask' label. A small but significant proportion of candidates drew a diagram showing distillation.

Question 19(c)(ii)

(ii) Analyse the information to identify **E**, **F** and **G**.

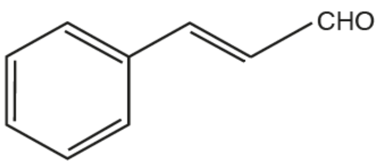
Show your working.

[3]

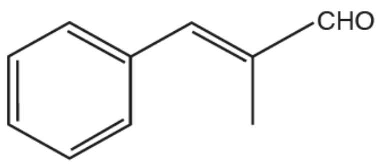
This question, requiring candidates to analyse the information to identify compounds **E**, **F** and **G**, discriminated well. Many candidates deduced that **G** was a silver halide but not all provided working to back up their choice of AgBr. Some candidates appeared to guess and AgCl was commonly seen. Some candidates used the molar mass of **F** provided to deduce the molecular formula of $C_4H_{10}O$ but lower ability responses did not process this further. Higher ability candidates identified **F** as butan-2-ol, showing the chiral carbon clearly. Other alcohols were also seen including butan-1-ol and methylpropan-2-ol. The highest ability candidates linked all the information and provided a structure for **E** that was consistent with their suggestions for **F** and **G**.

Question 20(a)

20 Cinnamaldehyde and methylcinnamaldehyde are naturally occurring organic compounds.



cinnamaldehyde



methylcinnamaldehyde

(a) Methylcinnamaldehyde is an *E* stereoisomer.

Explain this statement in terms of the Cahn-Ingold-Prelog (CIP) rules.

....

....

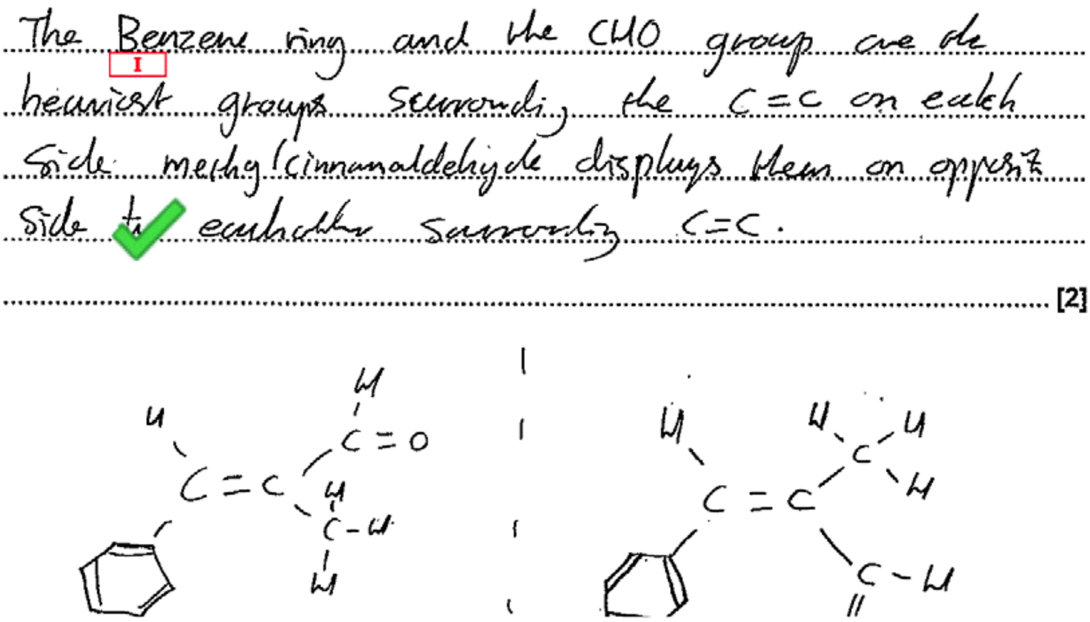
....

....

.... **[2]**

Many candidates explained that methylcinnamaldehyde is an *E* isomer as the highest priority groups are on opposite sides, but only the highest ability candidates applied the CIP rules to identify the highest priority groups as C_6H_5 and CHO. A common misconception was to refer to the molecular mass of the groups instead of priority as in Exemplar 7.

Exemplar 7



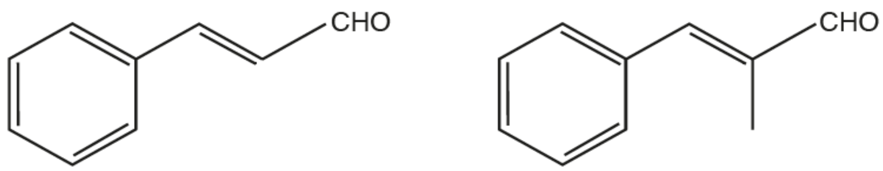
The Benzene ring and the CHO group are the heaviest groups surrounding the C=C on each side methylcinnamaldehyde displays them on opposite side to eachother surrounding C=C.

[2]

This response uses the mass of the benzene and CHO groups to attempt to justify their priority. This was ignored by the mark scheme as the CIP rules use atomic number to determine the highest priority groups. However, this response does clearly communicate that these two groups are on different sides of the carbon-carbon double bond so scored one mark.

Question 20(b)(i)

(b) A student plans to carry out some chemical tests on both cinnamaldehyde and methylcinnamaldehyde.



cinnamaldehyde **methylcinnamaldehyde**

(i) Suggest a suitable chemical test to confirm that both compounds contain an unsaturated carbon chain.

Your answer should include the reagent and observations.

....

.... **[1]**

Almost all candidates were able to correctly describe the use of bromine as a test for an unsaturated chain.

Question 20(b)(ii)

(ii) Describe a chemical test to confirm that both compounds contain an aldehyde functional group.

Your answer should include the reagent and observations.

....

.... **[1]**

Almost all candidates were able to correctly describe the use of Tollens' reagent as a test for an aldehyde functional group.

Question 20(b)(iii)

(iii) Describe a chemical test to confirm that cinnamaldehyde and methylcinnamaldehyde contain a carbonyl group.

How could the products of this test be used to distinguish between the two compounds?

Your answer should **not** include spectroscopy.

....

....

....

....

....

....

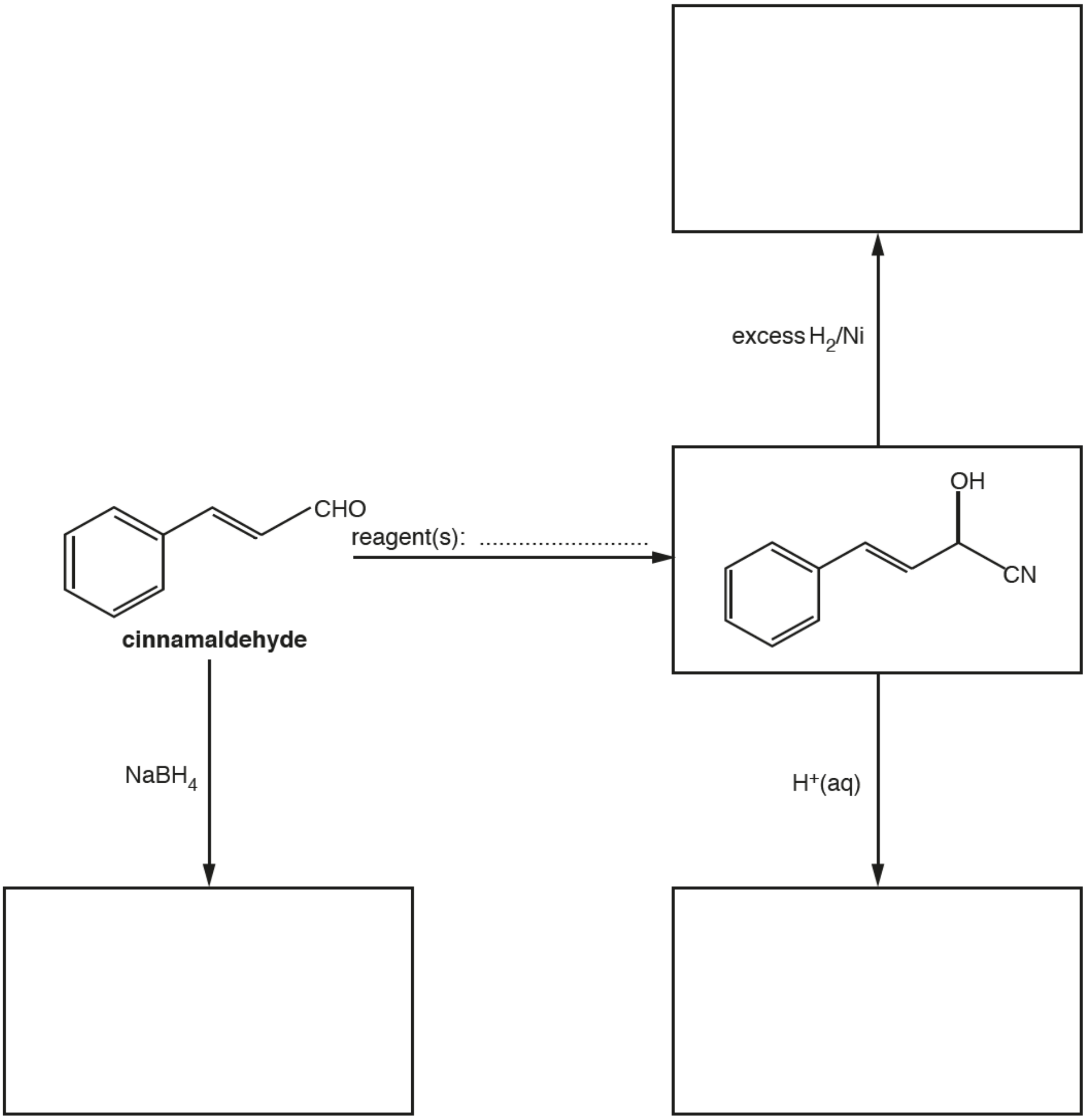
.... **[3]**

The use of 2,4-dinitrophenylhydrazine as a test for the carbonyl group is well known by candidates at this level. The majority of the cohort correctly identified this test and the subsequent analysis of the melting point of the products as a method of identifying each compound. Lower ability candidate responses made reference to analysis of the boiling points of the cinnamaldehyde and methylcinnamaldehyde as a means of identification.

Question 20(c)

(c) The flowchart below shows some reactions starting with cinnamaldehyde.

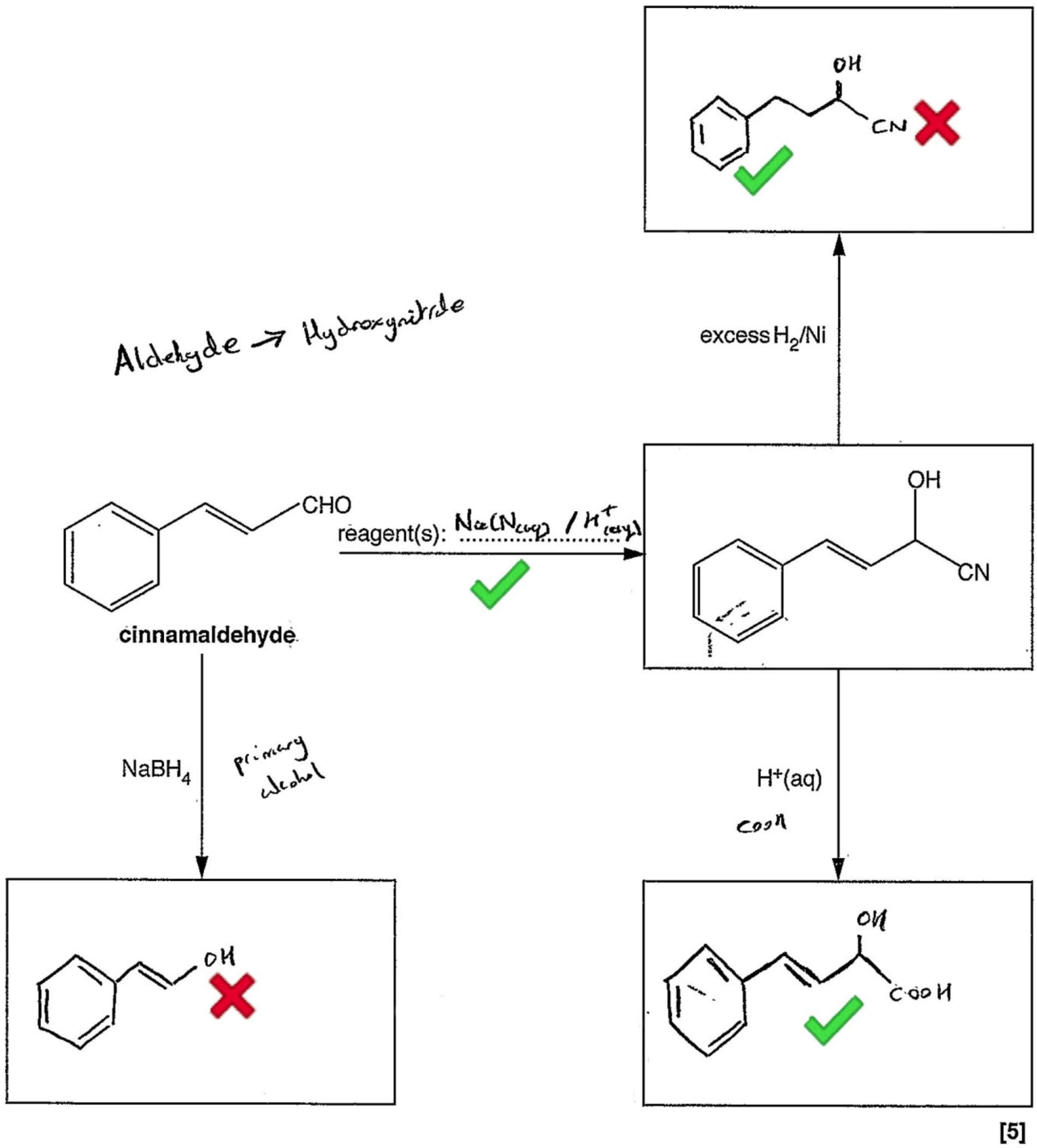
Draw the structures of the missing organic compounds in the boxes and add the missing reagent(s) on the dotted line.



[5]

This question proved difficult and although the majority of candidates scored in some parts, only the very best responses secured all five marks. More detailed feedback is discussed with Exemplar 8.

Exemplar 8



Cinnamaldehyde was the starting point for this flowchart of reactions.

The most frequently scored mark was correct identification of the reagents required for the formation of the hydroxynitrile. This response uses NaCN/H^+. Other candidates used HCN which was also acceptable.

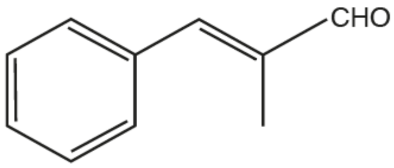
The flowchart shows two different reactions of this hydroxynitrile. The first is the reaction with excess hydrogen in the presence of Ni. Most candidates scored one mark for their product. As in this exemplar, the double bond was often reacted to form a saturated chain. Some candidates identified that the CN group would also react but instead of writing CH_2NH_2 they replaced the CN group with just NH_2, effectivity removing a carbon atom from the chain. The second reaction of the hydroxynitrile is acid hydrolysis of the CN group. This response identifies the correct carboxylic acid. However, this reaction seemed unfamiliar to many candidates and a range of incorrect responses were frequently seen.

The final reaction is the reduction of cinnamaldehyde with $NaBH_4$. Many candidates recognised this reaction, but as can be seen in this response the alcohol group is shown on the incorrect carbon atom. This was a common error.

Candidates are advised to number carbon atoms present if provided with a complex structure, such as cinnamaldehyde. Numbering will ensure that each carbon is considered when drawing reaction products and would minimise errors, such as those demonstrated in the reduction product.

Question 20(d)*

(d)* Methylcinnamaldehyde reacts with iodine monochloride, ICl, by electrophilic addition. The reaction produces a mixture containing two different organic products.



methylcinnamaldehyde

The electronegativity values of chlorine and iodine are given in the table below.

	Pauling electronegativity value
Cl	3.0
I	2.5

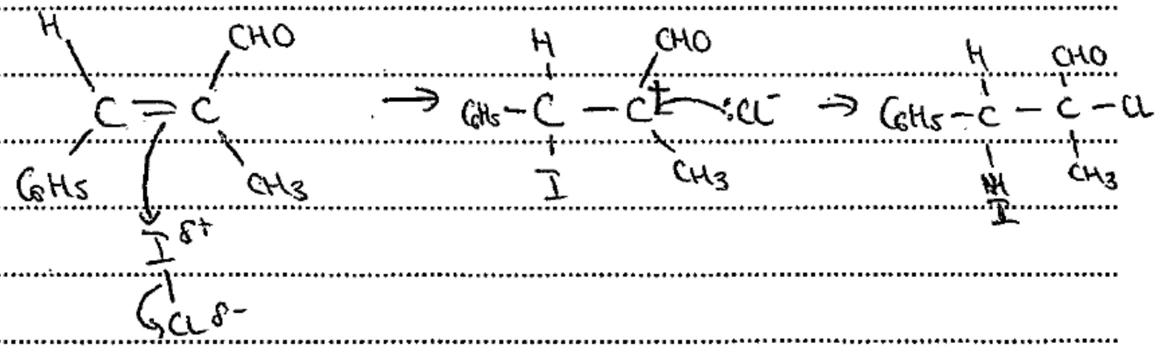
Outline the mechanism, using the 'curly arrow' model, for the formation of **one** of the organic products and explain which of the two possible organic products is more likely to be formed.

In your mechanism, you can show the phenyl group as C_6H_5. **[6]**

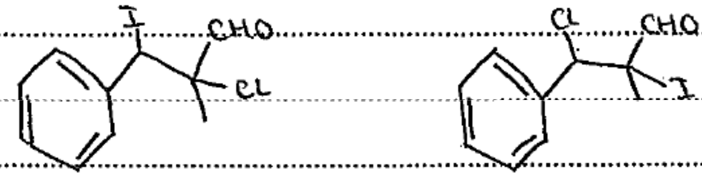
This question was marked using a level of response mark scheme. Most candidates gave an answer worthy of at least level two (3-4 marks) by providing a suitable mechanism and identifying the major product. The strongest candidates identified both products and were able to describe which was most likely. Such responses received level 3 (5-6 marks) as shown in Exemplar 9. Lower ability candidate responses seemed to ignore the reference to electrophilic addition in the question and tried reacting ICl with either the benzene ring or the aldehyde group.

Exemplar 9

The mechanism for this reaction is electrophilic ~~sub~~ addition.



The two possible organic products are:



Product A Product B

Product A is the major product (more likely product) and product B is the minor product. This is due to Markownikoff's rule. The Iodine will become attached to the carbon with the most hydrogen ~~less~~ attached, in an unsymmetrical alkene, as it produces the most stable carbocation intermediate. The intermediate in the mechanism for product A is a tertiary carbocation which is more stable than the secondary carbocation intermediate in the mechanism for product B. Therefore, product A is the major product.

L3

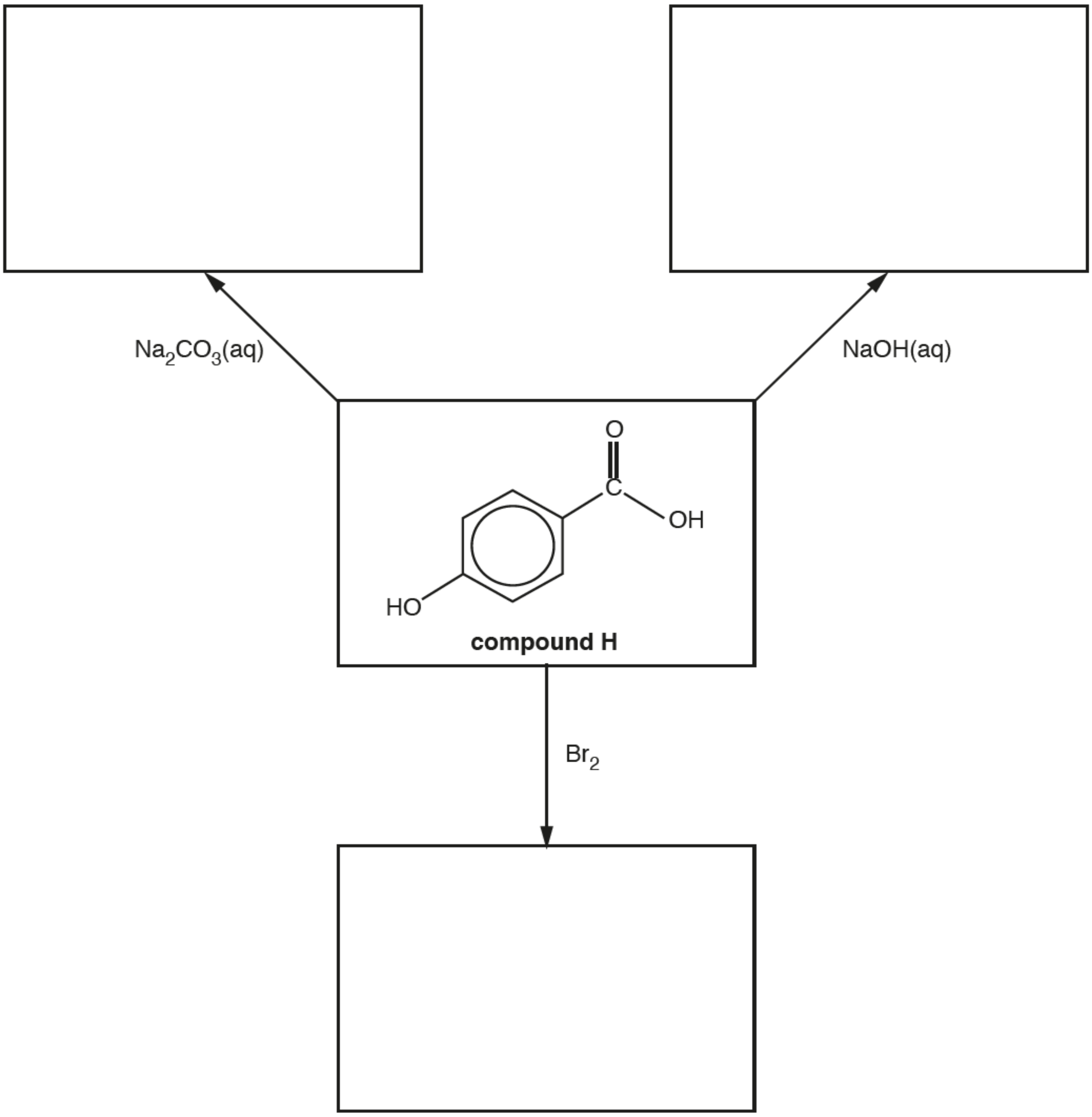
This response starts with a clear outline of the electrophilic addition mechanism showing correct partial charges and accurately drawn curly arrows. The structures of the two possible organic products are shown and the most likely product to be formed is identified correctly. Notice that the candidate has labelled these structures as 'Product A' and 'Product B' and refers to the labels later in the response. This is a good strategy, which enables the candidate to provide a clear and easy to follow answer. The response concludes with a detailed explanation, referring to carbocation stability to justify why product A is most likely to be formed. This response therefore satisfies the Level 3 criteria. The response is logically structured with a well-developed line of reasoning and was therefore credited the upper mark within the level and achieved six marks.

Question 21(a)

21 This question is about aromatic carboxylic acids and their derivatives.

(a) The flowchart below shows some reactions of compound **H**.

In the boxes, draw the organic products of these reactions.



[3]

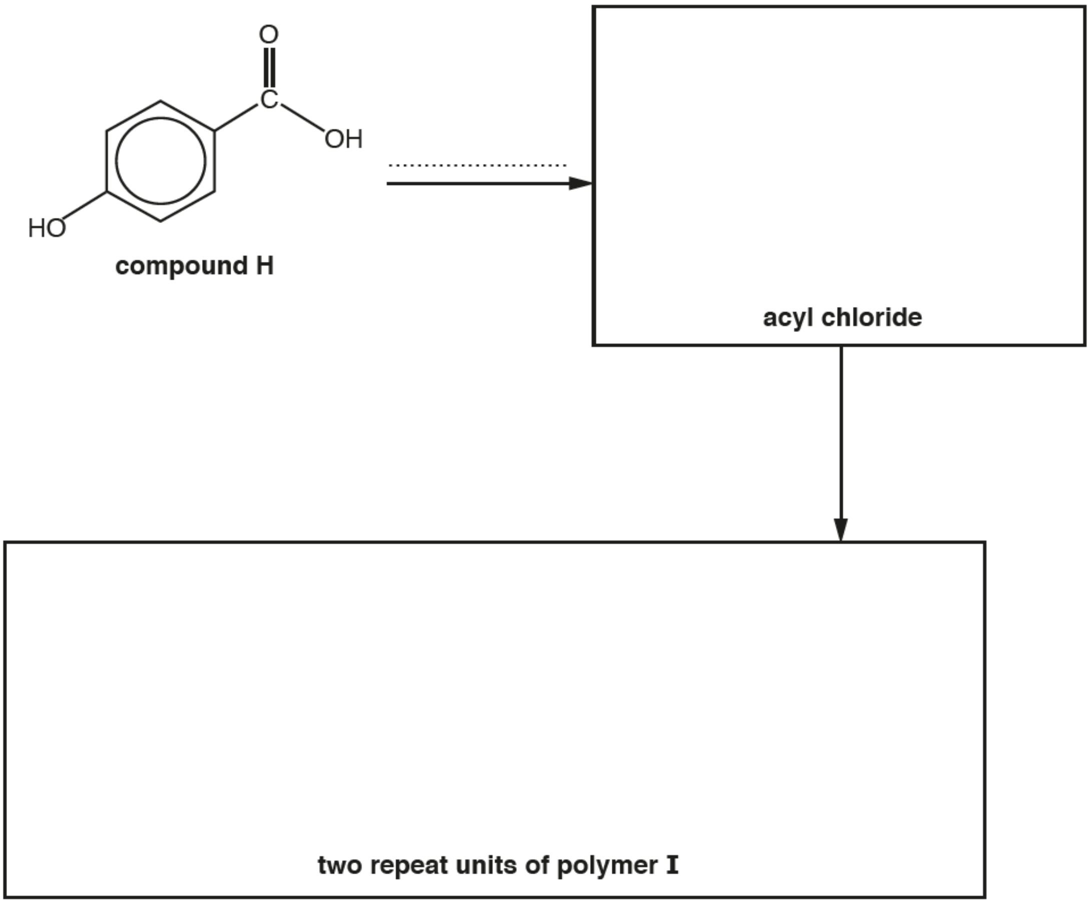
This question assessed different reactions of compound **H**, 4-hydroxybenzoic acid, and discriminated well. Two of the reactions focused on acid-base chemistry, using the reagents Na_2CO_3 and NaOH. Many candidates recognised that the carboxylic acid group would react in both cases but only some managed to identify when the phenol group was involved correctly. A number of responses suggested that a phenoxide ion was formed with sodium carbonate but not with sodium hydroxide.

The third reaction was substitution with bromine. This reaction appeared more familiar to all candidates with the majority scoring this mark. A small proportion of candidates substituted the phenol OH group or carboxylic acid group.

Question 21(b)

(b) Compound **H** is used in the synthesis of polymer **I**, as shown in the flowchart below.

Complete the flowchart by drawing the structure of the acyl chloride and **two** repeat units of polymer **I**, and stating the **formula** of the reagent(s) required for the first stage on the dotted line.



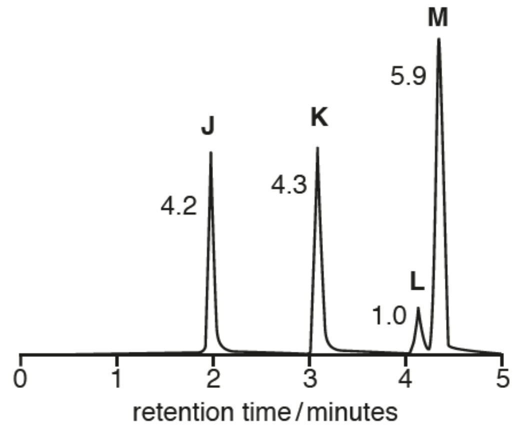
[4]

Compound **H** was also the focus for this question. Most candidates were able to provide the structure of the acyl chloride obtained from **H** but only some identified $SOCl_2$ as the correct reagent. Common incorrect reagents included HCl and $AlCl_3$. Most candidates recognised that polymer **I** was a polyester but only some were able to draw two repeat units correctly. Candidates are advised to practice drawing different polymers, taking care to ensure the correct number of repeat units are present when a specific number is required.

Question 21(c)

(c) A cosmetic product containing four esters, **J**, **K**, **L** and **M**, is analysed by gas chromatography and mass spectrometry. The results are shown below.

Gas chromatogram



The numbers by the peaks are the relative molar proportions of the compounds in the mixture.

Mass spectrometry

ester	*m/z* of molecular ion peak
J	152
K	166
L	180
M	180

(i) The concentration of ester **K** in the cosmetic product is $9.13 \times 10^{-2}\,g\,dm^{-3}$.

Using the results, calculate the concentration, in $mol\,dm^{-3}$, of ester **M** in the cosmetic product.

Give your answer to **two** significant figures.

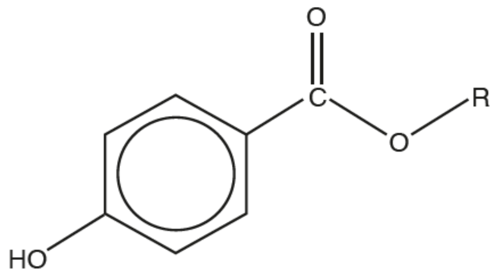
concentration of ester **M** = ... $mol\,dm^{-3}$ **[2]**

This question required candidates to apply their knowledge of gas chromatography and the mole to solve this problem. Most candidates recognised the need to use the relative peak areas to determine the relative proportion of **M**. Many also realised that division by the molar mass was required to ensure the final answer was given in mol dm^{-3}. However, some used molar mass of **M** rather than **K** in this step, leading to an answer of 7.0×10^{-4} mol dm^{-3}.

Answer = 7.5×10^{-4} mol dm^{-3}

Question 21(c)(ii)

(ii) A general structure for esters **J**, **L** and **M** is shown below.



Where 'R' is an alkyl group.

Use the mass spectrometry results to deduce possible structures for esters **J**, **L** and **M**.

J	**L**	**M**

[3]

Examiners were encouraged by the number of good responses to this problem solving question. Most candidates achieved at least one mark in this part, often from a correct structure of **J**. Although many candidates deduced that the R group for both **L** and **M** consisted of 3 C atoms and 7 H atoms, only the highest ability candidates were able to join these correctly. A small but significant number of responses showed R groups that involved O atoms, despite the prompt that the R represented an alkyl group. Candidates are advised to read questions carefully.

Question 22(a)

22 The relative molecular masses and boiling points of some fuels are shown in **Table 22.1**.

Fuel	Relative molecular mass	Boiling point/°C
hexane	86	69
pentan-1-ol	88	138
heptane	100	98

Table 22.1

(a) Write an equation for the incomplete combustion of heptane.

.... **[1]**

The majority of candidates were able to provide a correct equation for the incomplete combustion of heptane.

Question 22(b)

(b) Explain the difference in the boiling points of the fuels in **Table 22.1**.

....

....

....

....

....

....

....

....

....

.... **[4]**

This question was answered well with most candidates scoring three or four marks. Examiners were impressed by the number of responses that accurately referred to induced dipole-dipole interactions or London forces rather than van der Waals' forces, which is ambiguous. Some responses lacked detail, as demonstrated in Exemplar 10.

Exemplar 10

Pentan-1-ol has the highest boiling point because the OH group can form hydrogen bonds which require more energy to break

Heptane has a higher boiling point than hexane because it has a longer chain length therefore a larger surface area and more induce dipole - induce dipole attractions.

This response attributes the higher boiling point of pentan-1-ol to the amount energy required to break hydrogen bonds. However, it does not refer the relative strength of this type of interaction. Consequently, the first paragraph only scores marking point four and not marking point three.

The higher boiling point of heptane compared to hexane is explained by a correct comparison of the induced dipole-dipole interactions present in these compounds, so marking point two was achieved. However, the justification for the difference in intermolecular forces lacks precision. Candidates should be encouraged to focus on surface contact or surface interaction between molecules rather than referring to surface area alone.

Question 22(c)(i)

(c) Fuel additives are often used to improve the combustion of a fuel.

(i) Compound **N** is a fuel additive containing carbon, hydrogen and oxygen only.

Complete combustion of 1.71 g of compound **N** produces 2.97 g of CO_2 and 1.62 g of H_2O. The relative molecular mass of compound **N** is 76.0.

Calculate the molecular formula of **N** and suggest a possible structure for the compound.

compound N

[5]

The majority of candidates approached this problem by initially calculating the number of moles of CO_2 and H_2O produced. Many candidates were able to process these amounts to deduce the molecular formula for **N**, as shown in Exemplar 11. Alternate approaches were seen, but with much less frequency.

Exemplar 11

2.97g ÷ (12+32) = 0.0675 mol CO_2 ✓

1.62g ÷ (2+16) = 0.09 mol H_2O ✓

1.71g ÷ (76) = 0.0225 mol N

0.0675 ÷ 0.0225 = 3

0.09 ÷ 0.0225 = 4

N + XO_2 → 3CO_2 + 4H_2O

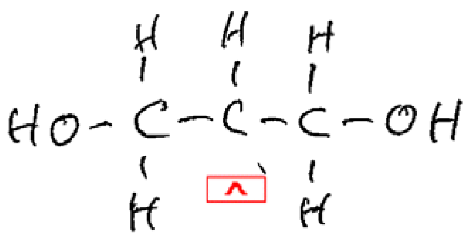
3C 8H

3(12)+8 = 44 76−44 = 32

$\frac{32}{16}$ = 2 O

N = $C_3H_8O_2$ ✓✓

HO−C−C−C−OH



compound N

[5]

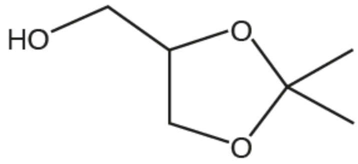
This response is logically presented with clear working demonstrating the candidate's approach. In the first part the candidate determines the amount, in moles, of carbon dioxide and water produced. This response uses the number of moles of **N** to deuce the molar ratio of CO_2 to H_2O. Other candidates obtained this by dividing the moles of carbon dioxide by the moles of water.

The candidate uses a balanced equation to deduce the molar ratio of C to H in **N**; this is an excellent strategy that is worth highlighting to future candidates. The working on the right hand side shows how the amount of O in compound **N** is determined.

It is a shame that the structure suggested has one H atom missing, as this omission has prevented full marks from being credited. Candidates are encouraged to check structures carefully to ensure that all atoms are drawn with the correct number of bonds.

Question 22(c)(ii)

(ii) Solketal has been investigated as a potential fuel additive.



solketal

Solketal is synthesised from propane-1,2,3-triol and a carbonyl compound.

Construct a balanced equation for this synthesis.
Show structures for the organic compounds in your equation.

[2]

Many candidates found this demanding question very difficult. Some were able to deduce that propanone was the carbonyl compound in the reaction. Only the most able recognised that water was a by-product of this reaction.

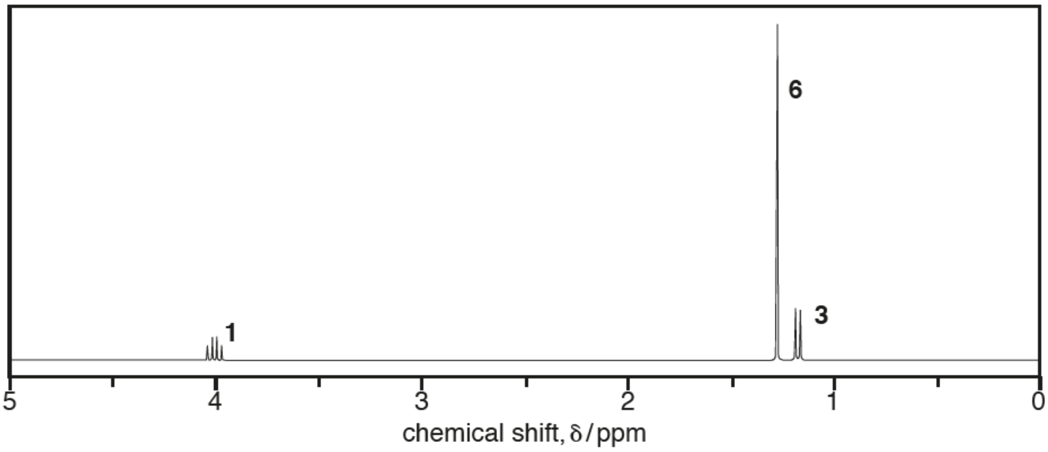
Question 22(d)*

(d)* A scientist is researching compounds that might be suitable as fuel additives.
One of the compounds gives the analytical results below.

Elemental analysis by mass:
C: 54.54%; H: 9.10%; O: 36.36%

Mass spectrum:
Molecular ion peak at *m*/*z* = 132.0

^1H NMR spectrum in D_2O



The numbers by the peaks are the relative peak areas.

When the spectrum is run without D_2O, there are **two** additional peaks with the same relative peak areas at 11.0 ppm and 3.6 ppm.

Use the information provided to suggest a structure for the compound.

Show **all** your reasoning. **[6]**

Most candidates were able to determine the empirical and molecular formula of the unknown compound. A number of excellent and clear response were seen, where the NMR data was explained, including interpretation of the additional peaks observed without D_2O. However many candidates were unable to suggest a structure that matched their NMR interpretation. Some candidates used the quartet, doublet and singlet to suggest a structure that would give rise to this splitting pattern, but which was not consistent with the chemical shifts, see Exemplar 12. Such responses received a level 2 mark (3-4). Stronger responses were able to use all the data to suggest a correct structure. The most common was $CH_3CH(OH)C(CH_3)_2COOH$ although other viable structures, including $CH_3CH(OH)COC(CH_3)_2OH$, were also seen. Examiners were impressed with the problem solving ability shown by candidates and a significant proportion of responses were credited six marks.

Exemplar 12

C	H	O
54.54	9.10	36.36
12	1	16
4.545	9.10	2.2725
2	4	1

empirical formula = C_2H_4O

Mr = 44

$\frac{132}{44} = 3$

molecular formula = $C_2H_4O \times 3 = C_6H_{12}O_3$

peak at 1.2ppm = HC – R. It's a doublet so adjacent carbon has 1 H.

Integral of 3 => CH_3

peak at 1.3ppm = HC – R. Singlet so adjacent C has no protons. Integral of 6 = $(CH_3)_2$

Peak at 4ppm indicative of HC – O.

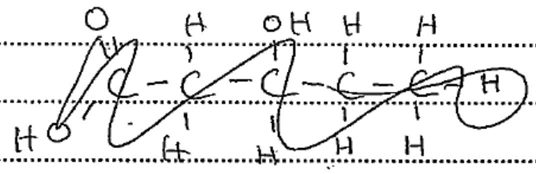
Quartet so adjacent C has 3 protons.

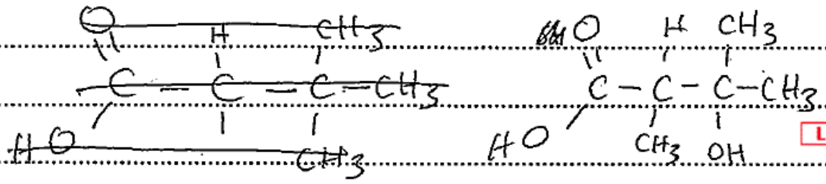
Integral of 1 = CH

Additional answer space if required.

D_2O at 11ppm = –COOH and 3.6ppm indicative of HC – O.

M.f. = $C_6H_{12}O_3$





L2

This logically presented Level 2 response uses the elemental analysis and mass spectrum data to determine the correct empirical and molecular formula of the unknown compound. The peaks in the NMR spectrum are analysed in detail, with a clear explanation of the splitting patterns. A comment about the two additional peaks observed when the spectrum is run without D_2O is also provided. The response concludes with a structure of $C_6H_{12}O_3$ that would show a singlet, doublet and quartet in its ^1H NMR spectrum. However, this structure is not consistent with the chemical shift values shown in the spectrum provided. In particular this structure would produce a quartet between 2.0–2.9 ppm, rather than at 4.0 as in the spectrum shown. Consequentially this response does not achieve Level 3. When tackling questions of this type candidates are advised to check that a proposed structure would produce peaks in the correct region of the NMR spectrum to ensure it is totally consistent with the data analysed.

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