Qualification Accredited

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A LEVEL

Examiners' report

CHEMISTRY A

H432

For first teaching in 2015

H432/02 Summer 2024 series

Version 1

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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. A selection of candidate answers is also provided. 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 and the mark scheme can be downloaded from OCR.

Paper 2 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 three of the A Level components and as such each also contains content from Modules 1 and 2; here questions are set in the context of organic chemistry. The paper consists of two sections: Section A is comprised of multiple-choice questions and Section B a mixture of short and long response questions.

Candidates who did well on this paper generally:	Candidates who did less well on this paper generally:
• accurately draw organic structures throughout, often making use of skeletal formula therefore avoiding issues with missing hydrogen atoms. • gave detailed organic mechanisms from across the whole specification, with correct dipoles and curly arrows clearly showing the movement of electron pairs – **Questions 19** and **21 (a) (ii)** • demonstrated a secure knowledge of synthetic pathways and reagents/conditions required, even for unfamiliar compounds – **Questions 17 (a) to (d)** and **18 (b)** • able to balance a range of different equations – **Questions 18 (a) (i), 20 (b) (ii)** and **21 (b) (ii)** • able to apply knowledge of practical organic synthesis techniques and evaluate them - **Questions 18 (a) (ii), 23 (a), 23 (b) (ii)** and **23 (d)** • decoded the questions correctly and gave responses that addressed them fully, using subject-specific language accurately • showed evidence of thorough practice of past paper questions.	• struggled with using skeletal formula. Often unable to correctly count the number of hydrogens and subsequently made errors in molar mass calculations – **Questions 22 (a)** and **23 (c)**. • drew structures that often had missing or additional hydrogens or carbons. • drew structures that often showed poor connectivity especially for -OH groups, e.g. **Question 20 (c).** • unable to clearly identify different functional groups or recall correct reagents/conditions required for different interconversions, sometimes including contradictory reagents alongside correct ones - **Questions 17 (a) to (d)** and **18 (b).** • able to attempt part of the analysis for **Question 24** but found drawing this together to give a feasible structure challenging.

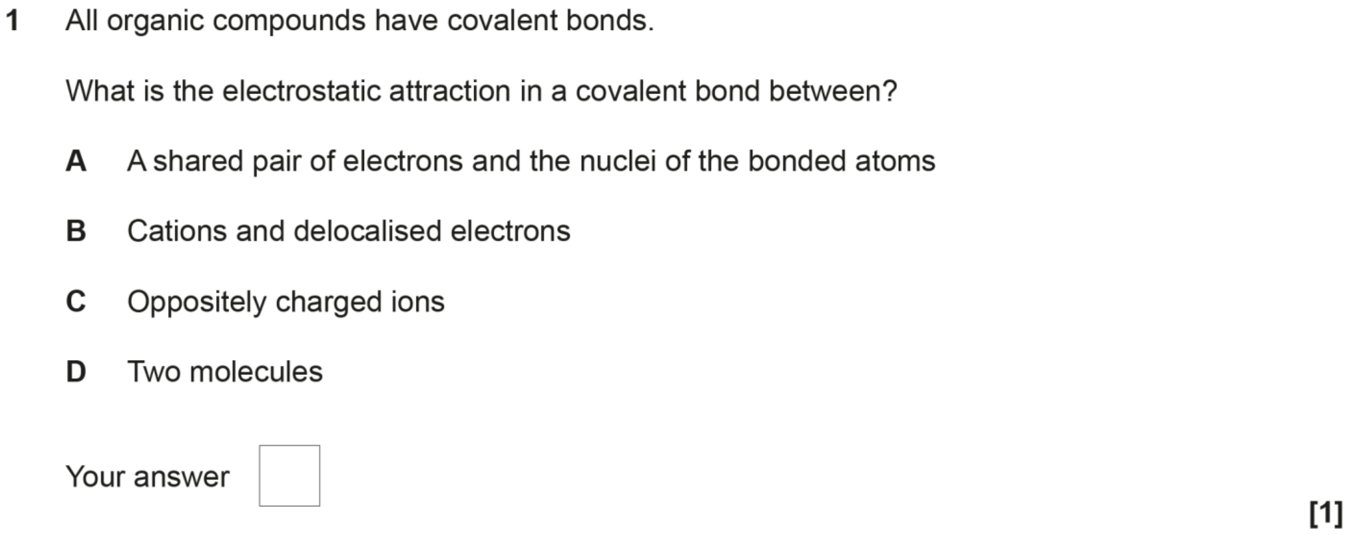
Section A overview

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.

OCR support

OCR has a wide range of digital multiple-choice quizzes available via Teach Cambridge. Instructions on how to download and use these quizzes can be found here.

Question 1



1 All organic compounds have covalent bonds.

What is the electrostatic attraction in a covalent bond between?

A A shared pair of electrons and the nuclei of the bonded atoms

B Cations and delocalised electrons

C Oppositely charged ions

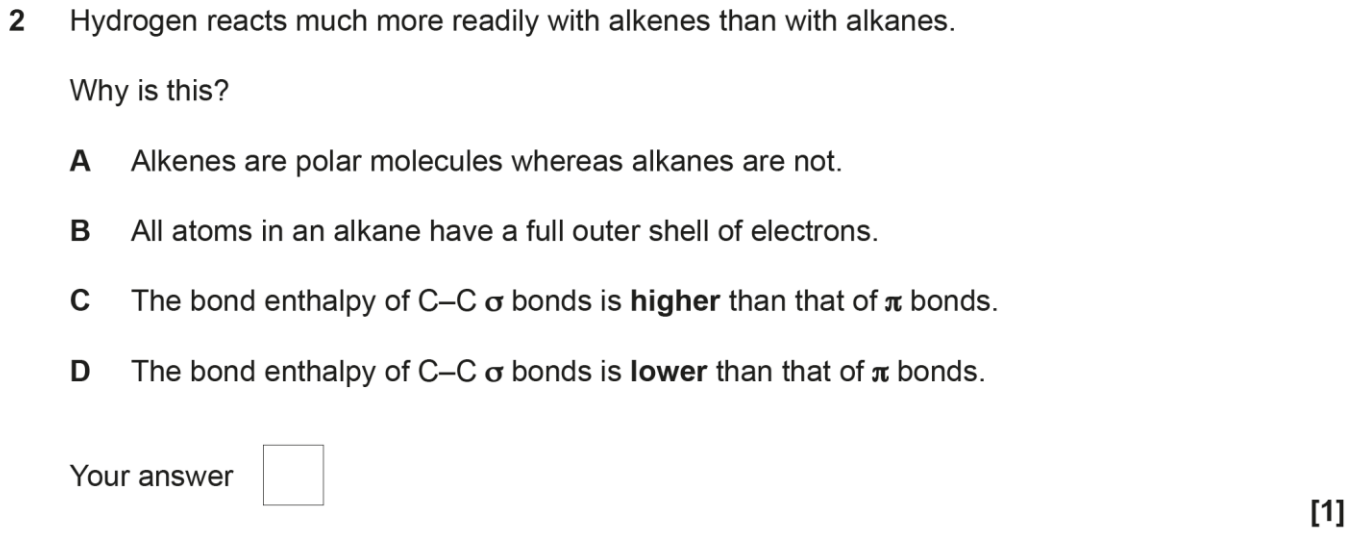
D Two molecules

Your answer ☐

[1]

Nearly all candidates were able to correctly recognise that covalent bonding is the electrostatic attraction between a shared pair of electrons and the nuclei of the bonded atoms. The most common incorrect response was C, confusing it with ionic bonding.

Question 2



2 Hydrogen reacts much more readily with alkenes than with alkanes.

Why is this?

A Alkenes are polar molecules whereas alkanes are not.

B All atoms in an alkane have a full outer shell of electrons.

C The bond enthalpy of C–C σ bonds is **higher** than that of π bonds.

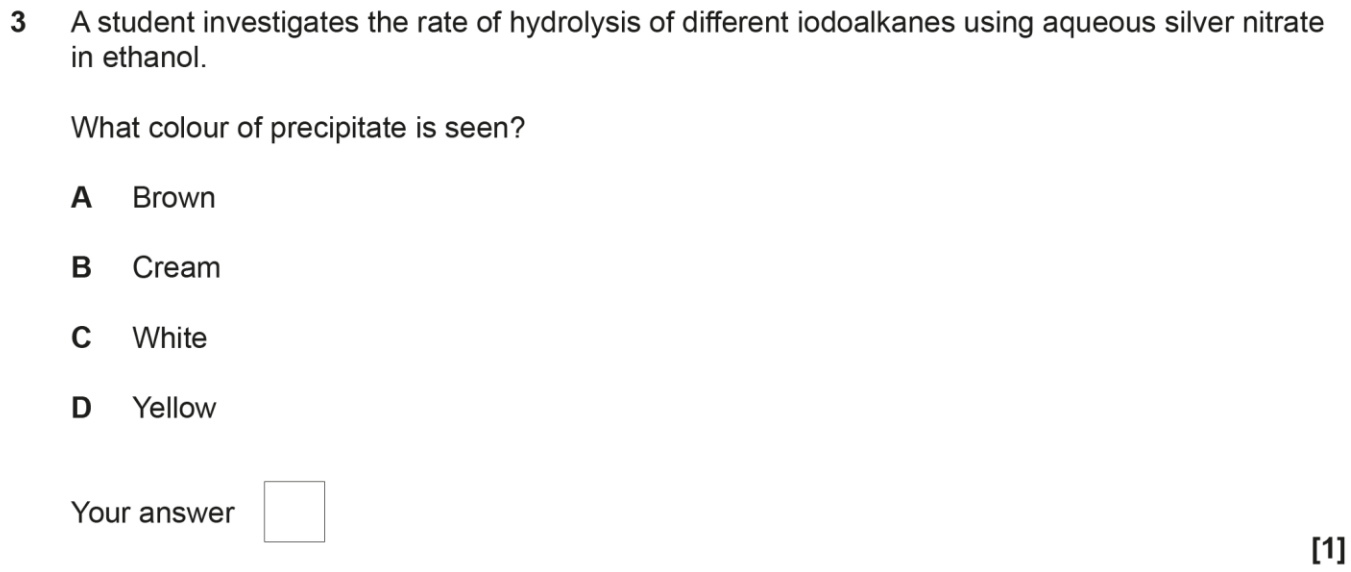
D The bond enthalpy of C–C σ bonds is **lower** than that of π bonds.

Your answer ☐

[1]

Approximately two thirds of candidates gave the correct answer C. The most common incorrect response seen was D, confusing the strength of the σ and π bonds, possibly as a C=C bond is stronger than C-C. Some gave D assuming alkenes are polar due to their reactivity and showing a misunderstanding of the term 'polar'.

Question 3



3 A student investigates the rate of hydrolysis of different iodoalkanes using aqueous silver nitrate in ethanol.

What colour of precipitate is seen?

A Brown

B Cream

C White

D Yellow

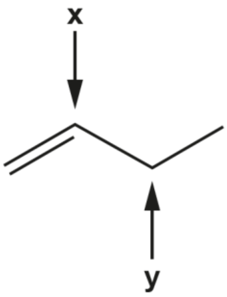
Your answer ☐

[1]

Most correctly identified the colour of the precipitate as yellow, D. The most common incorrect response was brown, A, possibly linking to the colour of iodine.

Question 4

4 The structure of but-1-ene is shown below.



Which row has the correct **shape** around carbon atoms labelled **x** and **y**?

	x	**y**
A	Tetrahedral	Pyramidal
B	Trigonal planar	Tetrahedral
C	Trigonal planar	Pyramidal
D	Pyramidal	Tetrahedral

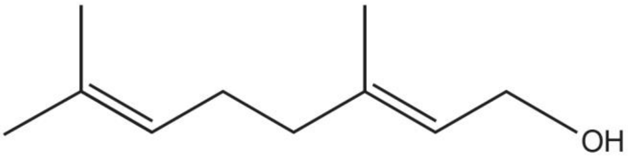
Your answer ☐

[1]

A large majority of candidates were able to correctly identify shape at x as being trigonal planar and y as being tetrahedral. The most common incorrect responses seen were for getting one of these incorrect i.e. D incorrect for x or C incorrect for y.

Question 5

5 Geraniol, shown below, is a component in many natural oils.



Geraniol

Which pair of reagents identifies both functional groups in geraniol?

A Acidified dichromate(VI) and 2,4-dinitrophenylhydrazine.

B Bromine water and 2,4-dinitrophenylhydrazine.

C Bromine water and acidified dichromate(VI).

D Tollens' reagent and aqueous silver nitrate in ethanol.

Your answer ☐

[1]

The majority of candidates were able to correctly identify the two functional groups and the correct corresponding test i.e. alkene using bromine water and primary alcohol using 2,4-dinitrophenylhydrazine. The most common incorrect response was B.

Question 6

6 4.30 g of the alcohol C_5H_9OH, (M_r = 86.0), is burned in oxygen.

$C_5H_9OH(l) + 7O_2(g) \rightarrow 5CO_2(g) + 5H_2O(l)$

Which volume of oxygen gas is needed, in dm^3, for this complete combustion of C_5H_9OH, at RTP?

A 1.2

B 2.4

C 5.8

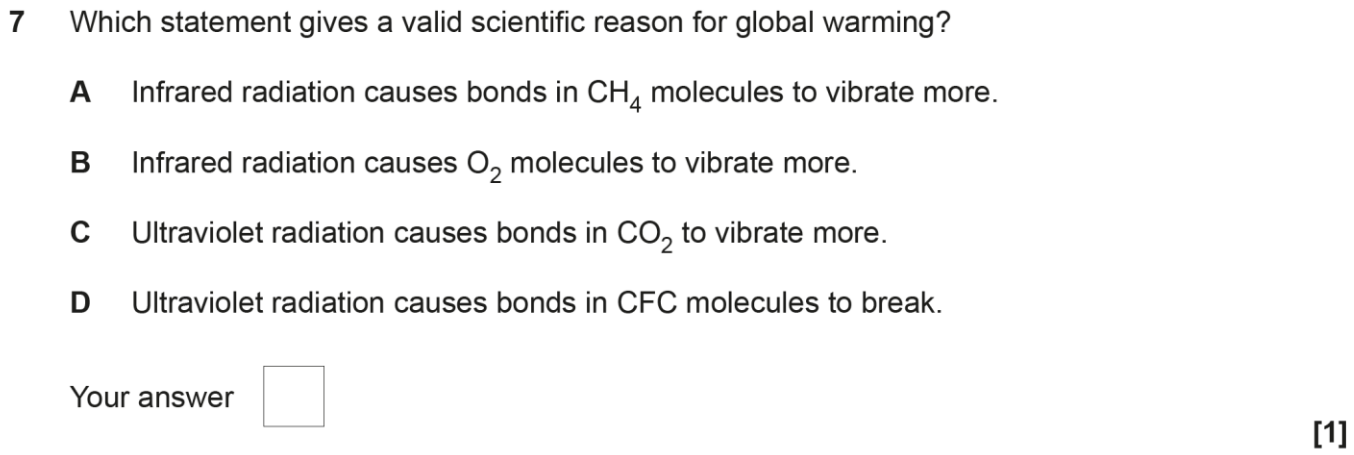
D 8.4

Your answer ☐

[1]

Most were able to correctly calculate the moles of alcohol using the mass and M_r provided and then multiply by 24 dm^3 mol^{-1} to give the correct answer D. All other distractors were seen as incorrect responses from calculations involving the incorrect molar ratio.

Question 7



7 Which statement gives a valid scientific reason for global warming?

A Infrared radiation causes bonds in CH_4 molecules to vibrate more.

B Infrared radiation causes O_2 molecules to vibrate more.

C Ultraviolet radiation causes bonds in CO_2 to vibrate more.

D Ultraviolet radiation causes bonds in CFC molecules to break.

Your answer ☐

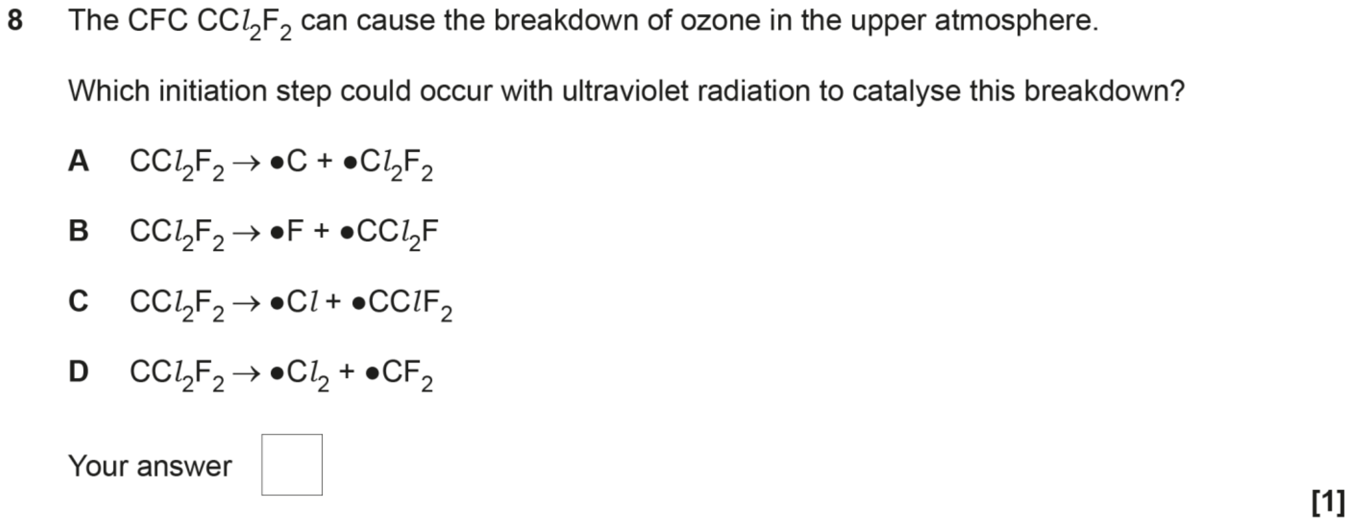
[1]

Most candidates gave the incorrect response D as their answer. Ultraviolet radiation does cause bonds in CFC molecules to break, and candidates may have been influenced by Question 8. However it is not a valid scientific reason for global warming. It suggests candidates may be confused about global warming verses the depletion of the ozone layer. This question was looking for candidates to link global warming to infrared active molecules i.e. C-H bond in methane. Just under a fifth of candidates gave the correct answer A.

Misconception

Many candidates believed there was a link between ultraviolet radiation and global warming. This is a topical issue so can be explored by looking at a range of resources including current news reports or exploring the United Nations resources.

Question 8



8 The CFC CCl_2F_2 can cause the breakdown of ozone in the upper atmosphere.

Which initiation step could occur with ultraviolet radiation to catalyse this breakdown?

A $CCl_2F_2 \rightarrow \bullet C + \bullet Cl_2F_2$

B $CCl_2F_2 \rightarrow \bullet F + \bullet CCl_2F$

C $CCl_2F_2 \rightarrow \bullet Cl + \bullet CClF_2$

D $CCl_2F_2 \rightarrow \bullet Cl_2 + \bullet CF_2$

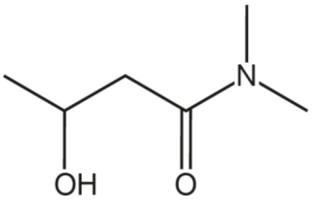
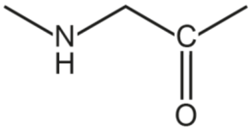
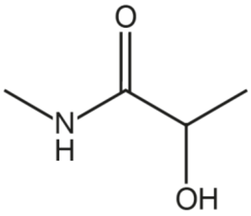
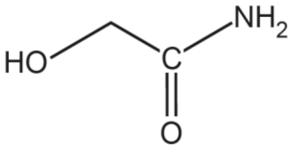
Your answer ☐

[1]

Most candidates correctly identified C as the correct initiation step forming a chlorine radical. A few gave B which forms an ∙F radical instead. It is always good to discuss the reason why the C-Cl bond will break but C-F won't in the presence of ultraviolet light.

Question 9

9 Which compound is a secondary amide?

A	
B	
C	
D	

Your answer ☐

[1]

More than three quarters of candidates were able to identify C as being the secondary amide, with many annotating each structure with the correct functional group. Some gave B, i.e. a secondary amine not amide, and a few gave A, i.e. tertiary amide not secondary.

Question 10

10 1.35 g of ethylamine gas, $CH_3CH_2NH_2$ (M_r = 45.0), is reacted with 20 cm^3 of 2.0 mol dm^{-3} hydrochloric acid forming a solution of ethylammonium chloride.

$$CH_3CH_2NH_2(g) + HCl(aq) \rightarrow CH_3CH_2NH_3^+(aq) + Cl^-(aq)$$

What is the concentration of ethylammonium chloride in mol dm^{-3}?

A 0.03

B 0.67

C 1.50

D 2.00

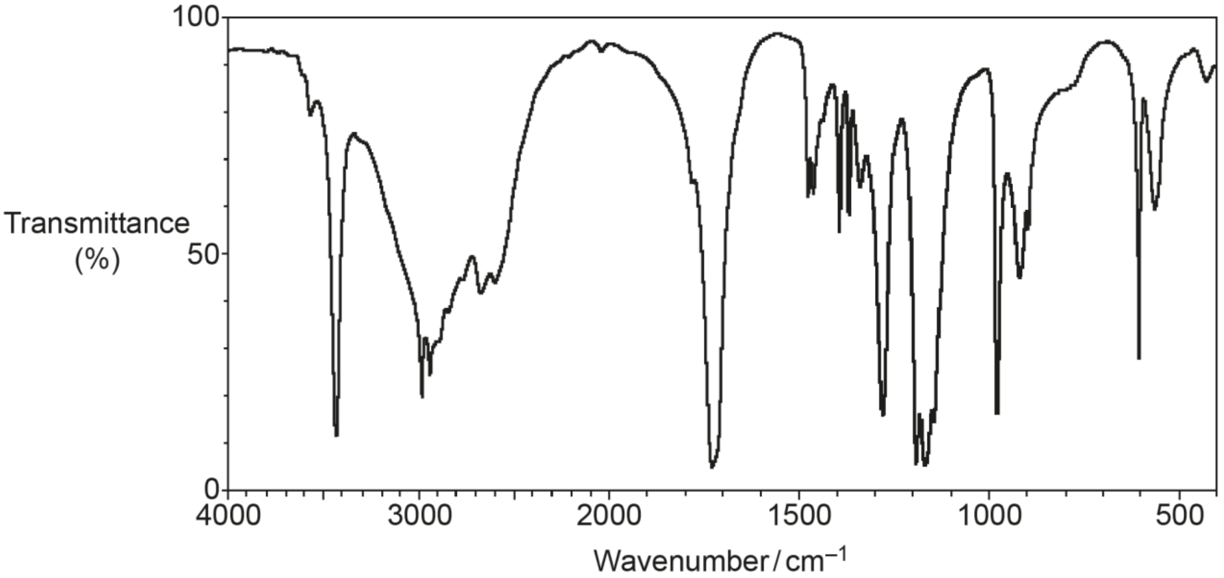
Your answer ☐

[1]

Around two thirds of candidates gave the correct answer C, 1.50 mol dm^{-3}. Those that showed working were more likely to have the correct answer. Some only found the moles of ethylamine from the mass and M_r give so gave 0.03, A. Some candidates struggled to figure out that HCl was in excess, so used 0.04 moles of HCl to give a concentration of 2.0 mol dm^{-3}, D.

Question 11

11 Which compound could have produced the IR spectrum shown below?



A $HOCH_2CHO$

B CH_3CH_2COOH

C $CH_3CH_2COOCH_3$

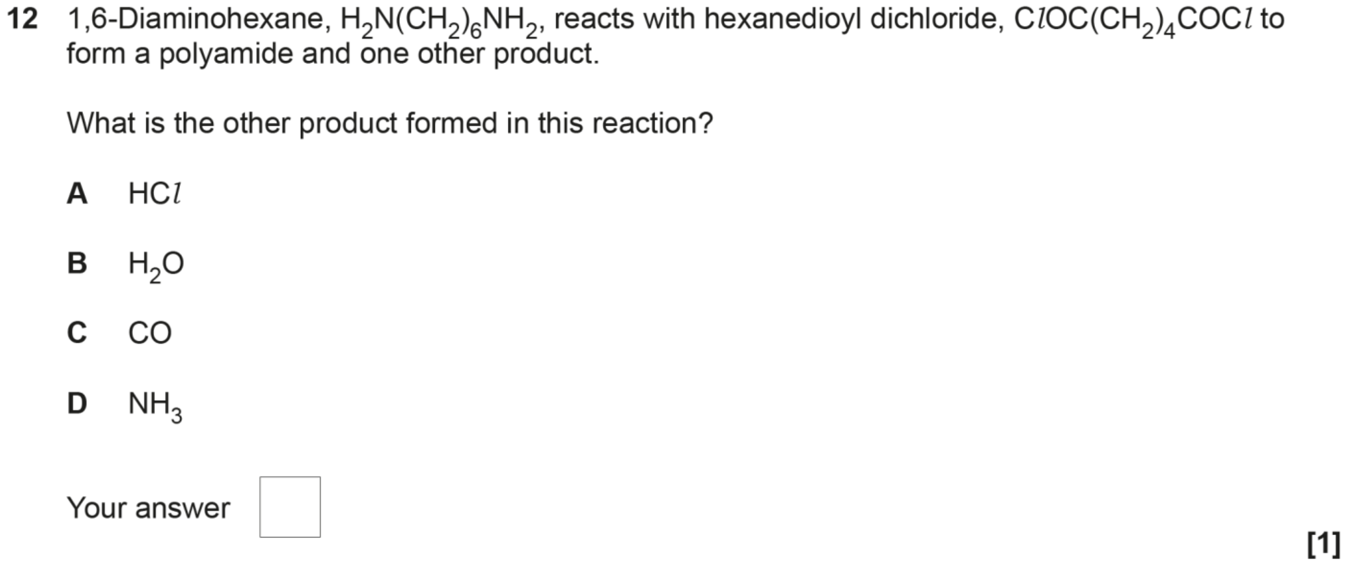
D $(CH_3)_2C(OH)COOH$

Your answer ☐

[1]

Many missed the separate O–H in alcohol and O–H in carboxylic acid peaks as it is unusual to see clearly defined peaks for both in an IR spectrum. Those who got D tended to annotate the spectrum, noting the sharp peak as O–H bond, as well as drawing out structures for each option. A was the most common incorrect response. It is good to remind candidates to look at all possible options before making a final decision.

Question 12



12 1,6-Diaminohexane, $H_2N(CH_2)_6NH_2$, reacts with hexanedioyl dichloride, $ClOC(CH_2)_4COCl$ to form a polyamide and one other product.

What is the other product formed in this reaction?

A HCl

B H_2O

C CO

D NH_3

Your answer ☐

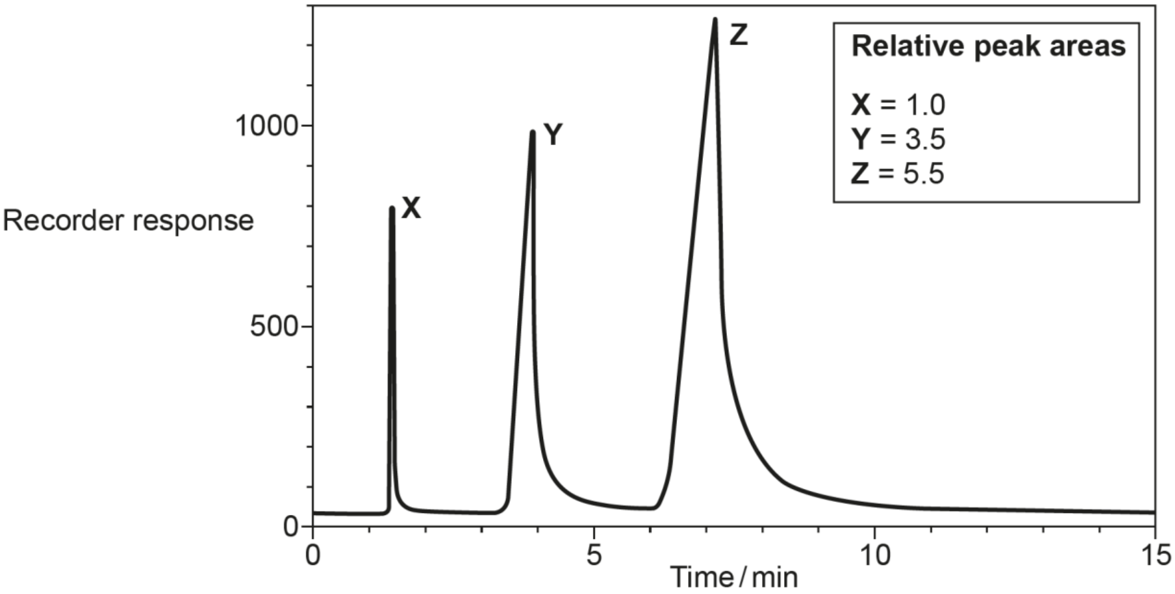
[1]

The vast majority of candidates gave the correct option A, HCl. The most common incorrect response was B i.e. H_2O.

Question 13

13 A sample containing a mixture of 3 components, **X**, **Y** and **Z**, is analysed using gas chromatography.

The gas chromatogram below is obtained.
The relative peak areas of **X**, **Y** and **Z** are included.



Which statement(s) is/are true?

1 The peak for component **X** shows the mass of one mole.

2 Component **Y** stays in the column for longer than component **X**.

3 Component **Z** consists of more than half of the sample.

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer ☐

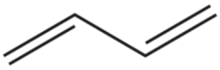
[1]

More than half of candidates were able to give C as the correct answer recognising that Statements 2 and 3 are correct. Some felt that Statement 1 was also correct giving A or B as the answer – relative peak area is not the same as the mass of 1 mole. Some were not able to relate the peak area to amount of compound present, so did not pick Statement 3 as one of the true statements, giving B or D.

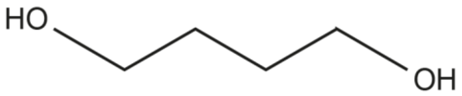
Question 14

14 The structures of 3 compounds, **1**, **2** and **3**, are shown below.

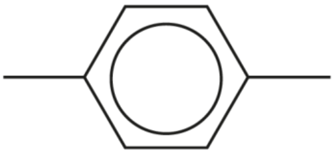
Which compound(s) would produce a carbon-13 NMR spectrum with 2 peaks?



1



2



3

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

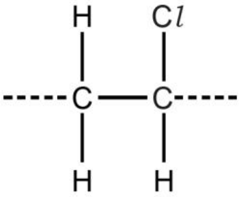
Your answer ☐

[1]

Around two-thirds picked the correct answer B, identifying Structures 1 and 2 as having 2 carbon environments. Most students labelled the carbon environments on the structures to help them. Candidates sometimes struggled to recognise the two different carbon environments within the benzene ring, in Structure 3, as well as the CH_3 group.

Question 15

15 Polymers, such as poly(chloroethene), shown below, are difficult to dispose of.



Poly(chloroethene)

Which statement(s) is/are true about poly(chloroethene)?

1 It is a photodegradable or biodegradable polymer.

2 When incinerated, it produces toxic waste products which need to be removed.

3 It can be recycled and processed for use as an organic feedstock.

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer ☐

[1]

On review of this question, during the standardisation process, it was agreed that aspects of this question were not part of the specification and consequently all candidates were given the mark. We do not expect candidates to have knowledge of specific examples of photodegradable polymers or indeed those that could be processed as feedstock.

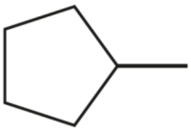
Section B overview

Section B includes a mixture of short answer and extended response questions, including two questions marked using a Level of Response mark scheme (19 and 23). This section of the paper is worth 85 marks.

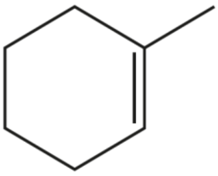
Question 16 (a)

16 This question is about hydrocarbons.

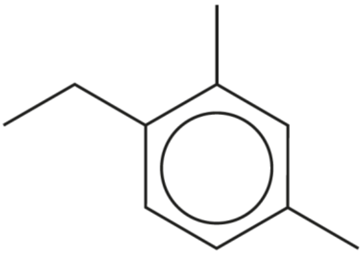
The structures of hydrocarbons **A–E** are shown below.



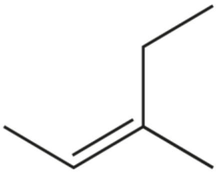
A



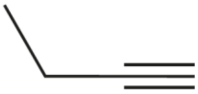
B



C



D



E

(a) Which hydrocarbons are unsaturated?

.... **[1]**

Over half the candidates found this question challenging an did not score the mark here. The most common error was to omit Structure C, but some also omitted Structure E. This suggested that many candidates may only apply the term 'unsaturated' to alkenes. It also highlights a potential lack of understanding of the delocalised ring in benzene and the relationship to the Kekulé structure.

Question 16 (b)

(b) Which hydrocarbons are alicyclic?

.... **[1]**

Most candidates were able to correctly identify the alicyclic compounds. Some candidates also included Structure C showing some confusion between terms alicyclic and aromatic. This was also noted in last year's paper on Question 13.

Misconception

A molecule is either aromatic, if it contains a benzene ring, or aliphatic. Aliphatic molecules which contain a ring can also be described as alicyclic. OCR have previously offered clarification for classification of organic compounds.

Question 16 (c)

(c) Which hydrocarbons have the general formula C_nH_{2n}?

.... **[1]**

This question was also challenging and just under half of candidates gave the correct response. Many wrote molecular formulae underneath each structure, but less successful responses often struggled to convert from the skeletal formulae correctly. Common errors included:

- just giving Structure D, and omitting Structure A
- including Structure E as they miscounted the number of hydrogens in the presence of a triple C-C bond
- including Structure B, on the basis that it had a double C-C bond
- some less successful responses just wrote "alkene" and did not apply their responses to the hydrocarbon structures given.

Question 16 (d)

(d) What is the systematic name of hydrocarbon **C**?

.... **[1]**

This question appeared to be equally challenging for candidates. Common errors included names without the lowest possible numbering. The methyl group was given on the top which could have influenced candidates to start counting from there – more practice is needed to help with naming simple aromatics. Other common errors included:1-ethyl-2,4-methylbenzene (missing di-) and 1-ethyl-2,3-dimethylbenzene (miss counting groups).

Question 16 (e)

(e) Explain why hydrocarbon **D** is a *Z*-stereoisomer.

....

....

....

.... **[2]**

Many candidates misunderstood the question instead explaining how a molecule shows stereoisomerism i.e. same structural arrangement but a different arrangement of atoms in space. Some gave details specific to alkenes i.e. restricted rotation around C=C and each carbon of C=C has 2 different groups attached. Just over a quarter of candidates did not score any marks here.

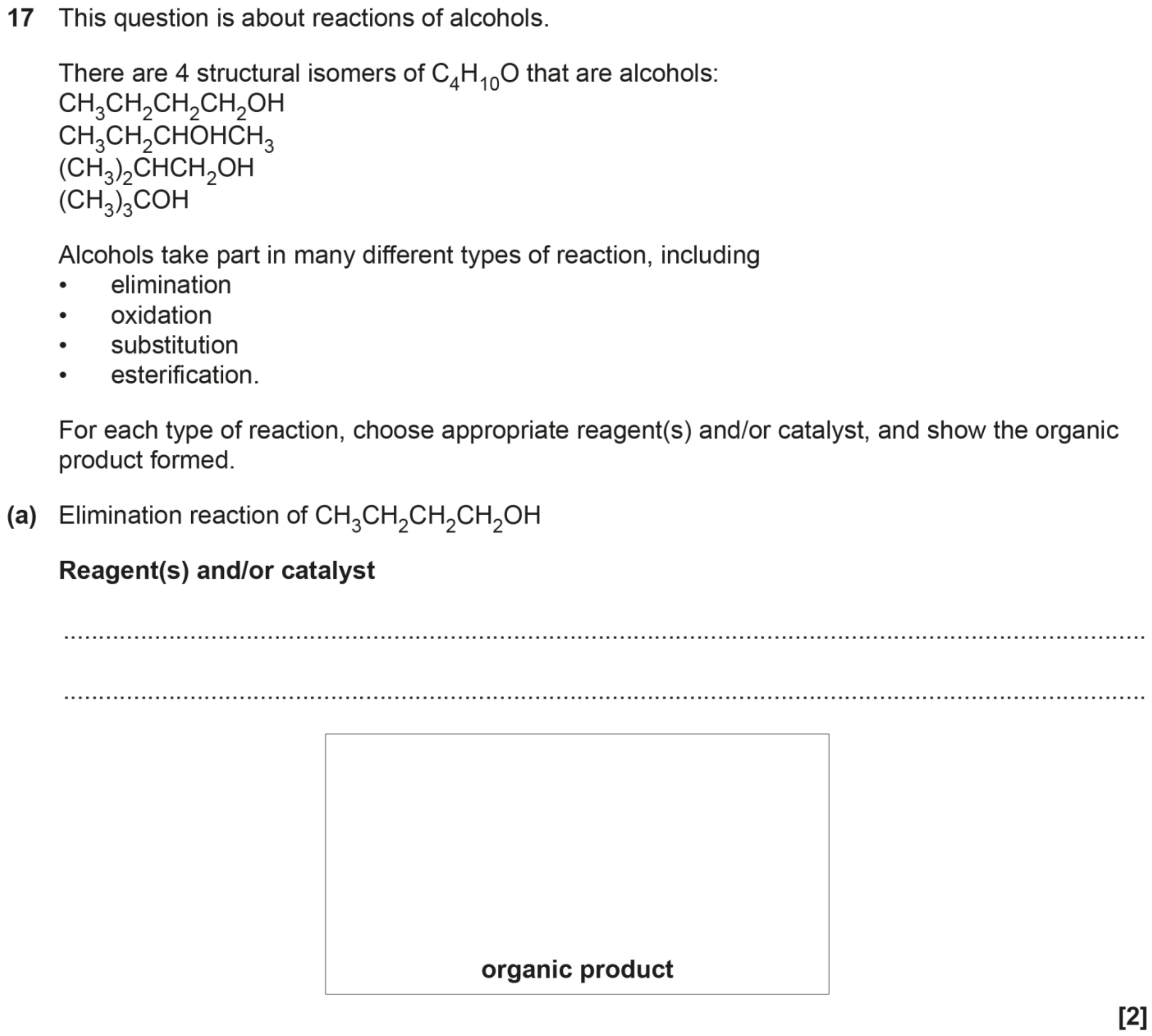
Many that did recognise that the 'priority groups' are on the same side' but did not then go on to score the second mark by identifying which groups they were referring. A significant number of candidates (including those gaining marks) described priority in terms of highest M_r or mass, suggesting that the Cahn-Ingold-Prelog priority rules of using atomic number are not well understood.

Many framed their answer in terms of the methyl groups, possibly showing confusion with cis-trans isomerism. Note that same 'plane' was not accepted as all the molecule is planar, so all groups are in the same plane. Teachers are recommended to encourage students to stick with conventional terminology i.e. Z: same side E: opposite sides.

OCR support

A useful PowerPoint presentation has been produced by OCR to help with teaching about CIP rules.

Question 17 (a)



17 This question is about reactions of alcohols.

There are 4 structural isomers of $C_4H_{10}O$ that are alcohols:
$CH_3CH_2CH_2CH_2OH$
$CH_3CH_2CHOHCH_3$
$(CH_3)_2CHCH_2OH$
$(CH_3)_3COH$

Alcohols take part in many different types of reaction, including
- elimination
- oxidation
- substitution
- esterification.

For each type of reaction, choose appropriate reagent(s) and/or catalyst, and show the organic product formed.

(a) Elimination reaction of $CH_3CH_2CH_2CH_2OH$

Reagent(s) and/or catalyst

....

....

organic product

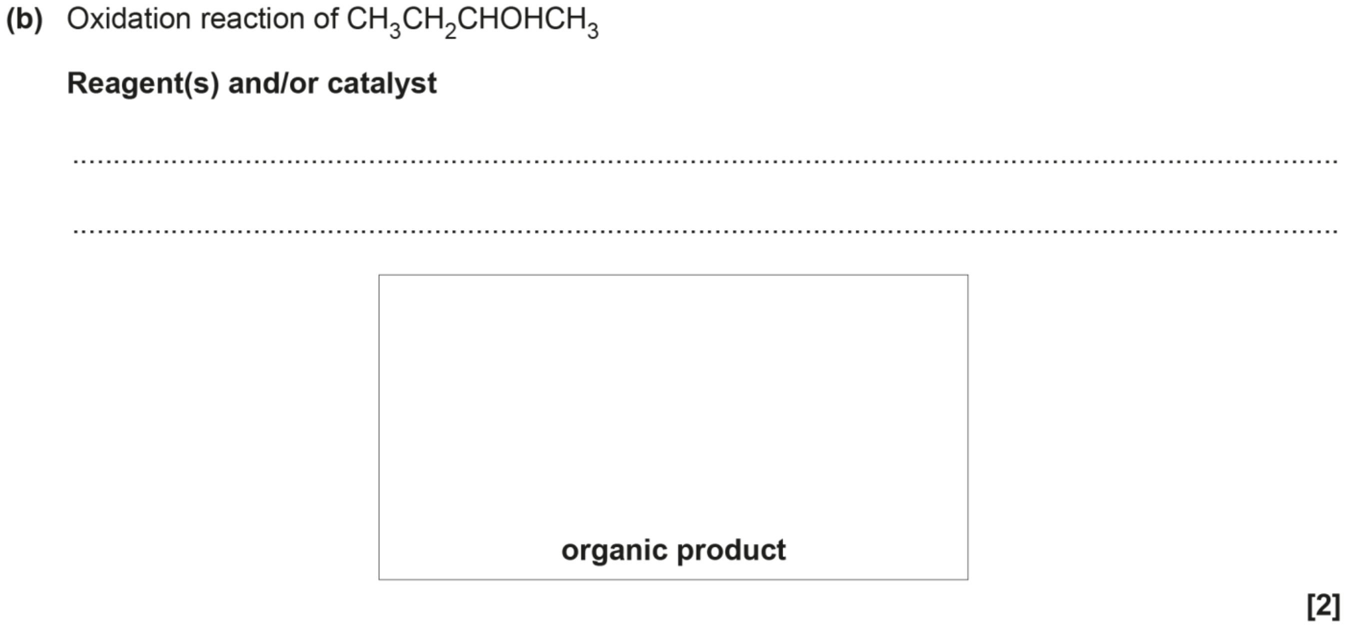
[2]

More than half scored both marks here. Common reasons for losing marks included adding water or steam as a reagent, using an incorrect chain length (5 carbons not 4 carbons), missing or adding hydrogens on the structure, e.g. $CH_3CH_2CH_2{=}CH_2$ or giving butane as the product.

OCR support

Useful synthetic route maps for the whole specification, both with and without reagents, can be found on Teach Cambridge.

Question 17 (b)



(b) Oxidation reaction of $CH_3CH_2CHOHCH_3$

Reagent(s) and/or catalyst

……………………………………………………………………………………

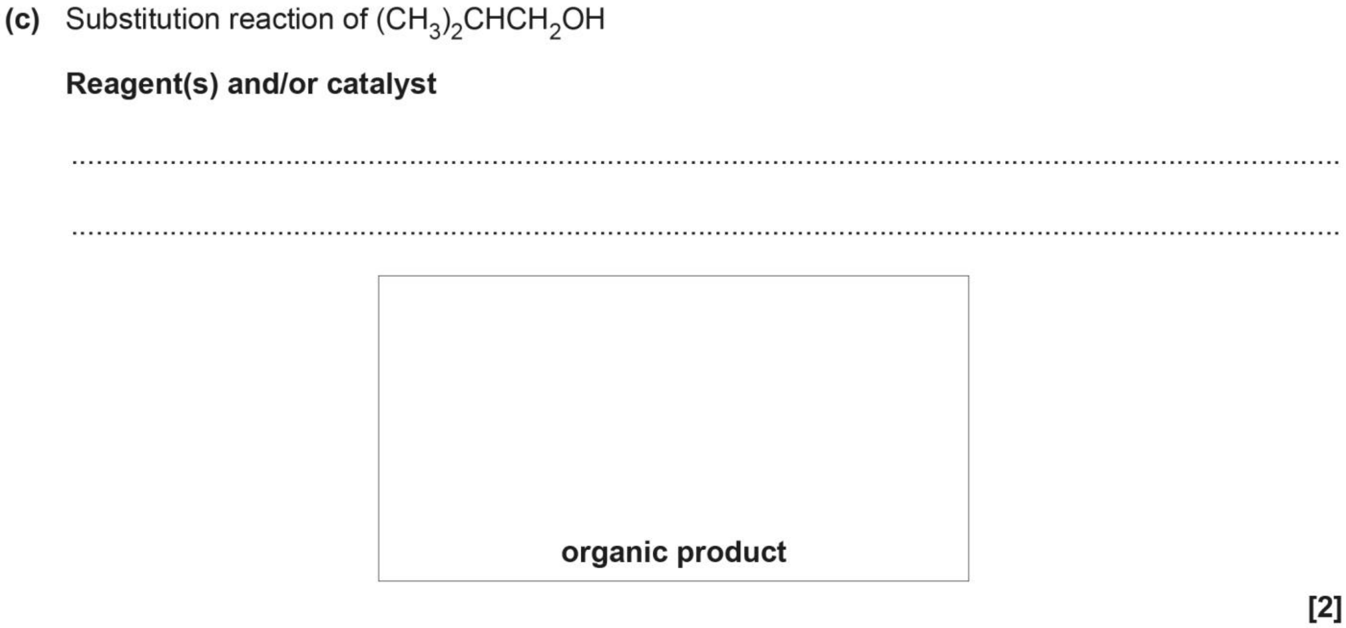
……………………………………………………………………………………

organic product

[2]

This was the most well-known out of the four reactions with more than three quarters of candidates getting both marks. The most common errors included omission of acid catalyst or adding an extra hydrogen on the carbonyl carbon of C=O. Candidates should be reminded to count the number of bonds around each carbon before moving on. A few attempted to oxidise this secondary alcohol to form a carboxylic acid.

Question 17 (c)



(c) Substitution reaction of $(CH_3)_2CHCH_2OH$

Reagent(s) and/or catalyst

……………………………………………………………………………………

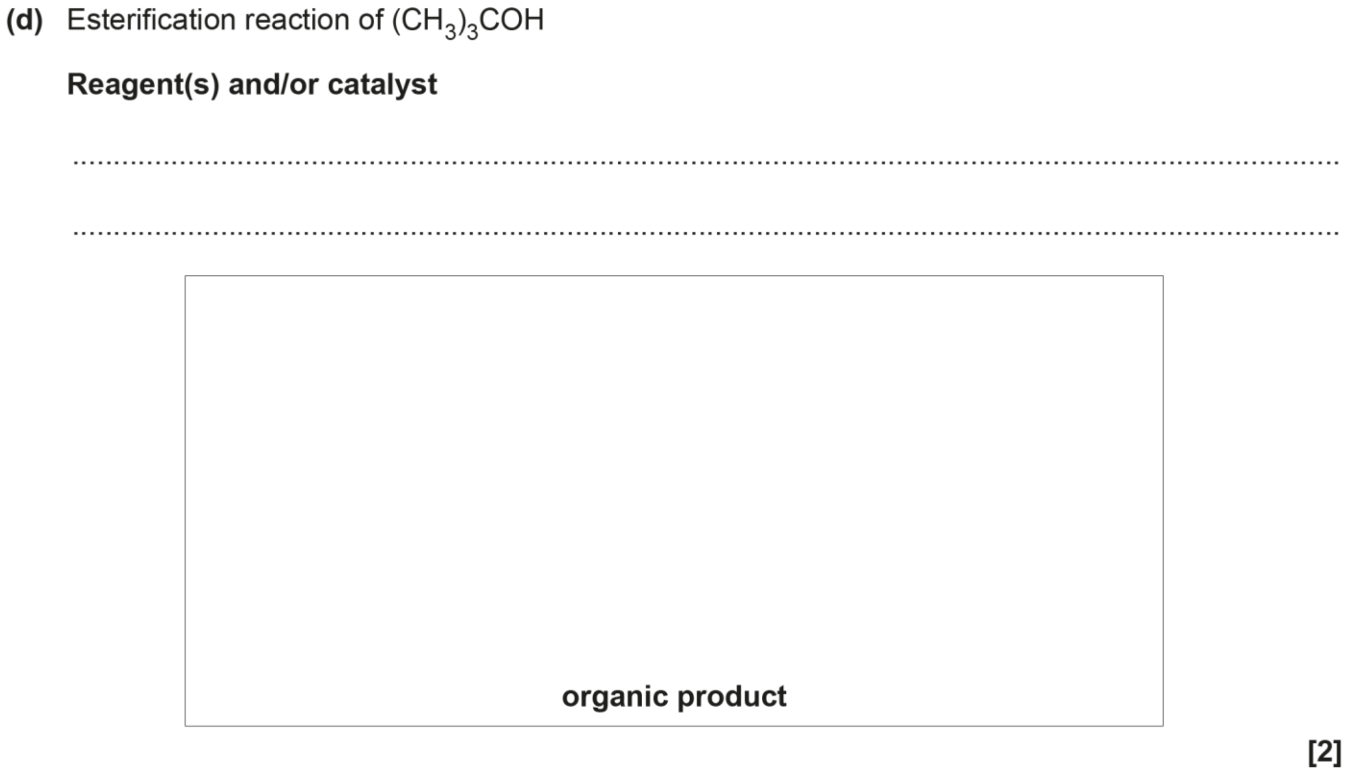
……………………………………………………………………………………

organic product

[2]

Generally well-answered with very few gaining no marks. Some lost marks for correctly giving sodium halide but forgetting the acid. Some gave the halogen rather than the halide. A few added an additional CH_2 to structure. Some attempted to substitute directly with cyanide to give a nitrile product, e.g. $(CH_3)_2CHCH_2CN$.

Question 17 (d)



(d) Esterification reaction of $(CH_3)_3COH$

Reagent(s) and/or catalyst

....

....

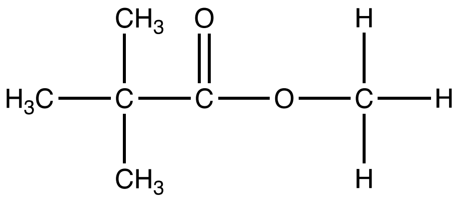
organic product

[2]

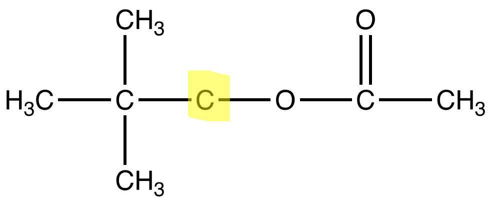
Once again, more than half scored both marks here but candidates found it more challenging than Question 17 (c). Many stated 'carboxylic acid' but did not identify the specific example to use to give their product. A common error was to omit the acid catalyst.

Some had the ester the wrong way round:

i.e.

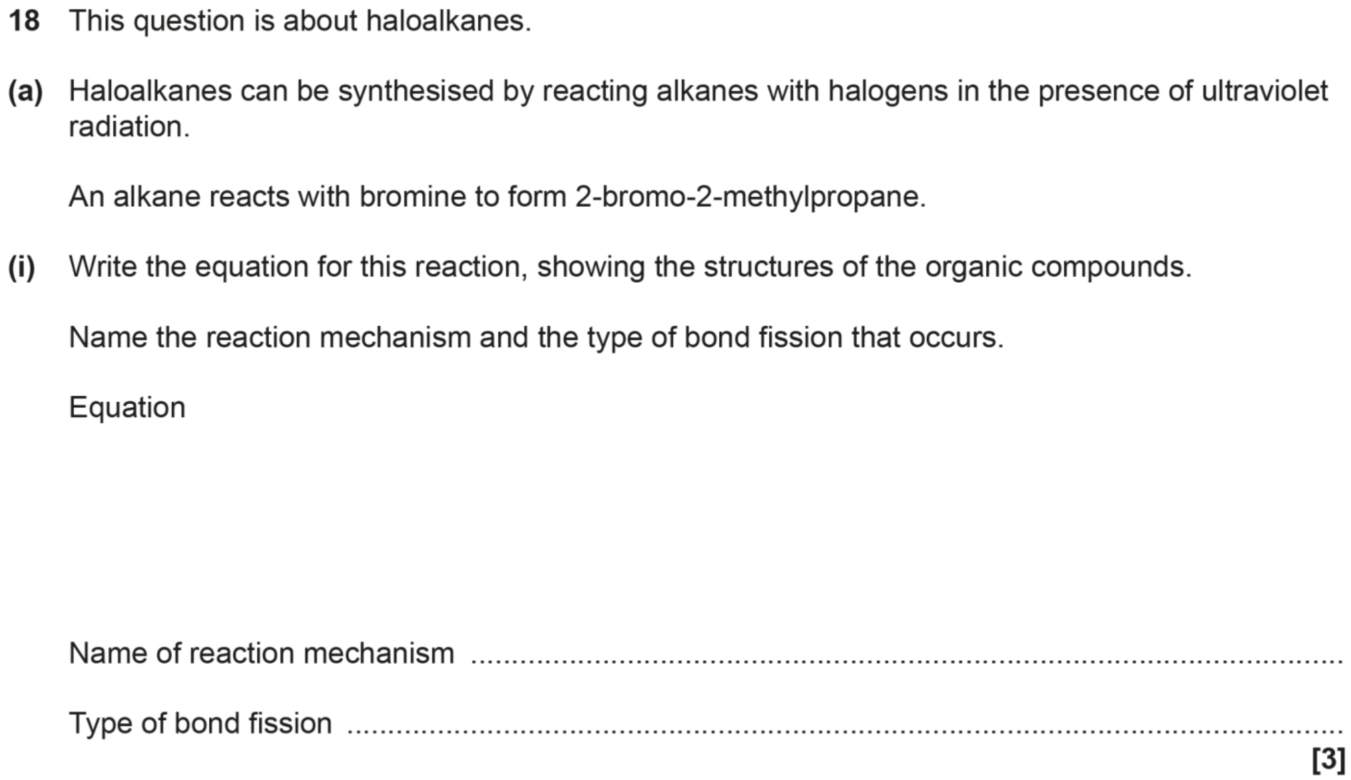


As seen with all parts of this question, some candidates struggled with the structural formula, resulting in some giving an additional carbon in their structure i.e.



A few candidates used an acyl chloride but it was rare to see an acid anhydride suggested.

Question 18 (a) (i)



18 This question is about haloalkanes.

(a) Haloalkanes can be synthesised by reacting alkanes with halogens in the presence of ultraviolet radiation.

An alkane reacts with bromine to form 2-bromo-2-methylpropane.

(i) Write the equation for this reaction, showing the structures of the organic compounds.

Name the reaction mechanism and the type of bond fission that occurs.

Equation

Name of reaction mechanism ....

Type of bond fission .... **[3]**

This question differentiated well, with a wide mix of responses given. Just over 40% scored all 3 marks.

Equation: The most common error was to omit HBr as a product. Some gave H_2 or just Br as a product. Some misunderstood the question and attempted to give either a partial mechanism, such as the propagation step or a complete mechanism, rather than the overall equation. Some gave molecular formula rather than structures as asked for. Those using structural or displayed formula were more prone to errors, such as missing hydrogens or incorrect chain length, than those that were confident using skeletal formula. Candidate should avoid giving equations in two formats, e.g. skeletal and structural because slips in one will lose marks.

Mechanism: Many candidates were able to identify the radical substitution mechanism, but a significant number did not score here. Most common incorrect responses were electrophilic or nucleophilic substitution but there were also those that thought it was an addition reaction.

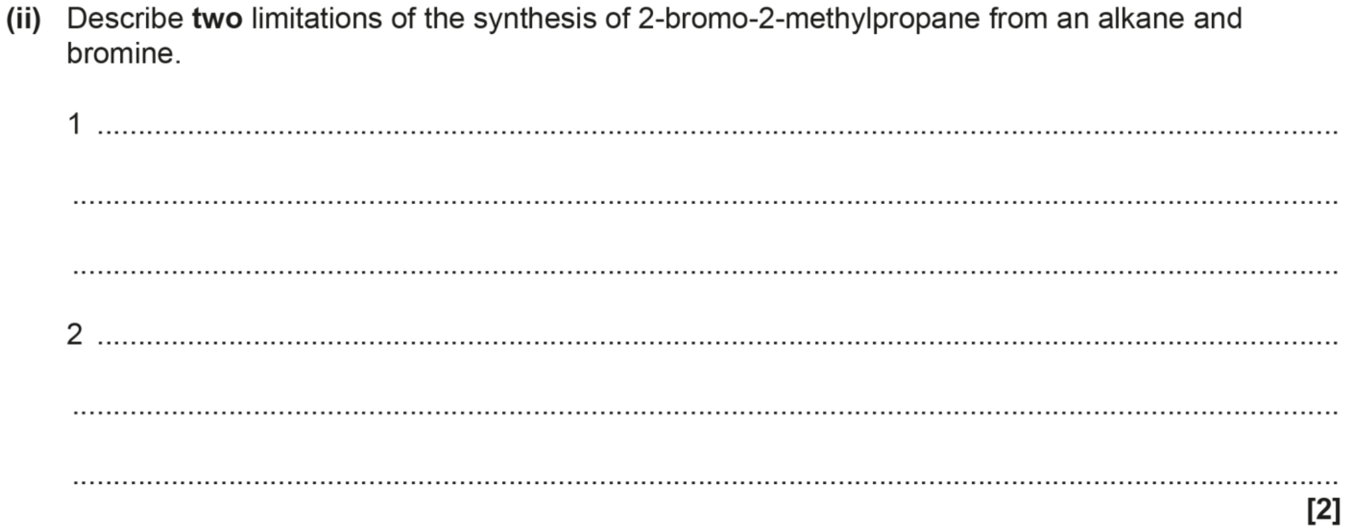
Bond fission: A significant number identified this as heterolytic, even if the recognised mechanism was radical. Some struggled with the spelling or even suggested homogeneous or heterogenous.

Misconception

Many struggled to identify the mechanism and then to link to bond fission. Try to introduce key terminology early on in teaching organic chemistry so that it can then revisited with each topic. Relevant mechanism terminology:

- substitution / addition / elimination
- electrophile / nucleophile / radical
- homolytic / heterolytic

Question 18 (a) (ii)



(ii) Describe **two** limitations of the synthesis of 2-bromo-2-methylpropane from an alkane and bromine.

1 ....

....

....

2 ....

....

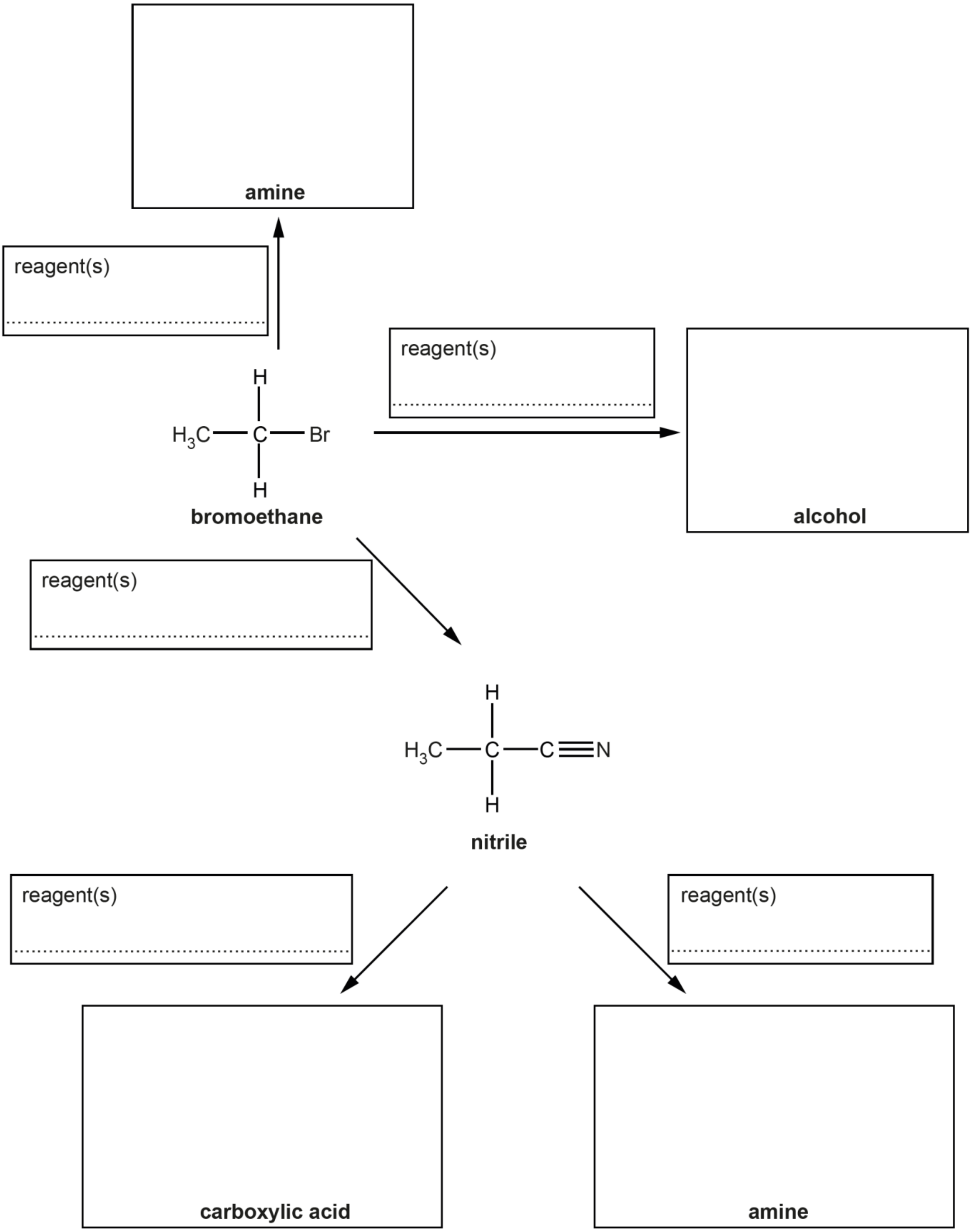
.... **[2]**

Most candidates scored one mark here, with approximately a third of candidates scoring both marks. Most recognised that further or multiple substitution would occur or that there would be a variety of termination products. The second mark was harder to achieve as although many responses suggested a different position, it was not always clearly conveyed that a hydrogen on a different carbon along the chain was being substituted, e.g. 'substitution can occur anywhere in the molecule'. The best responses gave examples to clarify their point, e.g. 'the bromine radical can be substituted anywhere along the hydrocarbon chain making other products such as 1-bromo-2-methylpropane'.

However, many gave vague answers such as poor yield or mixture of products, without explanation of how or what they might be. Some focused on HBr being formed as a product, suggesting it is toxic, or lowers the atom economy. Others highlighted ultraviolet radiation as being a limitation due to it being 'expensive', 'hard to achieve', 'lack of sources' or 'hazardous'. Others suggested that the reaction needed 'high temperatures'.

Question 18 (b)

(b) Complete the flowchart by filling in each box.



[9]

This question was well-answered with around a half of candidates scoring 8 or 9 marks. The full range of marks was seen across the whole cohort. The most common reasons for losing marks were for the addition of extra, contradictory reagents or for missing hydrogens from structures.

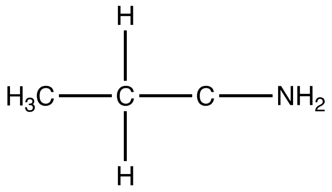
Bromoethane to amine: The amine structure was mostly correct with a few adding an extra hydrogen to the amine i.e. $CH_3CH_2NH_3$. Most gave the correct reagent as NH_3 but some omitted either ethanol or excess, so did not score here.

Bromoethane to alcohol: The alcohol structure was usually correct. However, many lost the reagent mark here for the addition of acid/ H^+/H_2SO_4 alongside the hydroxide.

Bromoethane to nitrile: A suitable cyanide was often used, but again many included an acid catalyst or aqueous conditions (aq) so lost the mark here. Ideally candidates would react in ethanol to prevent hydrolysis of the haloalkane.

Nitrile to carboxylic acid: Most gave the correct carboxylic acid structure, while occasionally ethanoic acid was given instead of propanoic acid. Most identified the need for acid as a reagent but some omitted water or (aq).

Nitrile to amine: H_2 was often seen as the reagent but sometimes without a catalyst. Many gave an incorrect structure here either with a missing C (i.e. ethylamine) or missing hydrogens on the first carbon i.e.



$$H_3C-\overset{H}{\underset{H}{C}}-C-NH_2$$

OCR support

A useful resource for teaching about organic synthetic routes including functional groups, reagents and two-step processes can be found in the Topic Exploration pack on Teach Cambridge.

Question 19*

19* Alkenes and carbonyl compounds take part in addition reactions.

Describe **one** addition reaction of an alkene and **one** addition reaction of a carbonyl compound. Include reagents and reaction mechanisms. **[6]**

A very good proportion of candidates scored all 6 marks, giving well-drawn mechanisms with some additional details such as mechanism names, functional group interconversions or other additional reaction information. Some attempted to 'describe' the mechanism using only words rather than drawing it out with a conventional curly arrow mechanism. Candidates may need more clarity on what 'describe' means in an organic chemistry context. Equally, a few gave just the mechanisms with no additional details, limiting themselves to Level 2.

Candidates were usually more confident with the addition to alkenes using an electrophilic addition mechanism. Some gave additional details about major and minor products, although not always relevant as for a symmetrical alkene. Some represented the addition of hydrogen or water to alkenes via an electrophilic addition mechanism. While not correct it showed an understanding of mechanisms and a correct addition reaction for alkenes, so credit was given. Some candidates included incorrect reagents for reactions, such as acid catalysts with addition of a hydrogen halide, or incorrect conditions, such as the requirement for ultraviolet light on addition of a halogen.

The addition to carbonyl compounds was not always as well-described. Some candidates struggled to identify carbonyl compounds, selecting carboxylic acids or their derivatives, with attempts at addition-elimination mechanism i.e. condensation reactions. Some gave incorrect reagents for carbonyls, including H_2 and HBr. However, some used off-specification reactions such as the addition of H_2O to form a geminal diol which was given but as the mechanism differs from the nucleophilic addition mechanism taught in this specification, full credit was rarely achieved. Some also considered oxidation of aldehyde or ketone to be an addition reaction.

Most who presented a correct mechanism for addition to a carbonyl used the reaction with cyanide rather than reduction with $NaBH_4$. Common errors included arrows coming from the N of CN^-, a lack of putting dipoles on carbonyl bonds, missing charges on O in intermediates or showing the wrong direction of arrows.

OCR support

The OCR Guide to Level of Response questions can be found on Teach Cambridge and can be used to help your students better understand this type of question.

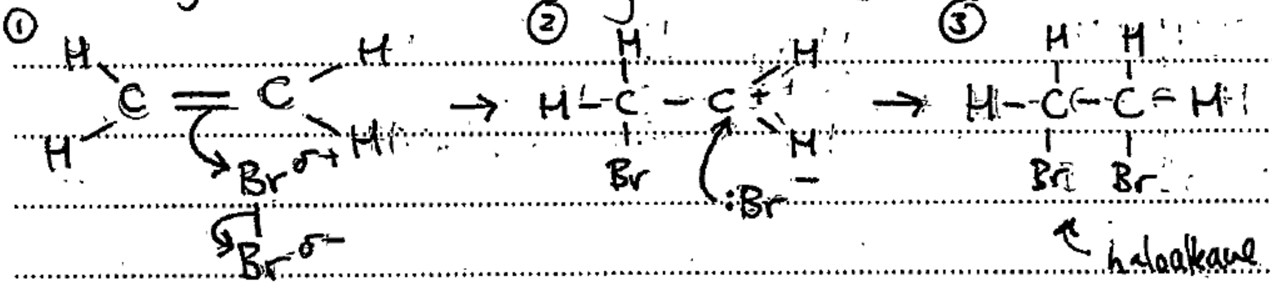
Exemplar 1

→ electrophilic addition of an alkene.

↳ C=C bond becomes a C-C bond.

↳ can form an alkane or haloalkane depending on reagents.

↳ e.g. ethene reacting with Br_2.

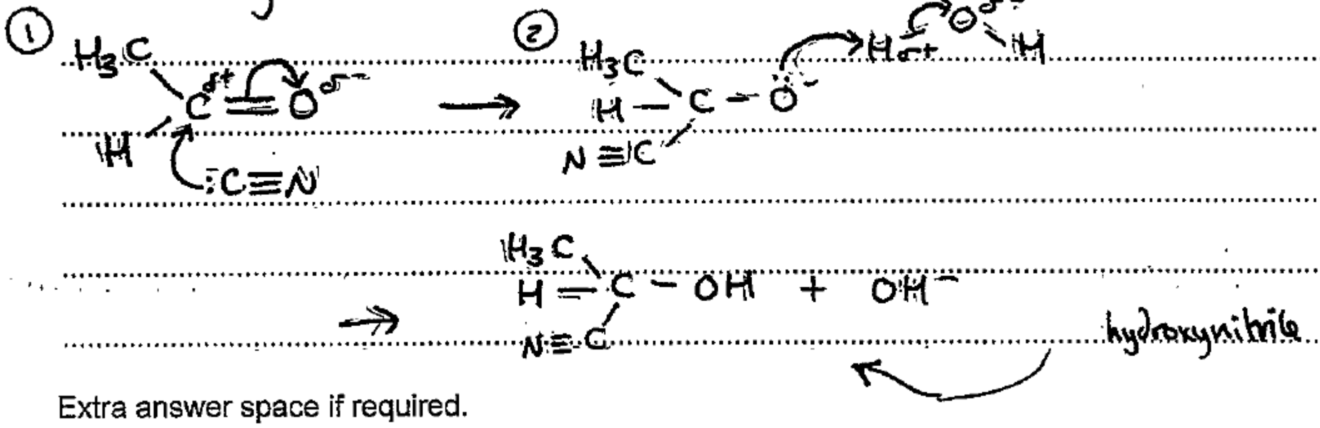


→ nucleophilic addition with carbonyls.

↳ used in carbon-carbon bond formation.

↳ usually in the production of nitriles/hydroxynitriles.

↳ e.g. ethanal and KCN (nitrile ions).

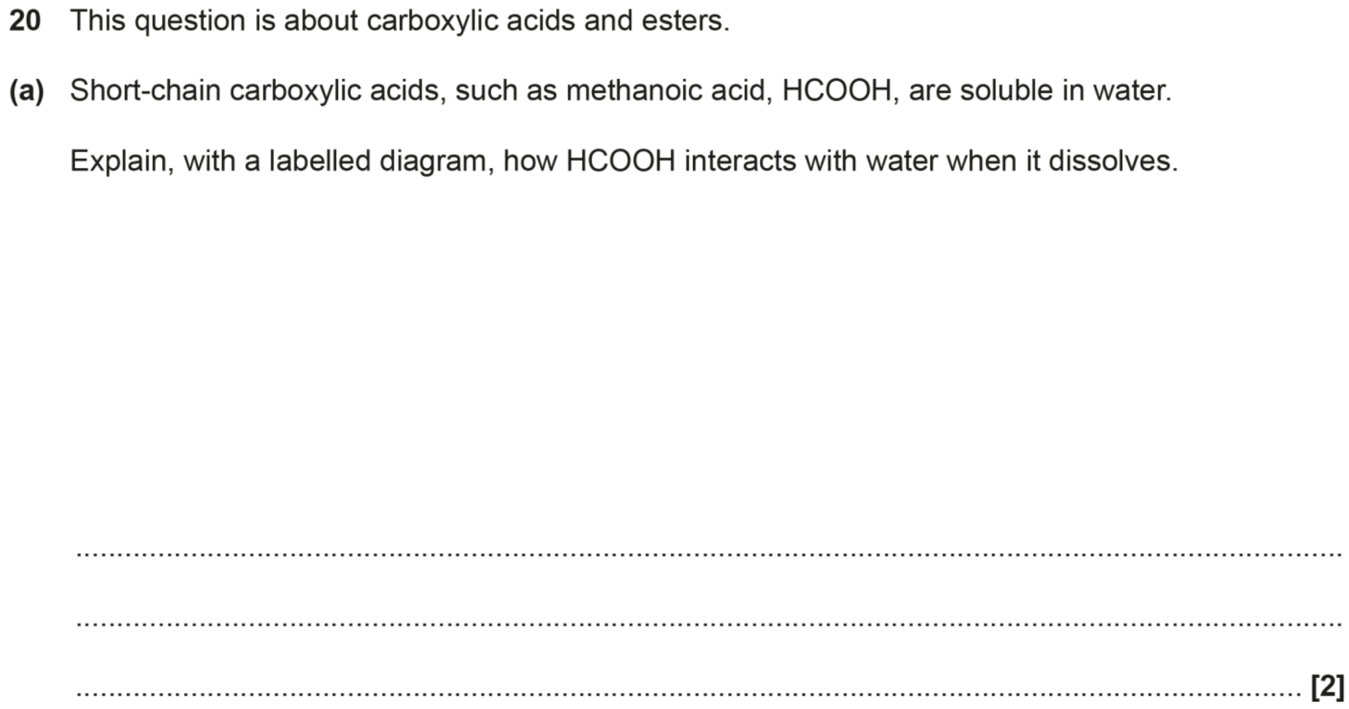


Extra answer space if required.

Level 3 – 6 marks

Two correct addition mechanisms have been shown, one for an alkene and one for a carbonyl compound. Additional details include the names of the mechanisms, names of the functional groups in the products, and the fact that a C-C bond is formed in the second mechanism. All curly arrows, charges and dipoles are correctly positioned so this response was also given the communication mark.

Question 20 (a)



20 This question is about carboxylic acids and esters.

(a) Short-chain carboxylic acids, such as methanoic acid, HCOOH, are soluble in water.

Explain, with a labelled diagram, how HCOOH interacts with water when it dissolves.

....

....

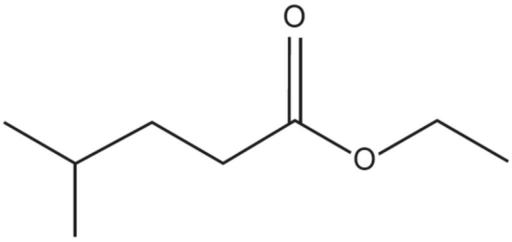
.... **[2]**

Most candidates were able to identify hydrogen bonding as being responsible for the solubility of methanoic acid. A minority of candidates did not gain any marks for this question. Some described the dissociation of methanoic acid into ions in water. Weaker candidates suggested this dissociation was sufficient to explain solubility. Some showed hydrogen bonds from H in the C-H bond in methanoic acid. Some drew hydrogen bonds from H to H or O to O.

Most scored the first mark but lost the second mark usually for missing dipoles and/or lone pairs. Candidates often overcomplicated diagrams with multiple hydrogen bonds shown, increasing the likelihood of losing a mark for errors.

Question 20 (b) (i)

(b) Ester **F** has the structure shown below.



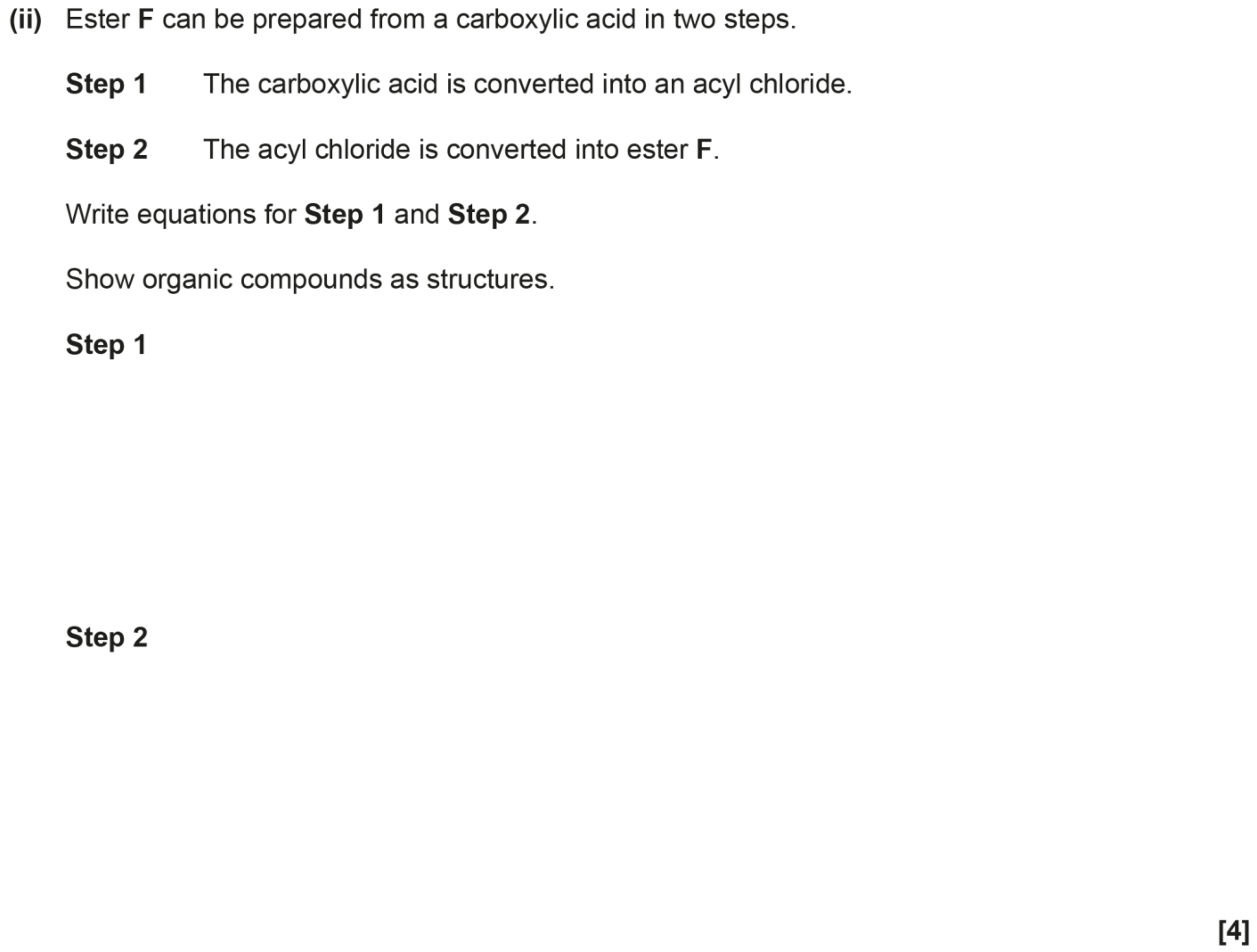
Ester F

(i) What is the systematic name for this ester?

.... **[1]**

Candidates found this difficult, with less than half gaining the mark. The most common error was incorrectly numbering the methyl group due to counting from the wrong end, giving ethyl-2-methylpentanoate.

Question 20 (b) (ii)



(ii) Ester **F** can be prepared from a carboxylic acid in two steps.

Step 1 The carboxylic acid is converted into an acyl chloride.

Step 2 The acyl chloride is converted into ester **F**.

Write equations for **Step 1** and **Step 2**.

Show organic compounds as structures.

Step 1

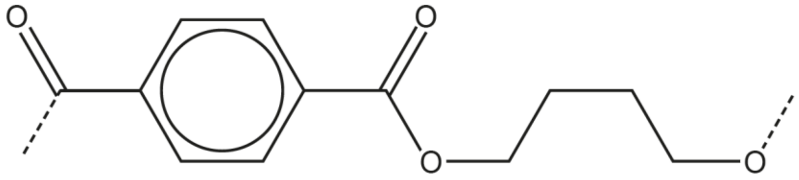
Step 2

[4]

This question differentiated between candidates well with the full range of marks seen. Some couldn't identify the correct reagent to use to form an acyl chloride i.e. $SOCl_2$, so lost 2 marks for the first step. Use of HCl as an alternative was common. A significant number used $SOCl_2$ but struggled to balance the equation. Many made errors with structures used, for example missing the CH_3 side chain, adding CH_3 to 3-position instead 4, inserting an additional CH_2 group or using a much easier structure, e.g. ethanoic acid. None of these structures were given marks as they would not form Ester F. Some used R- instead to simplify, for which credit was given, but only if it was clear what structure R represented. Another common error was to include an additional O in the acyl chloride group i.e. $COOCl$ not $COCl$. The most common error made in Step 2 was to omit the formation of HCl or to use H_2O instead. A few lost the final mark for a connectivity error on ethanol i.e. $OHCH_2CH_3$.

Question 20 (c)

(c) The repeat unit of a polyester is shown below.



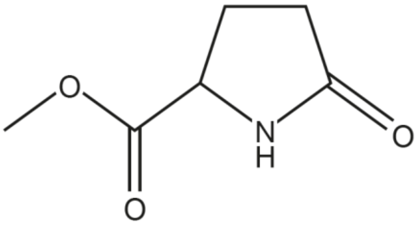
Draw the structures of monomers required to form this polyester.

[2]

The majority scored both marks here. A few drew the diacyl dichloride, but these were in the minority. A small minority only lost one mark, usually for incorrect connectivity on -OH groups. Some other errors seen included missing a carbon from alcohol, missing hydrogens on carbon if not drawn skeletally, carboxylic acid groups added directly on to the benzene ring with a pentavalent carbon atom or omitting the circle in the benzene ring.

Question 20 (d)

(d) The compound below contains an ester and an amide group.



Draw the structures of the organic products formed by the complete **alkaline** hydrolysis of this compound using NaOH(aq).

[4]

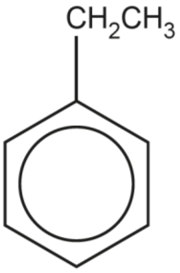
Just over a quarter of candidates were able to gain all 4 marks. The successful candidates clearly identified where the ester and amide would be hydrolysed on the structure provided, helping them draw out the correct products. This question differentiated well. Most were able to gain some credit for hydrolysing the ester to give methanol and a carboxylate or carboxylic acid, leaving the amide bond and ring intact. However, some lost the first mark for giving the methoxide ion, assuming that the alkaline conditions are capable of deprotonating the alcohol group.

Lower attaining candidates often broke other C-C bonds in the ring forming a range of products. A few displayed the structure as $C=O^-Na^+$ and some also protonated the amine group either with the ring intact or broken.

Question 21 (a) (i)

21 This question is about aromatic compounds.

(a) Ethylbenzene, $C_6H_5CH_2CH_3$, can be prepared by reacting benzene with chloroethane, CH_3CH_2Cl, in the presence of $AlCl_3$. The $AlCl_3$ acts as a halogen carrier.



Ethylbenzene

In the mechanism, chloroethane reacts with the halogen carrier to form a carbocation, which acts as the electrophile.

(i) What is meant by the term **electrophile**?

....

.... **[1]**

Most candidates were able to give the correct definition here. A common error was omission of 'pair' of electrons. Many also described that electrophiles are 'species attracted to areas of high electron density' or words to that effect, either alongside the accepted definition gaining credit or as the sole definition not gaining a mark.

Question 21 (a) (ii)

(ii) Outline the mechanism for this reaction, including the role of $AlCl_3$ as a halogen carrier.

[5]

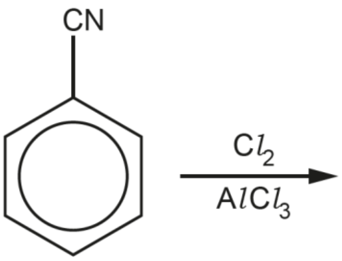
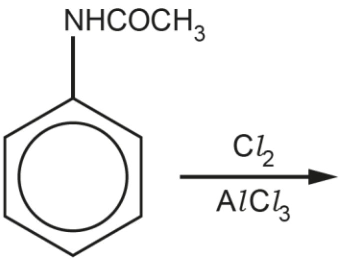
Most candidates were well prepared for this question, with over half of candidates gaining all 5 marks. A significant number of candidates showed halogenation, generating Cl^+ as an electrophile, instead of alkylation. Others attempted to substitute the ethylbenzene ring rather than benzene. Further common errors included incorrect connectivity in the ethyl group on the intermediate, curly arrows coming from hydrogen atoms rather than C–H bond to reform the π-ring and omission of an H^+ ion at the end of mechanism.

Question 21 (b) (i)

(b) The table shows directing effects for different groups in the electrophilic substitution of aromatic compounds.

Directing effect	**2- and 4- directing**	**3-directing**
Group	–OH	$-NO_2$
	$-NH_2$	$-COCH_3$
	$-NHCOCH_3$	–CN

(i) Draw all organic products formed from monosubstitution reactions of the substituted benzene compounds shown below.

Reaction	**Monosubstituted Product(s)**
	
	

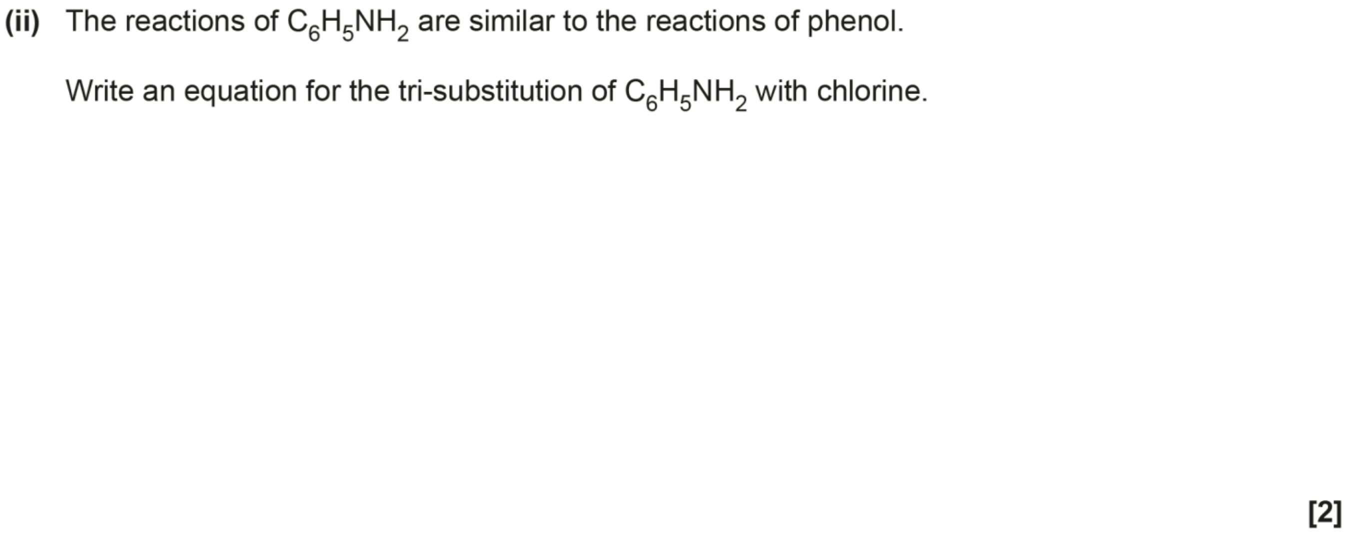
[3]

Most candidates were able to correctly recognise the correct direction for substitution, with over half gaining all 3 marks. Marks were most often lost for giving multiple substitution products despite being asked for the monosubstituted products. Many unnecessarily drew the same structures but with different orientations i.e. substituting on carbon-3 of a ring is the same as substituting on carbon-5.

Misconception

Ensure students understand the term 'monosubstituted' and practise naming compounds to give the lowest possible numbering. This will also help them to recognise the equivalent structures.

Question 21 (b) (ii)



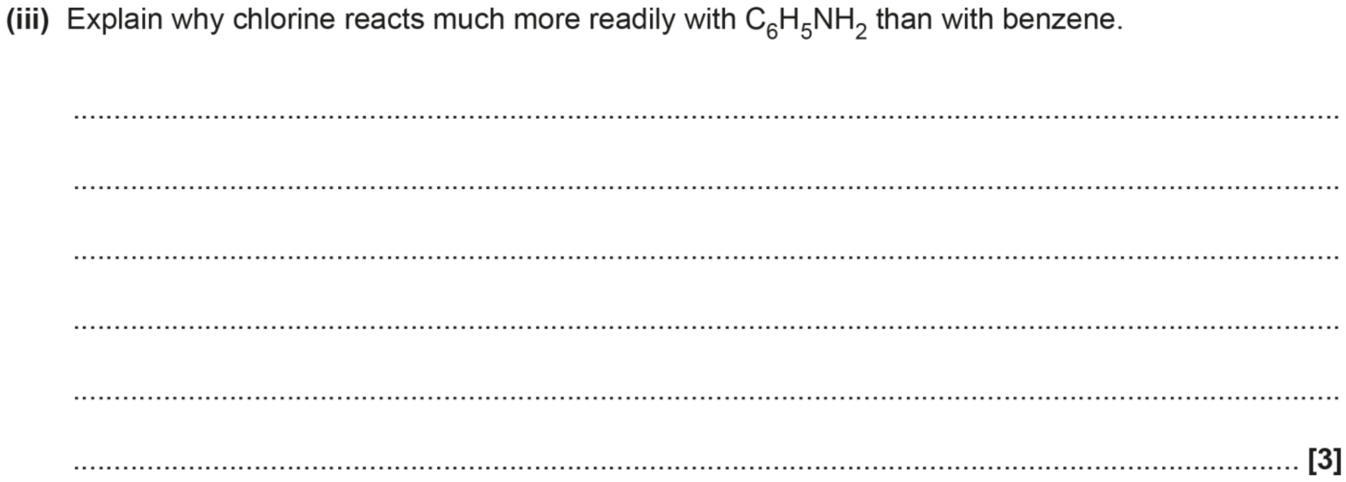
(ii) The reactions of $C_6H_5NH_2$ are similar to the reactions of phenol.

Write an equation for the tri-substitution of $C_6H_5NH_2$ with chlorine.

[2]

The majority of candidates were able to give a suitable tri-substituted product, with many showing the structure although not asked for in the question. Many were also able to give a correct balanced equation too. Some were unsure how phenylamine would react showing the reaction with the amine group or only giving a monosubstituted product. Some didn't form HCl as another product, reacting phenyl amine with 1.5 Cl_2 instead. Others gave hydrogen as the product.

Question 21 (b) (iii)

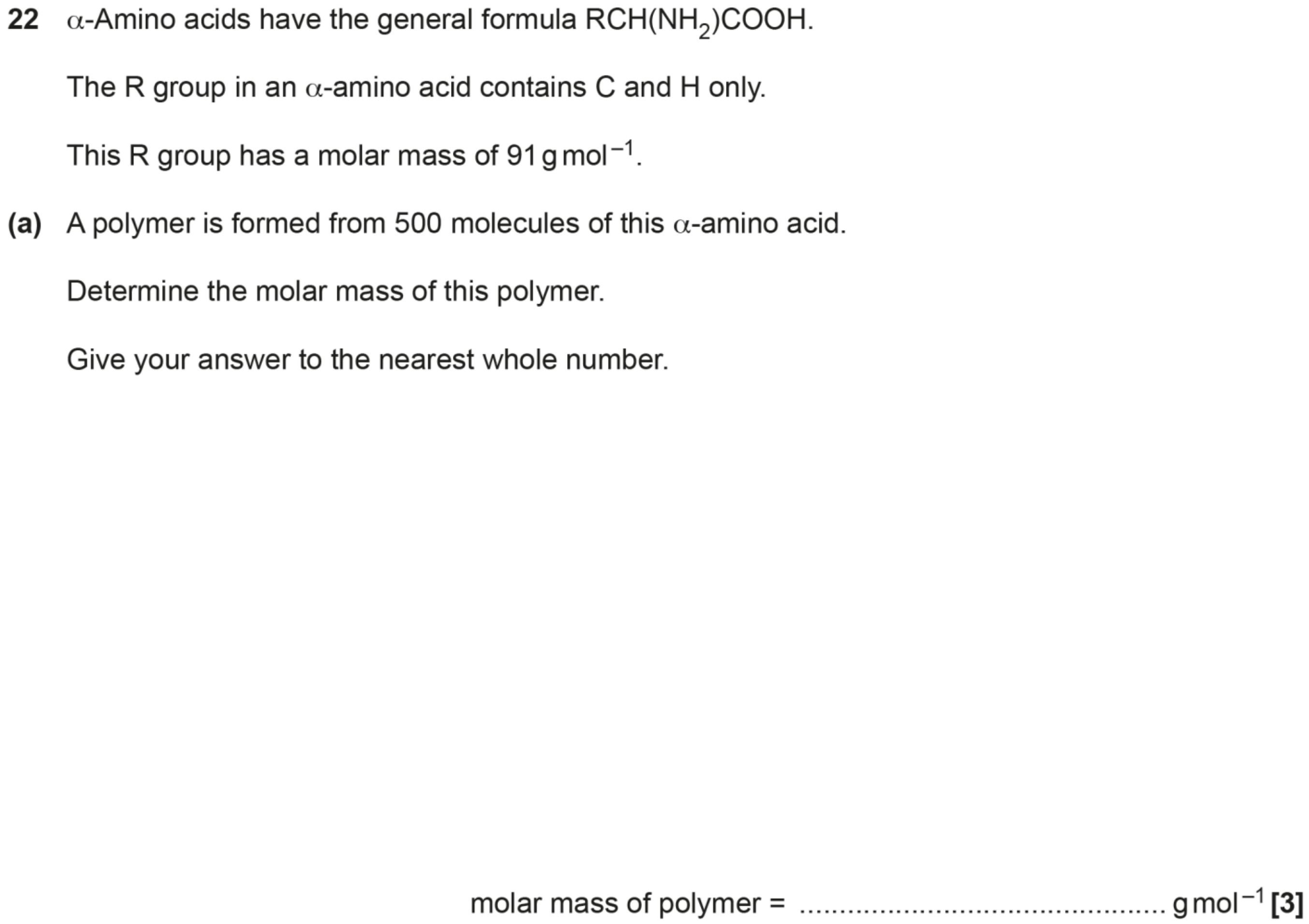


(iii) Explain why chlorine reacts much more readily with $C_6H_5NH_2$ than with benzene.

[3]

Similar questions have been seen previously and many candidates were able to give clear and concise responses. The first marking point was the most frequently lost as although many described -NH_2 as electron donating, they were not able to fully explain its role. Some understood that a lone pair was donated into the π-ring but did not specify that the lone pair was on the nitrogen. Other marks were lost by not making comparison to benzene, e.g. high electron density, polarises Cl_2. Some repeated the information from the question regarding phenylamine being more reactive with electrophiles but not explaining why. Lower attaining candidates often described the structure of the benzene ring or referred to phenylamine being more electronegative.

Question 22 (a)



22 α-Amino acids have the general formula $RCH(NH_2)COOH$.

The R group in an α-amino acid contains C and H only.

This R group has a molar mass of 91 $g\,mol^{-1}$.

(a) A polymer is formed from 500 molecules of this α-amino acid.

Determine the molar mass of this polymer.

Give your answer to the nearest whole number.

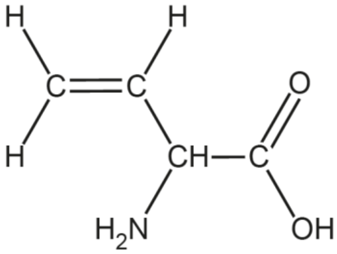
molar mass of polymer = ... $g\,mol^{-1}$ **[3]**

Most candidates managed to score at least one mark here, either for correctly determining the molar mass of the monomer, the repeat unit in the polymer or alternatively they multiplied a molar mass by 500. Many candidates gained 2 marks for either 73500 or 82500 but then struggled to account for the water lost.

Some candidates lost marks due to errors in calculating the molar mass of the monomer or some tried to incorporate the use of Avogadro's constant into the calculation. Many misunderstood what atoms would be lost during polymerisation. For example, a common incorrect response seen was found by subtracting 2 from the correct molar mass giving 163, followed by multiplication by 500 to give 81500 and finally adding of 2 to give 81502. Some struggled to understand what was meant by nearest whole number, e.g. rounding 73518 to 74000 or 82500 to 80000.

Question 22 (b)

(b) The amino acid below can form addition and condensation polymers.



Draw **2** repeat units of these polymers.
Display the sections linking the monomers together.

addition polymer (2 repeat units)

condensation polymer (2 repeat units)

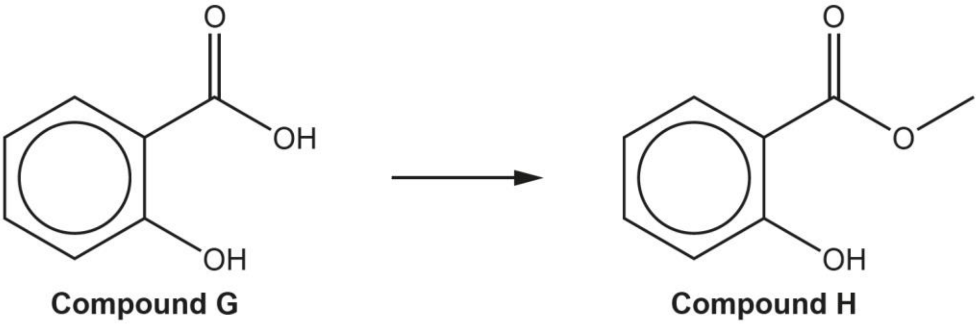
[3]

In general, candidates found it easier to give the correct addition polymer rather than the condensation polymer. Some lost the mark for using molecular formula on side chains rather than displaying the section correctly. The condensation polymer was generally less well answered, with candidates often struggling to give a correct amide bond – many had an oxygen atom retained between the carbonyl carbon and the amine group's nitrogen atom, giving C–O–N. Another common error was the omission of hydrogen atoms from nitrogen or from the carbon attached to C_2H_3. Just over a quarter of candidates did not score any marks. Some candidates drew ester linkages instead of amide linkages and struggled to include the side chains i.e. trying to incorporate the alkene into the main polymer chain.

Question 23 (a)

23 Oil of wintergreen is a liquid used in medicine to relieve muscle pain.

Compound **H** is a component in oil of wintergreen and can be synthesised from compound **G**, as shown below. The boiling point and density of compound **H** are stated.



boiling point = 222 °C
density = 1.174 g cm^{-3}

A student prepares a sample of compound **H** by the method below.

Step 1 Reflux 8.97 g of compound **G** for 30 minutes with an excess of methanol in the presence of a small amount of sulfuric acid as a catalyst.

Step 2 Add an excess of aqueous sodium carbonate, $Na_2CO_3(aq)$. Two layers are obtained.

Step 3 Purify the impure compound **H** that forms from the resulting mixture.

The student follows this method and obtains 5.32 g of pure compound **H**.

(a) Why does the student use reflux in **Step 1**?

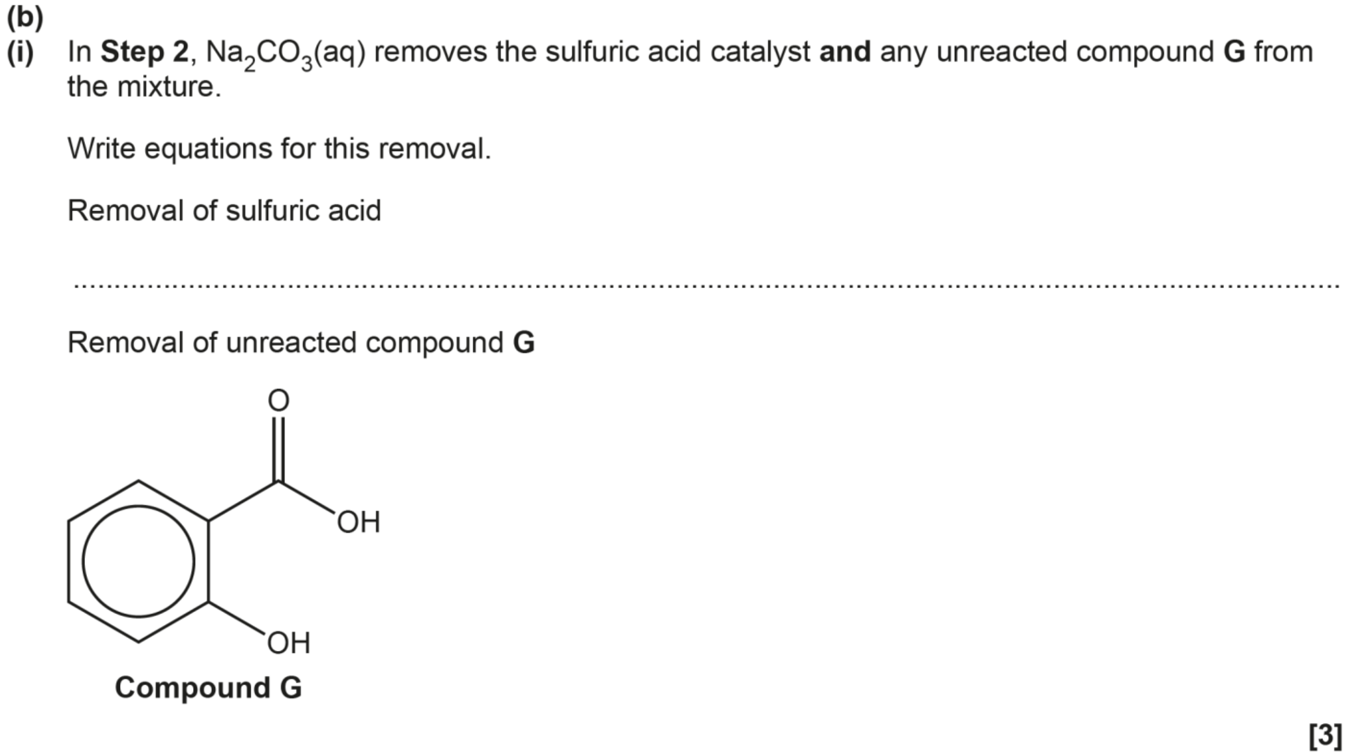
....

.... **[1]**

An unfamiliar question that proved challenging with only around a fifth of candidates obtaining the mark for correctly suggesting that reflux would prevent loss of volatile compounds. Many candidates suggested that reflux ensures the reaction goes to completion but here this was insufficient as esterification is an equilibrium reaction and additional information in (b)(i) indicates that there is unreacted compound **G** present.

It was necessary to focus on the purpose for reflux rather than other ways of heating a reaction, such as the energy needed to break bonds or speed up the rate of reaction. Some less successful responses linked to oxidation reactions, presumably as they understand the importance of either reflux or distillation in this context. For example, 'reflux is required for complete oxidation' or 'if distillation had been used an aldehyde would have been formed'.

Question 23 (b) (i)



(b)

(i) In **Step 2**, Na_2CO_3(aq) removes the sulfuric acid catalyst **and** any unreacted compound **G** from the mixture.

Write equations for this removal.

Removal of sulfuric acid

....

Removal of unreacted compound **G**

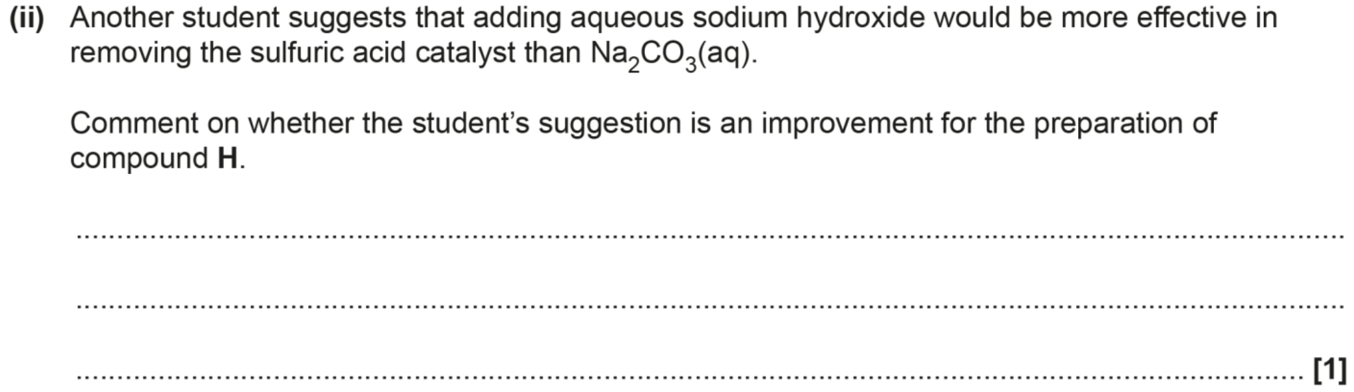
Compound G

[3]

Another fairly challenging question, however most secured at least one mark for giving an equation for the reaction of sulfuric acid with sodium carbonate. Less confident candidates struggled to gain any marks as they were unable to give correct formula for sodium sulfate, giving $NaSO_4$ for example.

Although many attempted the equation showing the reaction of compound **G** with sodium carbonate, only some correctly identified that only the carboxyl group would react, not the phenol. A small minority of students were able to balance the second equation gaining all 3 marks.

Question 23 (b) (ii)



(ii) Another student suggests that adding aqueous sodium hydroxide would be more effective in removing the sulfuric acid catalyst than $Na_2CO_3(aq)$.

Comment on whether the student's suggestion is an improvement for the preparation of compound **H**.

....

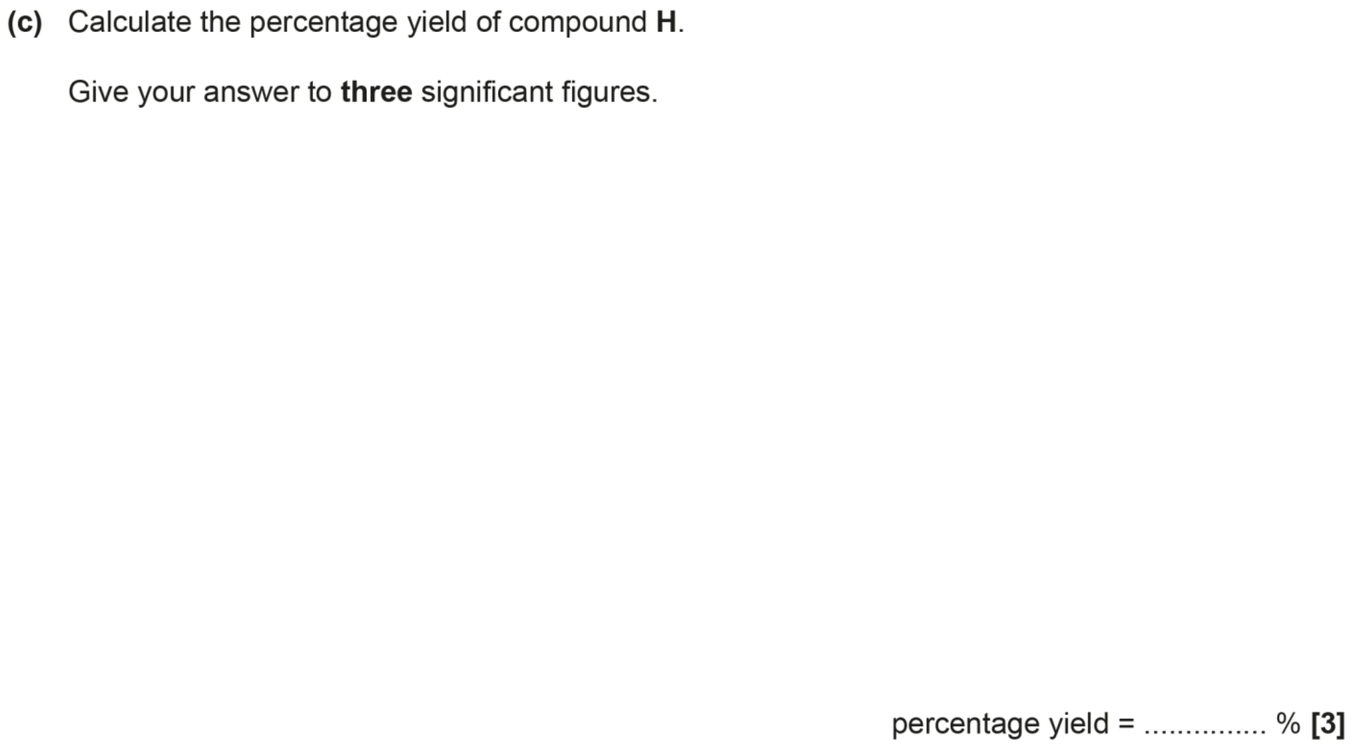
....

.... **[1]**

The best responses correctly identified that using sodium hydroxide was not an improvement and explained this either by stating that it would react with the phenol group or hydrolyse the ester group in compound **H**. However, most candidates appeared not to consider a reaction with **H** in their answer. Many focused on the neutralisation of sulfuric acid in a similar way to sodium carbonate and gave responses such as:

- stronger base
- no effervescence so harder to see when completely reacted
- no CO_2 produced so easier/safer/higher atom economy/less waste
- requires double the moles compared to Na_2SO_4 to react

Question 23 (c)



(c) Calculate the percentage yield of compound **H**.

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

percentage yield = ... % **[3]**

Many candidates were well prepared for this question and secured all 3 marks. Some however were unable to calculate the correct M_r of either **G** or **H** or both. A small proportion gained credit from error carried forward. A significant number of lower attaining candidates used both masses directly or found the mass lost as a percentage. A few tried to use density information, provided earlier in the question, in their calculation. Very few lost marks due to the wrong number of significant figures, however some initially rounded the answer to 4 sf i.e. 53.85 then rounded this value to 3 sf giving 53.9.

Question 23 (d)

(d) Describe how to purify the impure compound **H** from the two layers in **Step 2**.

....

....

....

....

....

.... **[4]**

Many candidates identified the need to describe the isolation and purification of a liquid in response to this question. Some struggled to remember the name of the apparatus required i.e. 'separating funnel' but could describe the separation of layers. The best responses used the density data provided to explain that the lower layer would contain compound **H**. A few gained a mark for a description of the addition of water to identify the correct layer to discard. In generally, candidates only have experience of the organic layer being less dense in their practical work which was reflected in their responses. The use of an anhydrous salt to dry the organic layer was well-known, but many candidates gave vague answers such as 'add anhydrous salt' failing to justify why the salt was needed. Many recognised the need to purify the resultant liquid by distillation, but not all linked to the boiling point of compound **H** to secure this final mark. Some who didn't dry with an anhydrous salt said to heat to 100°C to remove water.

Approximately a third of candidates gained no marks here. Candidates thought that compound **H** would form crystals so described recrystallisation rather than a method to purify an organic liquid. Other responses attempted to merge both methods together.

OCR support

The method to purify an organic liquid was poorly understood by many candidates. Many of the candidates answered this question using techniques to purify an organic solid which is covered in the second year of A Level, rather than an organic liquid which is covered in the first year. It is important to spend time comparing both methods and helping candidates identify when each method is required.

OCR have produced a range of practice exam questions linked to the purification of an organic liquid (PAG5). These can be found on Teach Cambridge.

Exemplar 2

Pour the mixture into a seperating funnel. Add some ~~inorganic~~ inorganic fluid to work out which layer is which as the organic part (H) will stay the same size. Then let out the inorganic layer leaving just the organic layer. The compound H should be at the top before separating as it has density $1.174 gcm^{-3}$ which is low. Distill the organic layer that remains after seperating to ~~[illegible]~~ get a pure compound. ~~Heat it in a capillary tube and check its~~ You could also instead recrystalise it by dissolving in the minimum amount of hot solvent and then allow it to cool and filter it under reduced pressure using a buchner flask and cold solvent. **[4]**

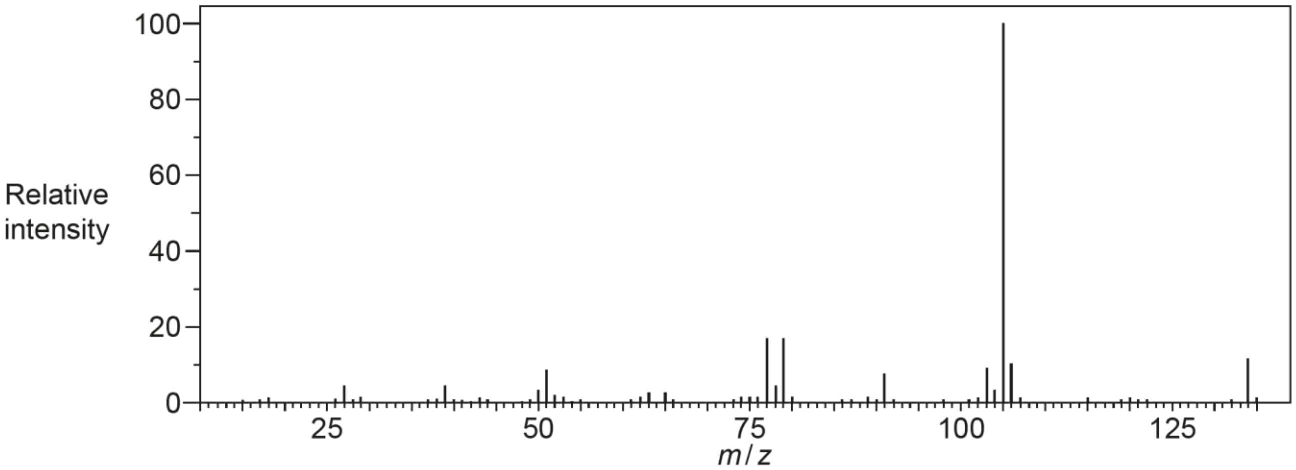
This candidate scored 1 mark for this response for the use of a 'separating funnel'. They have attempted to use the density information but have incorrectly identified that the density of **H** as being low which would make it the top layer. Candidates needed to know that the density of water is 1 g cm^{-3} to be able to make a correct comparison. There is no addition of an anhydrous salt to dry the organic layer. They have recognised the need to distil but have not given the correct temperature at which to collect the pure compound. However, if they had given the boiling point for distillation no mark would have been given as they would lose this final mark for describing the purification of a solid. It was very common to see responses which described the purification of a solid, often in addition to that of a liquid.

Question 24*

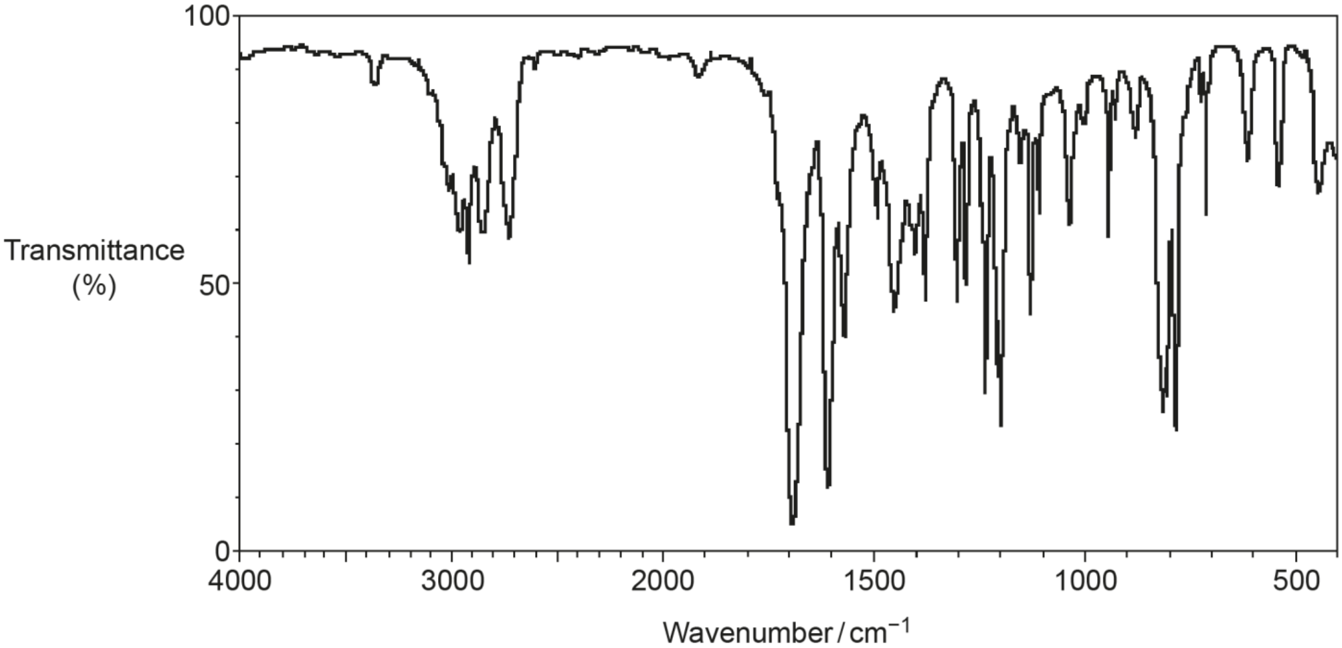
24* Analysis of an unknown organic compound **J** produces the following results.

Elemental analysis by mass of compound J
C, 80.60%; H, 7.46%; O, 11.94%

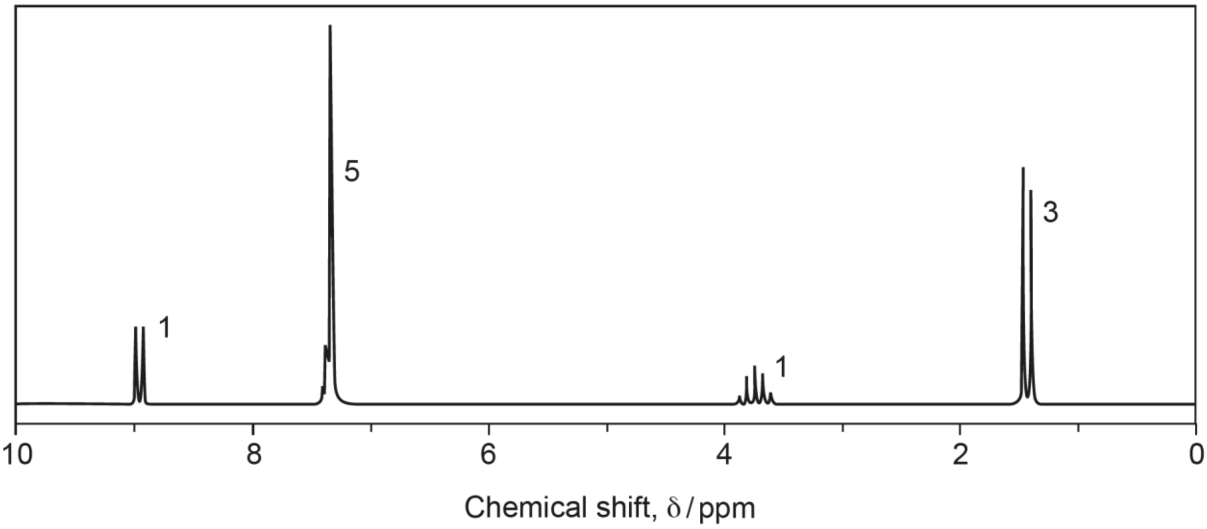
Mass spectrum of compound J



IR spectrum of compound J



Proton NMR spectrum of compound J



The numbers by the peaks are the relative peak areas.

Determine the structure of compound **J**, showing **all** your reasoning. **[6]**

This question was well-attempted by most candidates, with the majority of candidates gaining full marks or gaining 4 marks for a top Level 2 response.

Many candidates showed excellent recall of how to determine the correct empirical formula from the percentage composition data. Most then went on to use the m/z peak on the mass spectrum to confirm that the M_r was 134, and therefore the molecular formula was identical to the empirical formula. A few also made use of the mass spectrum to identify possible fragment ions including a correct positive charge.

Most candidates used the IR spectrum to identify a C=O bond and many also mentioned the absence of O-H or spotted C=C for arenes. Lower attaining candidates sometimes incorrectly mentioned the presence of a carboxylic acid O-H despite the molecular formula only having 1 oxygen atom.

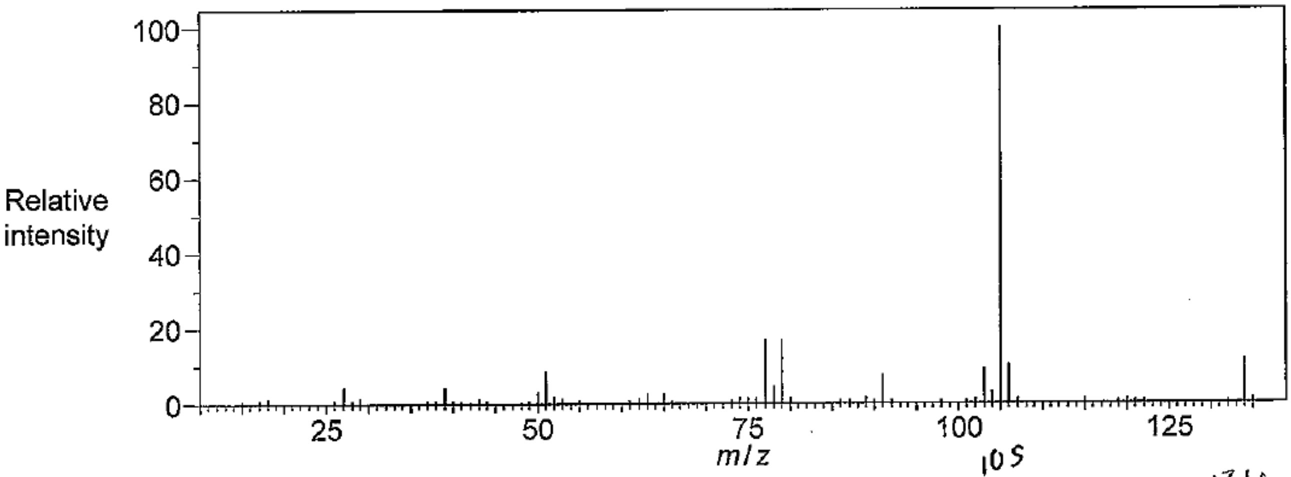
Many candidates annotated the NMR spectrum and/or presented their analysis clearly in a table format and were able to identify aldehyde and arene hydrogen environments. The best candidates had fragments built up alongside their NMR analysis clearly building them using chemical shift, integration ratios and splitting patterns. Those that struggled to interpret the splitting patterns correctly suggested incorrect structures but often with correct features so were still able to score Level 2, 4 marks. Some initially identified the multiplet peak at 3.8ppm as being **H**C-O environment but many realised this did not fit the IR data. However, some changed other evidence to fit this, e.g. the peak at 9.0 ppm being an O-**H** rather than C**H**O and the IR having C=C only without C=O as well.

A large proportion of candidates were able to correctly determine the structure of compound **J**, recognising that the peak at 3.8 ppm was shifted up-field as adjacent to both the benzene ring and the aldehyde group. The data sheet refers to this: 'C**H** bonded to 'shifting groups' on either side, e.g. O–CH_2–C=O, may be shifted more than indicated above'.

Several candidates who did not get the correct structure gave structures which were chemically unfeasible, e.g. with pentavalent carbons. Many candidates had several structures as part of working but did not always ensure their final structure was clearly highlighted.

A very small number of candidates received no credit for this question, as the majority were able to show analysis of 2 aspects, e.g. the calculation of empirical formula and labelling of IR or NMR spectra.

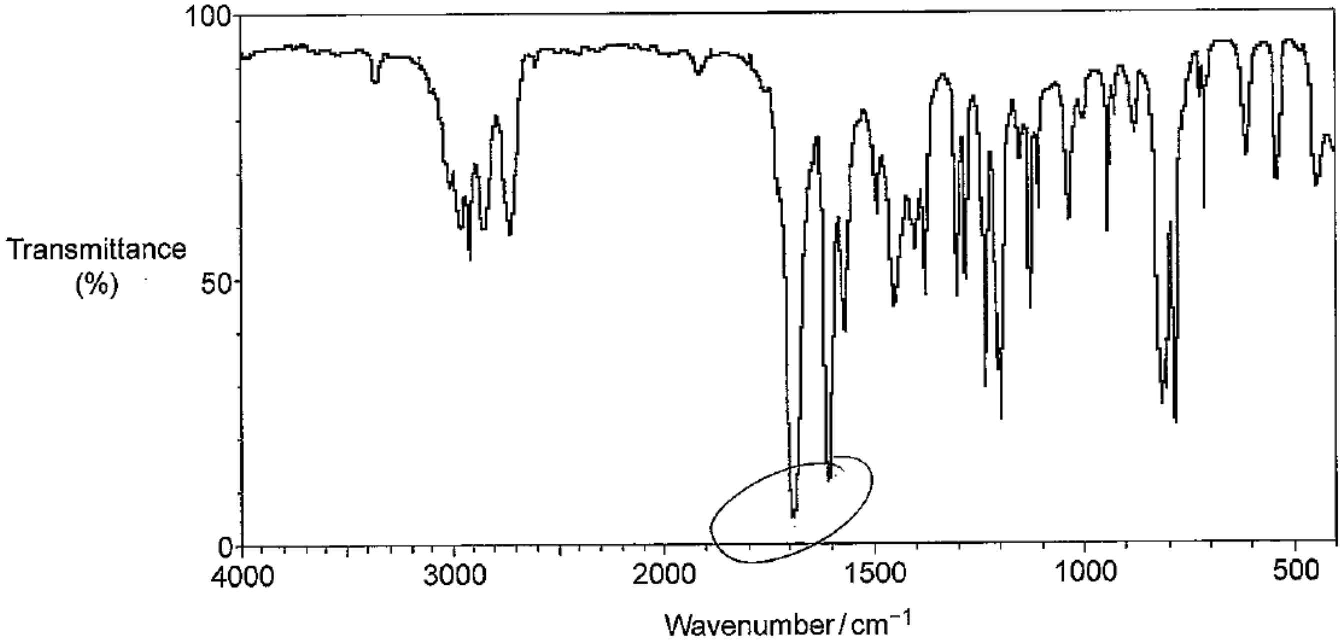
Exemplar 3



105

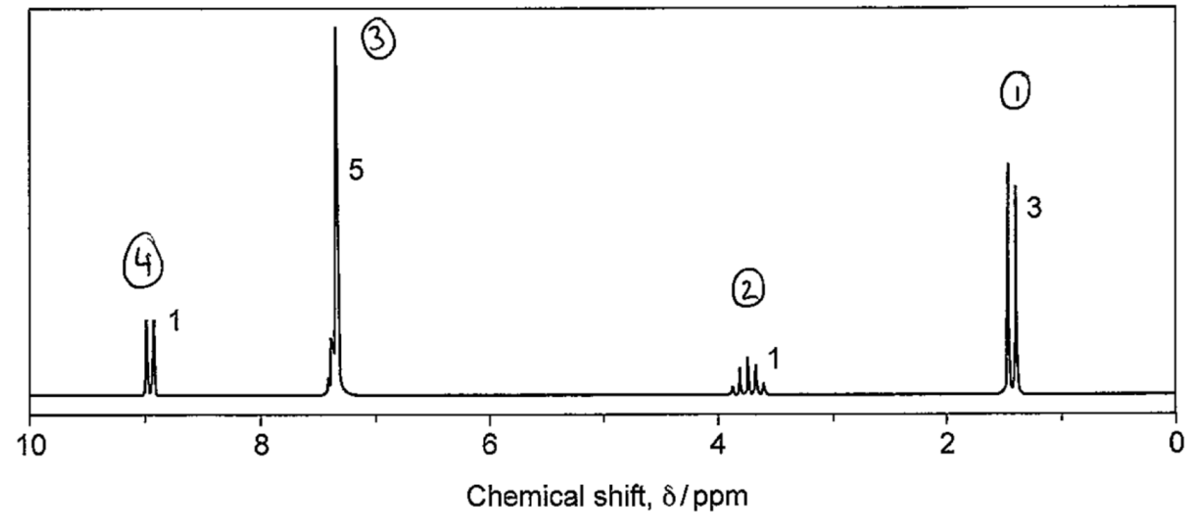
Mr = 134

IR spectrum of compound J



C = O

Proton NMR spectrum of compound J



The numbers by the peaks are the relative peak areas. 4 proton env

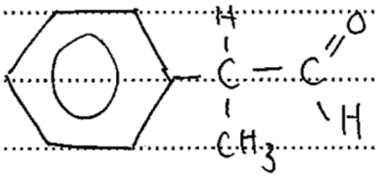
Determine the structure of compound **J**, showing **all** your reasoning. **[6]**

elemental analysis:

$n(C) = \frac{80.60}{12} = \frac{6.71667}{0.74625} = 9$

$n(H) = \frac{7.46}{1} = \frac{7.46}{0.74625} = 10$ $\underline{C_9H_{10}O} = 134$

$n(O) = \frac{11.94}{16} = \frac{0.74625}{0.74625} = 1$

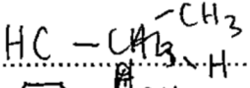
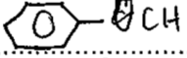
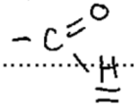


Infrared:

→ there is a peak at 1700cm^{-1}, which represents C=O bond, which occurs between 1630-1820cm^{-1}

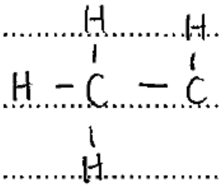
↳ aldehyde or ketone.

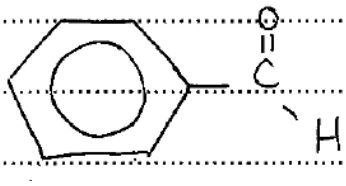
H^1 NMR:

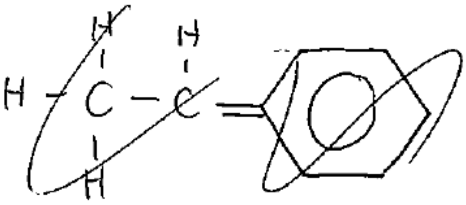
	ppm/δ	n.o of hydrogens	splitting	n.o of H on adjacent	
①	1.5	3	doublet	1	H_3C-CH
②	3.8	1	multiplet	4	
③	7.3	5	doublet ~~singlet~~	~~0~~ 1	
④	9.0	1	doublet	1	 $-C(=O)H$ (aldehyde)?

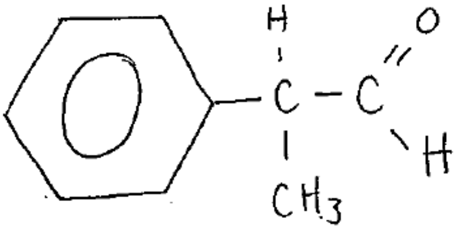
Extra answer space if required.

$C_9H_{10}O$

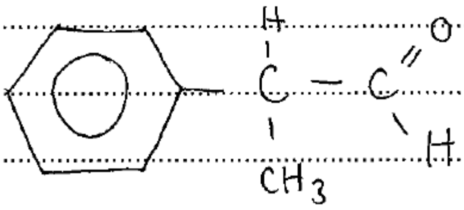








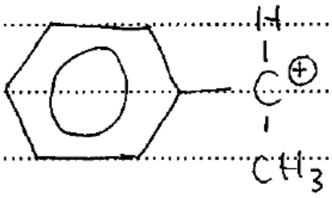
24) Final compound J :



mass spec :

there is a peak at m/z 105,

which represents :



: fragment

Level 3, 6 marks

There is clear and detailed analysis throughout this response to determine the correct final structure for **J**. The empirical formula calculation shows how the empirical formula was determined. On the mass spectrum the annotation links to the M_r of 134 and at the end of the response they have identified the fragment responsible for the parent ion. The C=O IR peak is labelled and described in the response. The NMR analysis is clear, with each peak being numbered and linked to a table which shows how the candidate has identified the hydrogens responsible for each peak as well as linking to neighbouring hydrogens from splitting patterns. The final compound is labelled as such to distinguish it clearly from other structures given, which were part of their problem solving to find a structure that fits all of the analysis they had completed.

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Question 22 (b): AIST: Spectral Database for Organic Compounds SDBS Infrared spectrum, © SDBSWeb : https://sdbs.db.aist.go.jp (National Institute of Advanced Industrial Science and Technology,22.11.2022)

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