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Examiners' report

CHEMISTRY A

H432

For first teaching in 2015

H432/02 Summer 2023 series

Version 1

Contents

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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.

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Paper 2 series overview

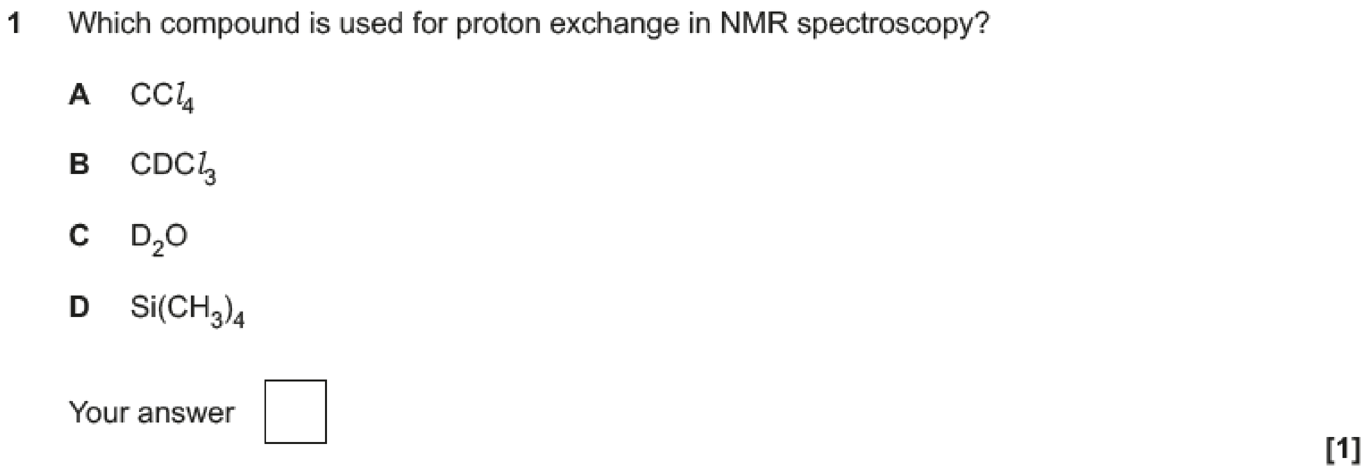
H432/02 is the second of the three examination components for GCE Chemistry A. This component is focused on organic chemistry and brings together topics from modules 4 and 6 of the specification, including relevant practical techniques. There is a synoptic element to all three of the A Level components 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 drew out a range of organic mechanisms – Questions 16 (b) (i), 18 (a) and 22 (a) (i) • demonstrated a secure knowledge of synthetic pathways and gave details of reagents/conditions required even for unfamiliar compounds – Questions 17 (c) (i), 19, 20 (a) and 22 (b) • were confident with a range of calculations showing clear and logical working – Question 16 (b) (iii), 18 (b) and 20 (b) (ii) • gave detailed, clear and concise explanations – Questions 16 (a), 17 (d) and 18 (c).	• left multiple choice questions blank • struggled with using skeletal formula, often unable to correctly count the number of hydrogens, and subsequently made errors in molar mass calculations. They were also not confident using skeletal formula in responses such as Question 16 (b) (i), where it made the mechanism simpler • often drew structures with missing or extra hydrogens or carbons • were unable to formulate a clear and concise explanation, writing extended answers which would often contain contradictions – Questions 16 (a), 17 (d) and 18 (c) • gave working for calculations which was not clearly or logically presented and often contained contradictory steps. Errors were made with significant figures and rounding of intermediate values.

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 for proton exchange in NMR spectroscopy?

A CCl_4

B $CDCl_3$

C D_2O

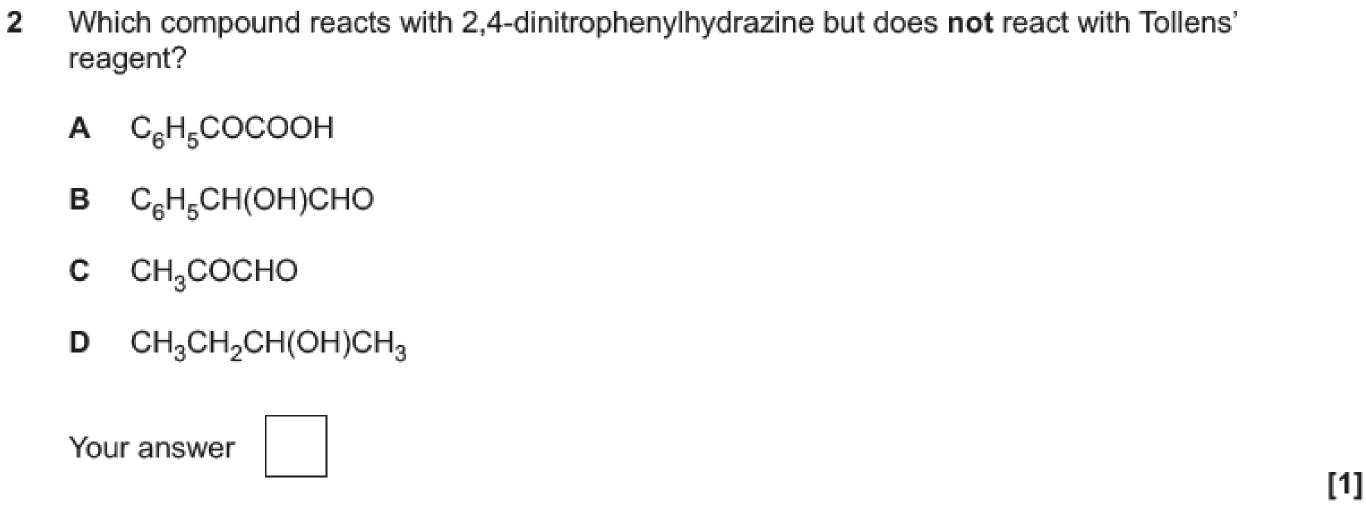
D $Si(CH_3)_4$

Your answer ☐

[1]

Many candidates were not able to identify the compound used for proton exchange, D_2O (C) and instead selected either $CDCl_3$ (B), a common NMR solvent, or TMS (D), an NMR standard. Potentially candidates may be familiar with shaking with D_2O to remove -OH and -NH protons but may not realise this is known as 'proton exchange'.

Question 2



2 Which compound reacts with 2,4-dinitrophenylhydrazine but does **not** react with Tollens' reagent?

A $C_6H_5COCOOH$

B $C_6H_5CH(OH)CHO$

C CH_3COCHO

D $CH_3CH_2CH(OH)CH_3$

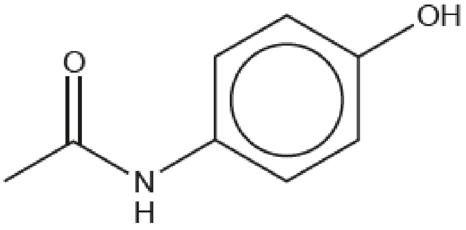
Your answer ☐

[1]

Drawing out the structures often helped candidates to identify each functional group and therefore spot the ketone which is key to correctly answering this question.

Question 4

4 The structure of the painkiller paracetamol is shown below.



Paracetamol

Which functional groups are present in paracetamol?

A alcohol, amide

B alcohol, arene, ketone, amine

C phenol, amide

D phenol, ketone, amine

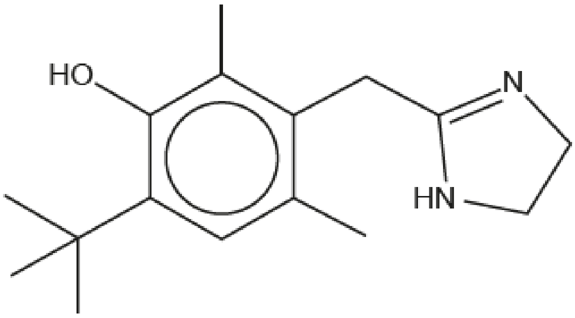
Your answer ☐

[1]

D was the most common incorrect response, separating the amide into a ketone and amine. This was followed by A, not recognising that a phenol OH is distinct from alcohol OH. A common strategy was to circle or label the functional groups on the structure of paracetamol.

Question 5

5 Oxymetazoline, shown below, is used as a decongestant in the treatment of colds.



Oxymetazoline

How many H atoms are in one molecule of oxymetazoline?

A 23

B 24

C 25

D 26

Your answer ☐

[1]

More than a third of candidates answered this question incorrectly. They struggled interpreting the skeletal formula for this more complex substituted benzene. An effective strategy used by many candidates was to label each C with number of H atoms using sticks or dots or numbers.

Question 6

6 Which statement supports the delocalised model of benzene and **not** the Kekulé model?

A Sigma bonds overlap to form a π-system.

B The carbon-carbon bond lengths are all the same.

C The enthalpy change of hydrogenation is more exothermic than expected.

D Benzene is more reactive than alkenes with bromine.

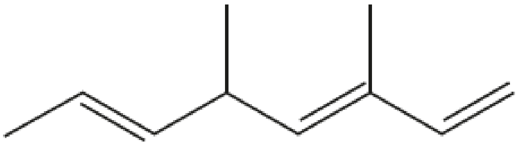
Your answer ☐

[1]

The answer to this question was generally well known. The most common incorrect response was A.

Question 7

7 What is the systematic name for the compound below?



A 3,5-dimethylocta-1,3,6-triene

B 3,5-dimethylocta-2,5,7-triene

C 4,6-dimethylocta-1,3,6-triene

D 4,6-dimethylocta-2,5,7-triene

Your answer ☐

[1]

This question was well answered. Some candidates used the strategy of numbering the C atoms in the structure to aid the deduction of the correct systematic name. D was the most common incorrect response by numbering from left to right.

Question 8

8 For complete combustion, 0.100 mol of an alkane requires 22.8 dm^3 of O_2, measured at RTP.

Which alkane has undergone complete combustion?

A pentane

B hexane

C heptane

D octane

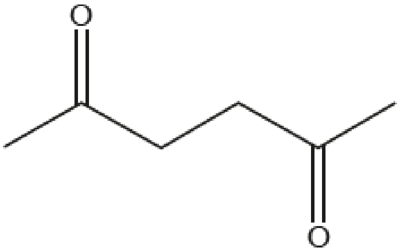
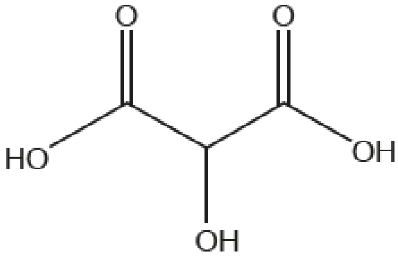
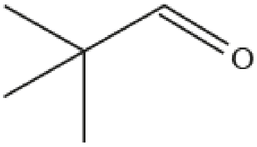
Your answer ☐

[1]

This was a demanding question. Candidates needed to calculate the moles of oxygen and then determine the ratio of alkane to oxygen to find the correct response. The majority of successful candidates clearly showed their working to help them to arrive at the correct answer. The most common incorrect answer was C.

Question 9

9 Which compound has the greatest number of peaks in its proton NMR spectrum?

A	
B	
C	
D	

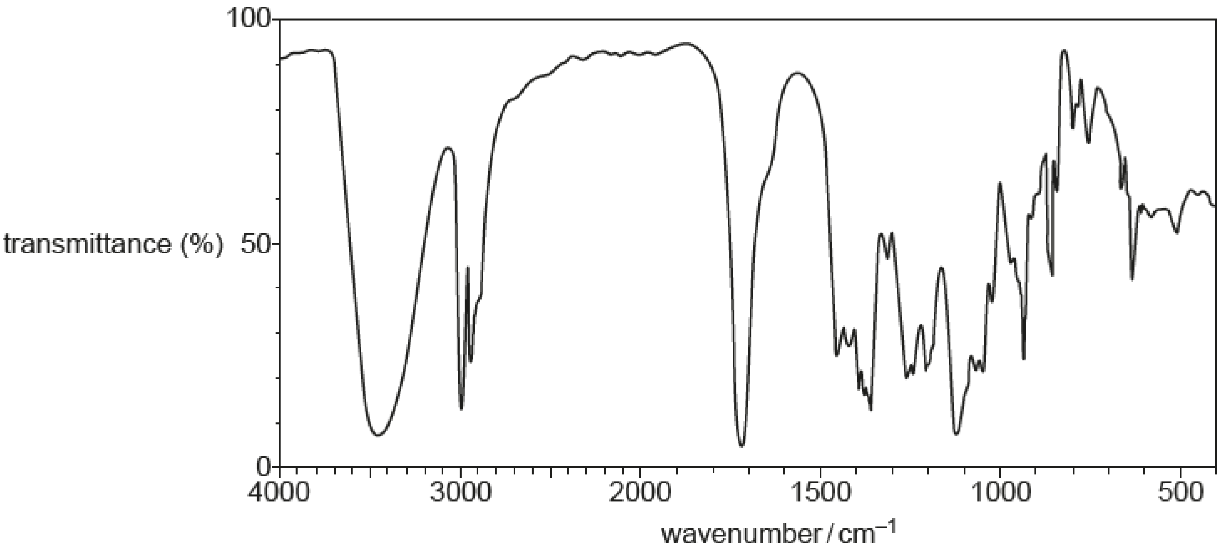
Your answer ☐

[1]

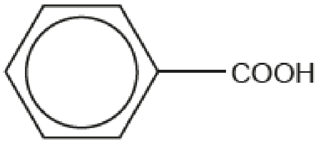
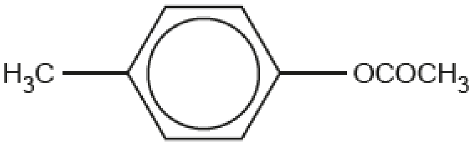
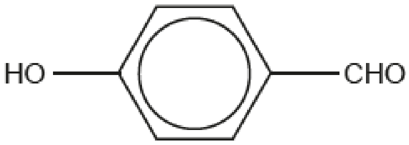
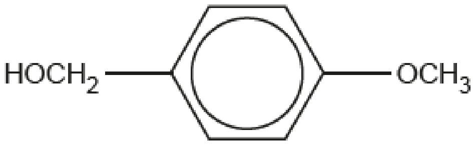
Many candidates wrote the number of proton environments next to each structure, circling or marking protons, but some struggled to spot equivalent environments in the skeletal structures. A and D were common incorrect responses. The correct answer also included -OH protons which candidates did not always include in their count.

Question 11

11 The infrared spectrum of an organic compound is shown below.



Which compound could have produced this spectrum?

A	
B	
C	
D	

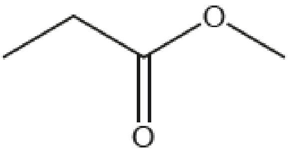
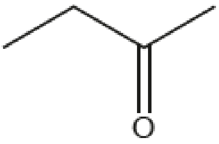
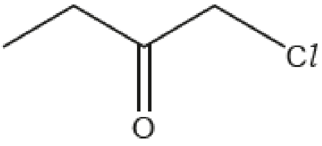
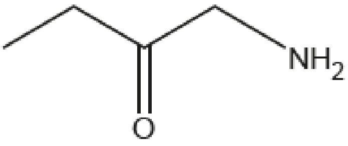
Your answer ☐

[1]

Many gained credit here but as A was the most common incorrect response it demonstrates the need to make sure candidates can recognise the difference between an alcoholic O-H and carboxylic acid O-H in IR.

Question 12

12 Which compound reacts with ethanoyl chloride?

A	
B	
C	
D	

Your answer ☐

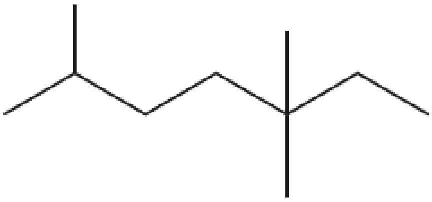
[1]

Most candidates were able to correctly identify that amine D would be the one to react. However, some did not know what could react or were unable to spot the functional groups using skeletal formulae.

Question 13

13 Which compound(s) is/are aliphatic?

1



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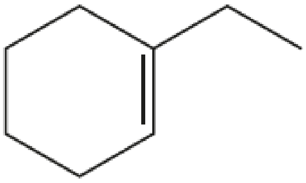

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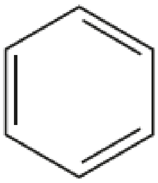


A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer ☐

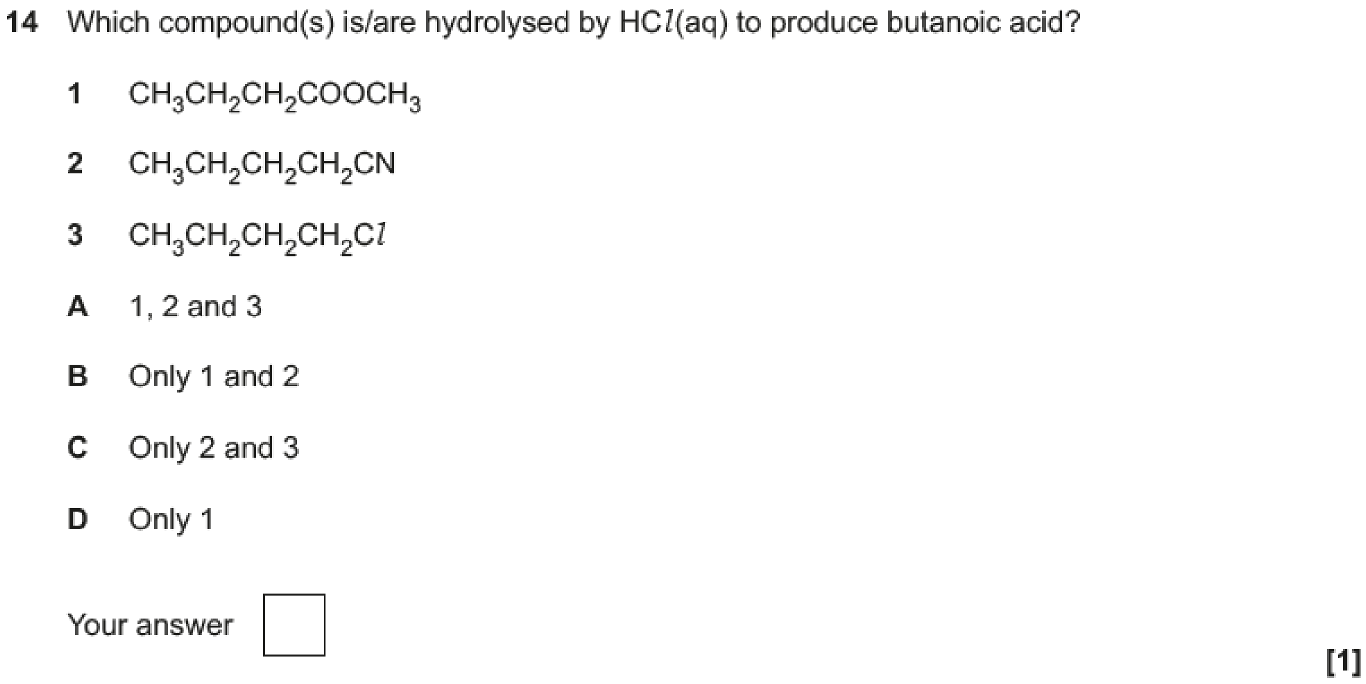
[1]

Few students gained marks on this question. The distinction between aliphatic and aromatic compounds was not well understood with many candidates giving D as their response. It is evident that there is confusion that a molecule can be both alicyclic and aliphatic. Alternatively, candidates may have believed that a cyclic compound with a double bond is aromatic.

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. This OCR article offers clarification for classification of organic compounds.

Question 14



14 Which compound(s) is/are hydrolysed by $HCl(aq)$ to produce butanoic acid?

1 $CH_3CH_2CH_2COOCH_3$

2 $CH_3CH_2CH_2CH_2CN$

3 $CH_3CH_2CH_2CH_2Cl$

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

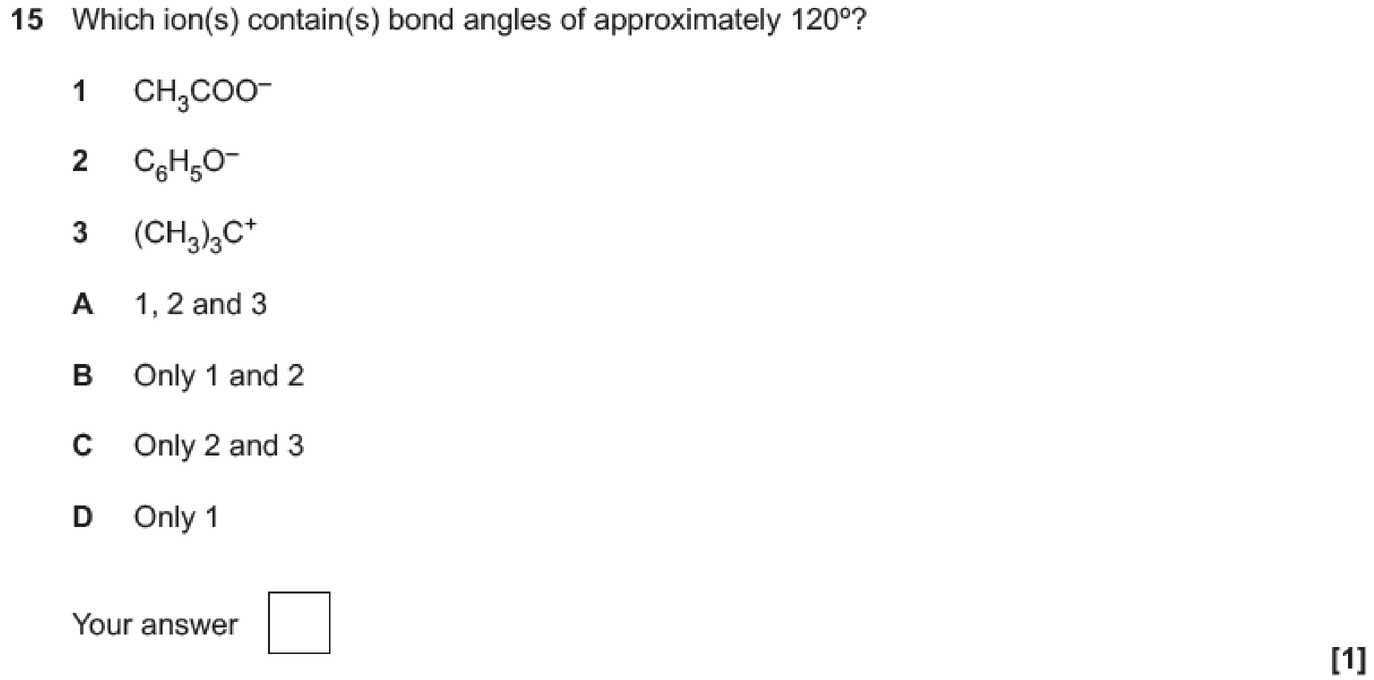
D Only 1

Your answer ☐

[1]

The most common incorrect response seen here was B. Candidates understood that nitriles can be hydrolysed but did not realise that it would give pentanoic acid not butanoic. Those who drew out the structures of the products for each were more likely to give the correct answer, D.

Question 15



15 Which ion(s) contain(s) bond angles of approximately 120°?

1 CH_3COO^-

2 $C_6H_5O^-$

3 $(CH_3)_3C^+$

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer ☐

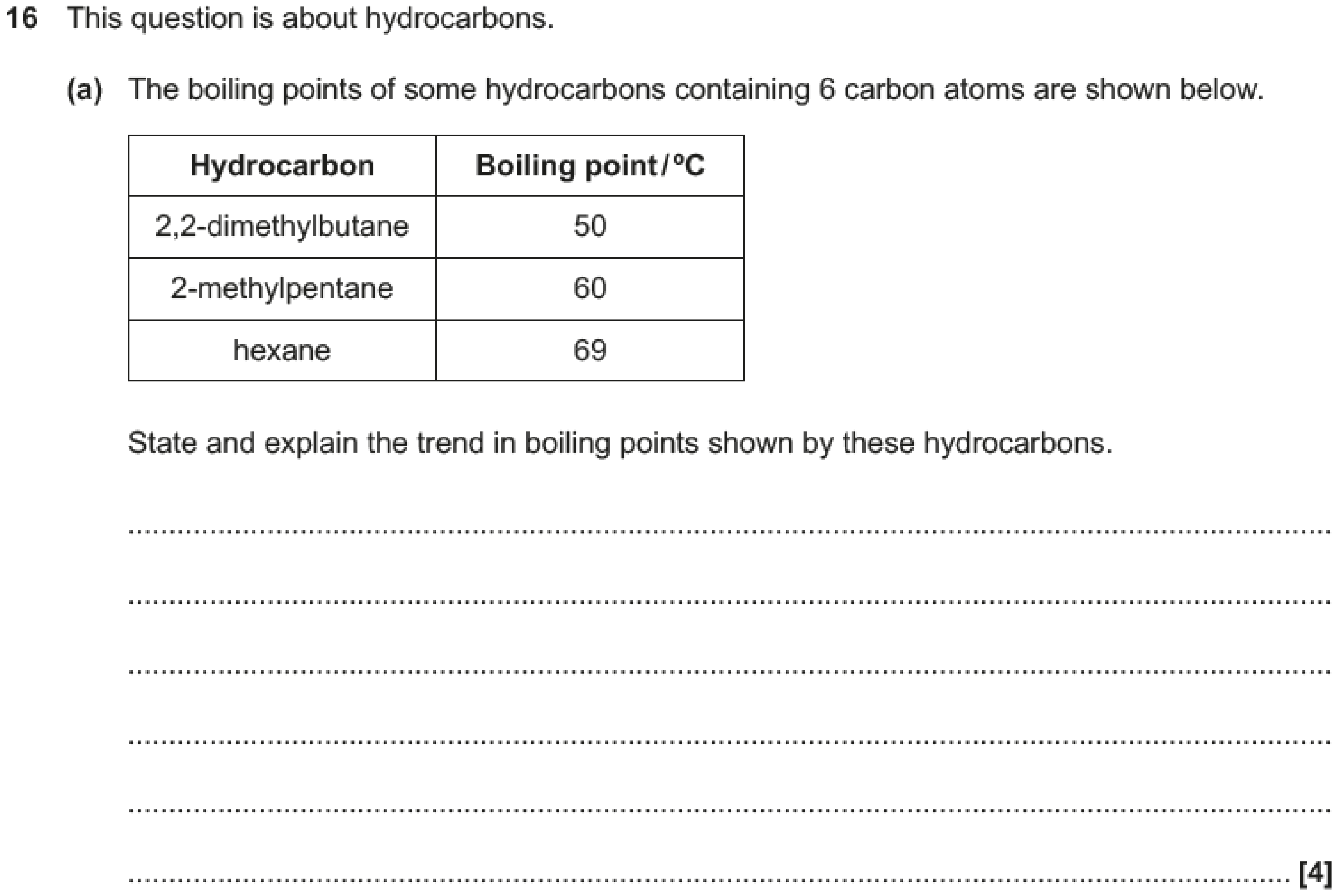
[1]

Fewer than a third of candidates gave the correct response, A. Most identified that compounds 1 and 2 contain a bond angle of approximately 120° and consequentially selected option B. Only the most able candidates were able to apply their understanding of shapes to deduce that the carbocation would also exhibit trigonal planar geometry.

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 (Questions 19 and 23). This section of the paper is worth 85 marks.

Question 16 (a)



16 This question is about hydrocarbons.

(a) The boiling points of some hydrocarbons containing 6 carbon atoms are shown below.

Hydrocarbon	Boiling point / °C
2,2-dimethylbutane	50
2-methylpentane	60
hexane	69

State and explain the trend in boiling points shown by these hydrocarbons.

....

....

....

....

....

.... **[4]**

Most candidates attempted this question, gaining at least 1 mark, with over half scoring 3 or more marks. Responses often lacked clarity as many candidates struggled to articulate their ideas. It was common to see lengthy responses often with unnecessary repetition and sometimes even contradictions. A good strategy adopted by some was to draw skeletal formulae for the compounds next to the data provided. This enabled them to focus their response more easily on the extent of branching.

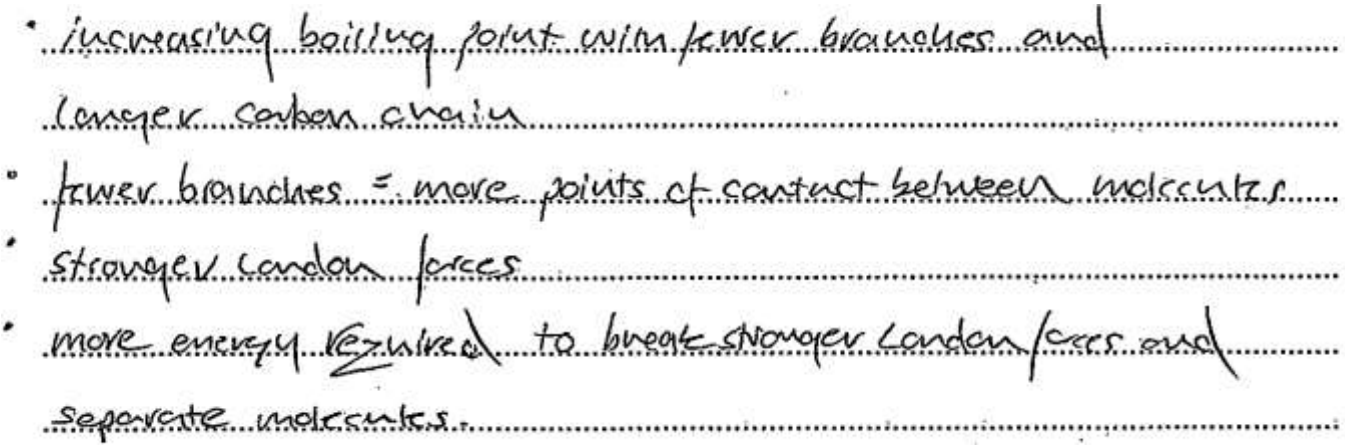
Many candidates were unable to give a clear trend for the first marking point, as asked for in the question, but were able gain credit by a lengthier comparison of all three as indicated in the extra guidance. However, this mark was often lost through incomplete explanation, not referring to boiling point at all or an attempt to compare just chain length. The most common error for the second mark was omission of 'contact' or 'interaction' with reference only to surface area or 'packing' of molecules. Some lost this mark for a change in number of electrons. The third marking point was the most frequently awarded. Some candidates lost the mark for not explicitly naming the intermolecular forces as London forces/induced dipole-dipole interactions or for incorrectly using van der Waals. Some lost the mark for not explicitly indicating how increased or decreased contact would affect the strength or magnitude of London forces, e.g. 'less contact to form London forces'. The final mark was harder to obtain as it needed to be clear that **energy** was required to break **intermolecular** forces. For example, 'less energy to break bonds' or 'easier to separate the molecules' or 'more energy to boil' were not sufficient.

Misconception

Responses often highlighted that candidates lacked understanding about what London forces are, e.g. indicating that they form 'between atoms' or referring to induced dipole-dipole forces as something else. Intermolecular forces are difficult to fully comprehend as they can't be visualised making this a challenging topic to teach.

OCR have produced a 'Bonding' teaching guide with lots of useful suggestions and resources. This includes a link to this Salters A Level chemistry revision activity on intermolecular bonding

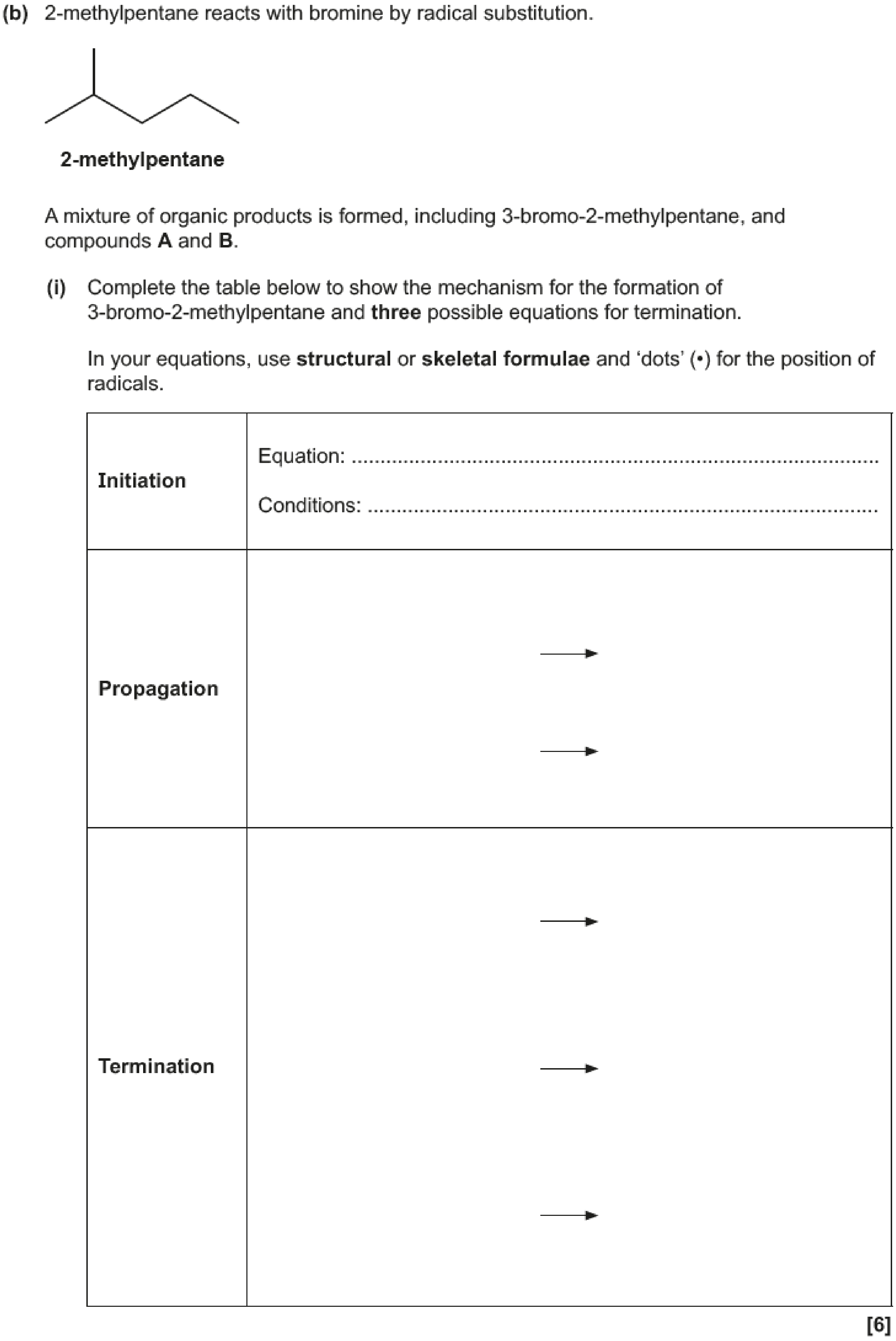
Exemplar 1



- increasing boiling point with fewer branches and longer carbon chain
- fewer branches = more points of contact between molecules
- stronger London forces
- more energy required to break stronger London forces and separate molecules.

This exemplar shows a clear, concise response. The candidate has drawn skeletal structures next to the table. The trend is stated first followed by a detailed explanation, presented as a bullet point list, with all 4 marking points awarded.

Question 16 (b) (i)



(b) 2-methylpentane reacts with bromine by radical substitution.

2-methylpentane

A mixture of organic products is formed, including 3-bromo-2-methylpentane, and compounds **A** and **B**.

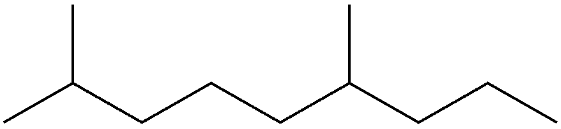
(i) Complete the table below to show the mechanism for the formation of 3-bromo-2-methylpentane and **three** possible equations for termination.

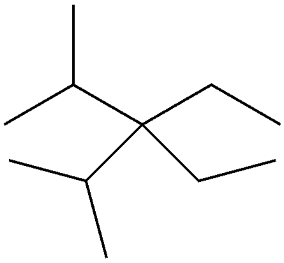
In your equations, use **structural** or **skeletal formulae** and 'dots' (•) for the position of radicals.

Initiation	Equation: .... Conditions: ....
Propagation	$\longrightarrow$ $\longrightarrow$
Termination	$\longrightarrow$ $\longrightarrow$ $\longrightarrow$

[6]

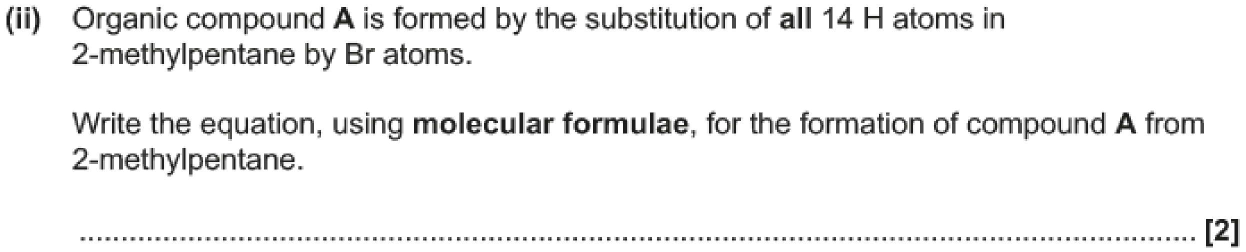
Many candidates tackled this question confidently, especially when using skeletal formula following the format of the structure given in the question. Over half the candidates scored 5 or 6 marks. Only the highest attaining candidates were able to provide all three correct termination steps. Many lost a mark for the combination of the two alkyl radicals, typically either by simply joining the ends of the chains or by missing the connecting C-C bond.





Those that attempted to use structural formula often lost marks due to missing Hs. Other common errors included the incorrect positioning of the radical dot, most typically on the terminal carbon, addition of Br in the first propagation step or use of molecular formula. Lower attaining candidates were often able to score a mark for the initiation step and the termination step involving two Br radicals. However, for some this was not a well-known mechanism, with attempts to break up the chain or form hydrogen radicals or charged species. Errors were also seen with correct balancing of equations such as truncated C chains or extra Br atoms added.

Question 16 (b) (ii)



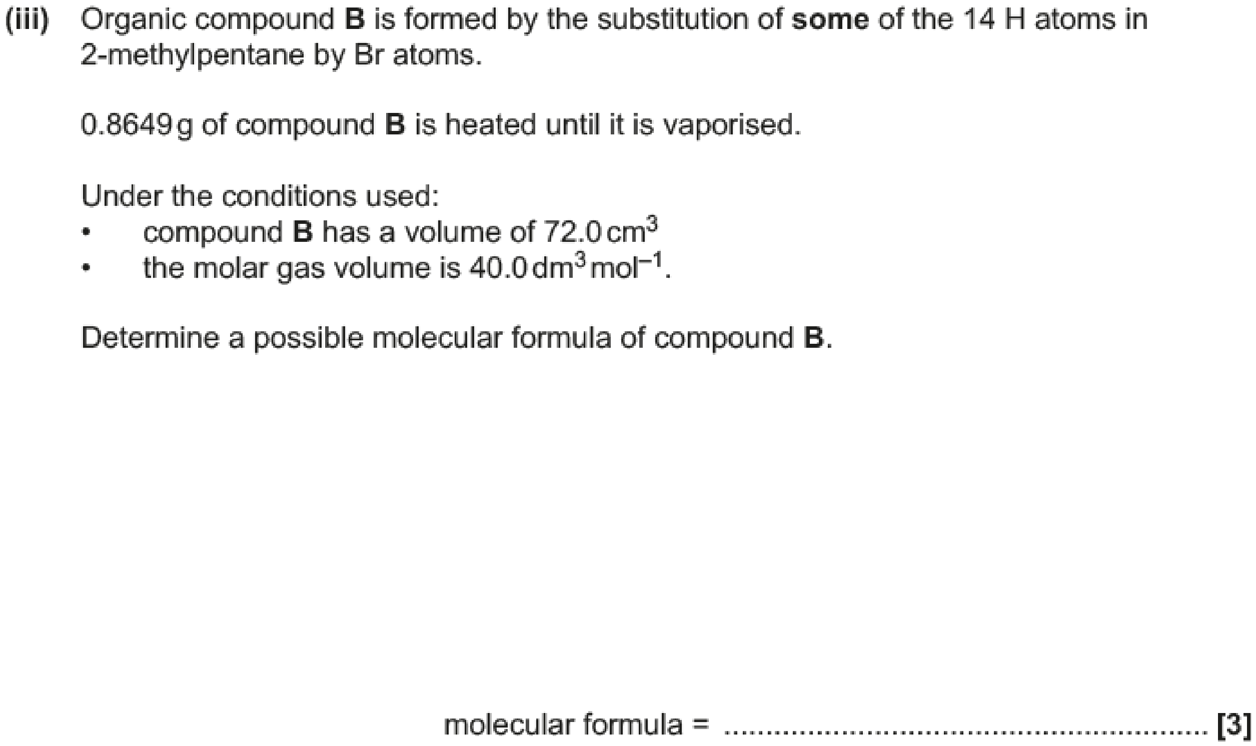
(ii) Organic compound **A** is formed by the substitution of **all** 14 H atoms in 2-methylpentane by Br atoms.

Write the equation, using **molecular formulae**, for the formation of compound **A** from 2-methylpentane.

.... **[2]**

Most responses gained at least 1 mark for this question giving the correct molecular formula of C_6Br_{14}. However many hadn't assimilated that when a hydrogen atom is substituted in an alkane it requires one mole of a halogen and produces one mole of the hydrogen halide. So many gave this incorrect equation instead: $C_6H_{14} + 7Br_2 \rightarrow C_6Br_{14} + 7H_2$. Some lost marks for C_5H_{14} or for use of structural formulae.

Question 16 (b) (iii)



(iii) Organic compound **B** is formed by the substitution of **some** of the 14 H atoms in 2-methylpentane by Br atoms.

0.8649 g of compound **B** is heated until it is vaporised.

Under the conditions used:

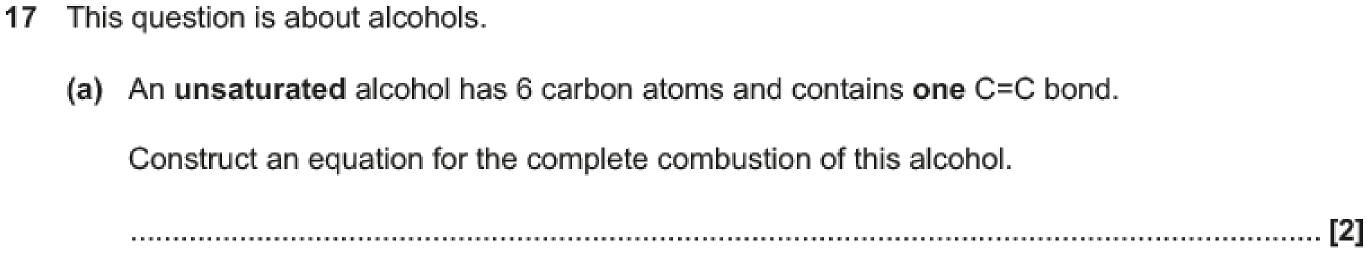
- compound **B** has a volume of 72.0 cm^3
- the molar gas volume is 40.0 $dm^3 mol^{-1}$.

Determine a possible molecular formula of compound **B**.

molecular formula = ... **[3]**

Overall, this question was well answered with over half of candidates gaining all 3 marks. The use of a different molar volume confused some candidates. Some attempted to use PV=nRT or different combinations of the figures given with varying degrees of success. Lower attaining candidates typically struggled with unit conversions and were unable to make use of the units to help them work out the methodology to use.

Question 17 (a)



17 This question is about alcohols.

(a) An **unsaturated** alcohol has 6 carbon atoms and contains **one** C=C bond.

Construct an equation for the complete combustion of this alcohol.

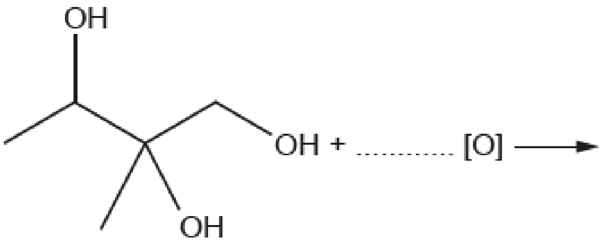
.... **[2]**

Approximately half the candidates gained both marks here but just over a third gained no credit. A very common error was $C_6H_{12} + 9O_2 \rightarrow 6CO_2 + 6H_2O$ missing the need for an alcohol group. Another common error was balancing with $9O_2$ i.e. not deducting O from alcohol from their count of O atoms. Some struggled to determine the correct number of Hs when a single C=C bond is introduced so gave $C_6H_{12}OH$ or $C_6H_{13}OH$ instead. Lower attaining candidates did not understand what happens during complete combustion. For example, they used [O] instead of molecular oxygen or didn't have CO_2 and water as the products. Some used structural formula which made it easier to get the correct formula of the reactant but often made it trickier to balance the equation.

Question 17 (b)

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

Complete the equation for this reaction.



Compound C

[3]

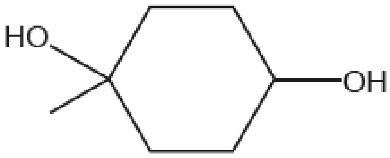
The higher attaining candidates scored well here, with many being able to identify both the primary alcohol being oxidised to the carboxylic acid and the secondary alcohol being oxidised to the ketone and obtaining correct balancing. A good strategy adopted by some candidates was labelling the three alcohol groups with their classification, i.e. primary, secondary, and tertiary. Some missed the water by-product or gave H_2 instead. Some gained credit for partial oxidation products as shown in the guidance on the mark scheme.

However, more than a third gained no credit here with many attempting to oxidise the tertiary alcohol or removing it entirely. Some made a mistake by adding an extra CH_2 on to the product before COOH group - again demonstrating the importance of counting atoms when balancing equations.

Oxidation of alcohols is typically taught in the first year with very simple examples, but candidates need to practise more complex examples. Candidates need to be reminded that every oxidation step requires an [O] and every OH group oxidised produces a water molecule.

Question 17 (c) (i)

(c) Compound **D**, shown below, is refluxed with H_2SO_4, as an acid catalyst, to form a mixture of three isomers with the molecular formula C_7H_{10}.



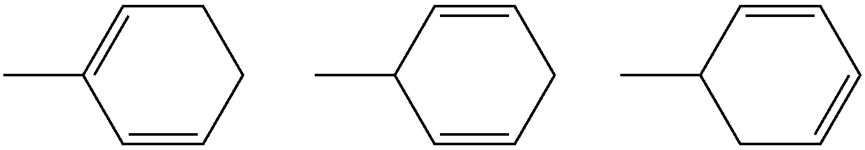
Compound D

(i) Draw the structures of the **three** isomers of C_7H_{10} formed from compound **D**.

[3]

Lots struggled here with just under half of candidates gaining no credit. Only the strongest responses recognised that a carbon-carbon double bond could be formed external to the ring from the methyl branch. A common error was repeating one of the first two isomers as a mirror or rotated image and so lost a mark - candidates need to be able to recognise same structures (especially using skeletal formula)

Lower scoring candidates didn't recognise this reaction would result in the elimination of water. So, it was common to see responses with three structures still containing the OH group or ketones (possible oxidation products), despite the molecular formula C_7H_{10} being provided twice in the question. Some candidates attempted to give structural isomers of C_7H_{10} that would not form from this reaction (see below) including those with smaller rings and even unsaturated straight chain compounds. Some even gave benzene structures.



This question was particularly problematic to mark if previous structures drawn were then rubbed out.

Drawing structures in exams

Please remind candidates to draw structures clearly in black ink. If incorrect cross them out and redraw them. Drawing in pencil then rubbing out often leads to extra lines showing when exam papers are scanned making it appear that structures are incorrect.

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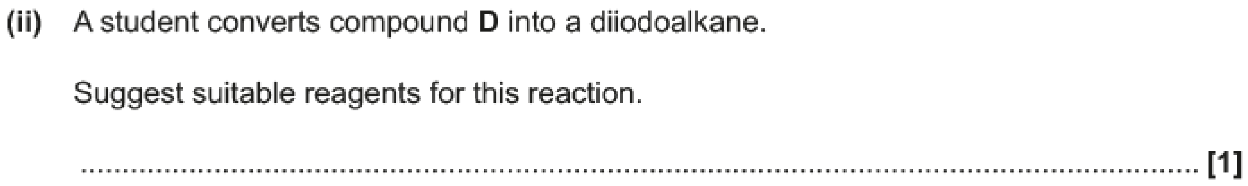
Question 17 (c) (ii)



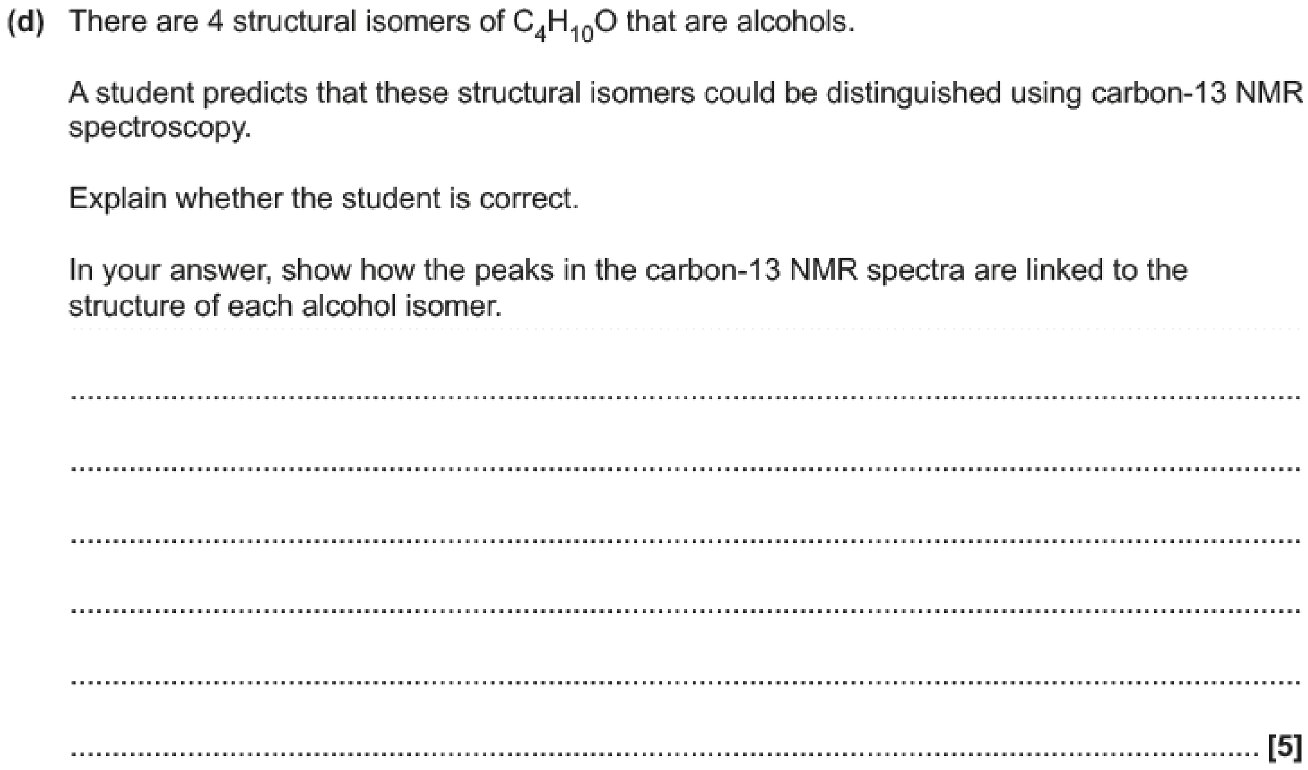
(ii) A student converts compound **D** into a diiodoalkane.

Suggest suitable reagents for this reaction.

.... **[1]**

Many candidates were unable to provide reagents and conditions for this reaction. Iodo- seemed unfamiliar to some with responses including NaBr or HBr suggesting substitutions with Br are more familiar. The most common errors were to use iodide with no acid or to use iodine, sometimes in conjunction with other reagents such as AlI_3 or FeI_3.

Question 17 (d)



(d) There are 4 structural isomers of $C_4H_{10}O$ that are alcohols.

A student predicts that these structural isomers could be distinguished using carbon-13 NMR spectroscopy.

Explain whether the student is correct.

In your answer, show how the peaks in the carbon-13 NMR spectra are linked to the structure of each alcohol isomer.

....

....

....

....

....

....

.... **[5]**

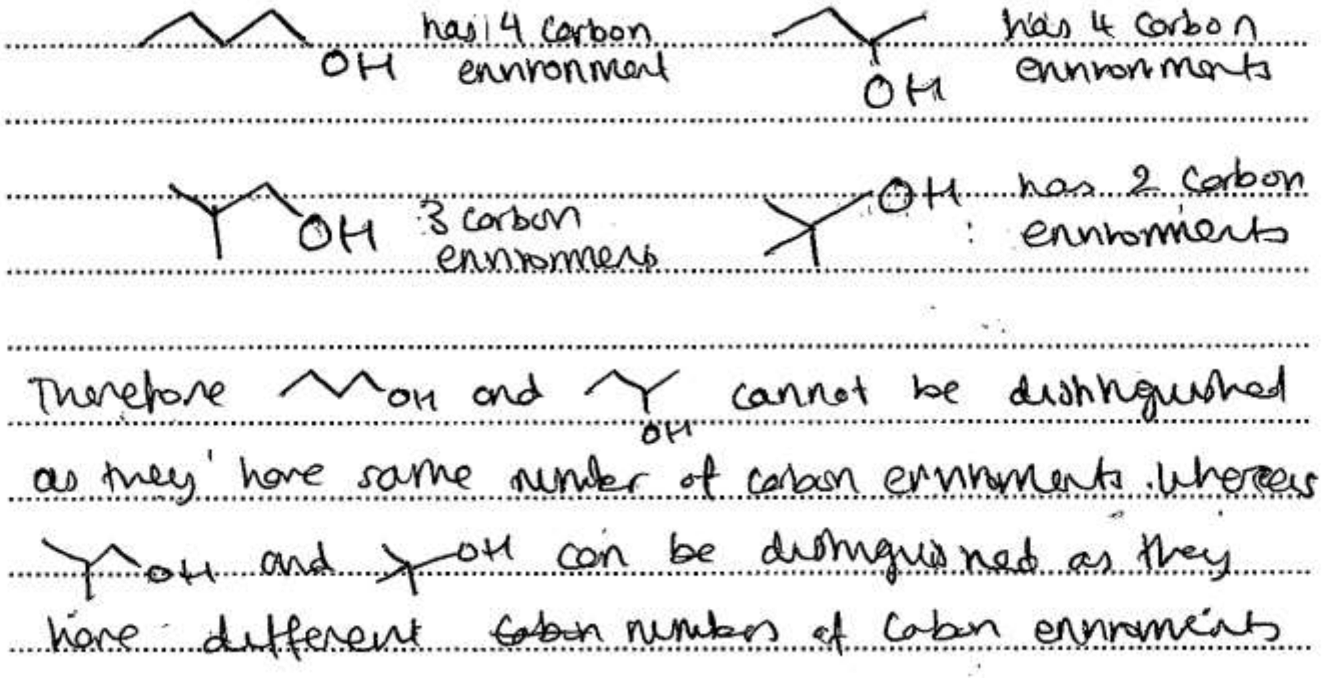
This question discriminated well with a variety of responses seen. The lower scoring candidates gave vague answers suggesting they did not fully grasp what the question was asking. They often filled the lines with generic responses in terms of what C NMR can do, e.g. chemical shift data/shows positions of Cs relative to OH group or number of peaks gives number of environment but made no reference to the isomers mentioned in the question. For some there was obvious confusion with proton NMR due to discussion of splitting patterns or relative peak areas/heights. Lots struggled to find all four isomers, often repeating one they already had, but drawing them with a different layout, or by giving cyclic structures. Some struggled to count the correct number of peaks for each. It was common to see false equivalency between CH_2 groups, e.g. butan-2-ol with three peaks. Many struggled to give a concluding statement, often focusing more on slight differences in chemical shift due to proximity to OH group.

The highest scoring responses were well structured and started by identifying the four isomers. After stating the number of carbon environments for each isomer these responses often concluded with a statement detailing whether the isomers could be distinguished.

Assessment for learning

Candidates often struggle with drawing out the different structural isomers. As a starter activity or plenary give candidates a molecular formula and challenge them to draw out all the different possible isomers. Using molymod can help candidates realise equivalent molecules. As candidates become more confident encourage them to draw structures using skeletal formula and to give the systematic names.

Exemplar 2



OH has 4 carbon environment

OH has 4 carbon environments

OH 3 carbon environmens

OH has 2 carbon environments

Therefore OH and OH cannot be distinguished as they have same number of carbon environments whereas OH and OH can be distinguished as they have different carbon numbers of carbon environments

This candidate has clearly drawn out all four isomer structures and next to each has identified the number of carbon environments. They have then made a concluding statement using this information. This response scored all 5 marks.

Question 18 (a)

18 1,3-dinitrobenzene is a solid at room temperature.

A chemist prepares 1,3-dinitrobenzene as outlined below.

Step 1 12.5 cm^3 of nitrobenzene (density = 1.20 $g\,cm^{-3}$) is refluxed with concentrated nitric acid in the presence of concentrated sulfuric acid as a catalyst.

Step 2 The mixture is cooled. Impure crystals of 1,3-dinitrobenzene appear.

Step 3 The impure crystals are purified to obtain pure 1,3-dinitrobenzene.

The chemist obtains 15.0 g of pure 1,3-dinitrobenzene.

(a) Outline the mechanism for this reaction, including the role of H_2SO_4 as a catalyst.

[5]

Many candidates knew this mechanism well with the majority gaining 4 or 5 marks here. The mark most frequently lost was for the incorrect drawing of the intermediate. Many candidates did not appreciate that two electrons are removed from the Π ring in the first stage of the mechanism resulting in the partial delocalisation of electron density across four sides of the benzene ring in the intermediate. In addition, it must have the correct orientation with the opening at the three position where the nitro group is added. Some candidates nitrated the 2 or 4 position instead. Some also showed nitration of benzene then the second nitration. Other common errors included missing or extra charges, missing NO_2 group on intermediate, use of NO_3^+ or other incorrect electrophiles.

Lower scoring responses were characterised by unclear diagrams and inaccurate use of curly arrows. Many were often able to score 1 mark for showing C-H bond on benzene ring breaking and electrons going back into the ring. Such responses often included errors in the equations showing the role of the sulfuric acid catalyst, e.g. formation of $H_3SO_4^-$, or omitted these steps entirely. Others evidently didn't know what a nitro group was with -NO_3 giving just -N and even -NH_3 instead.

Assessment for learning

Encourage candidates to look at more recent mark schemes to check for tips on how to correctly draw out mechanisms. An easy tip for ensuring the correct intermediate for electrophilic substitution is to place a dot inside the ring for each C without the new substituent attached and then connect the dots. Only four out of the six sides should be covered by the broken delocalised Π ring (as two electrons have formed the new bond). Alternatively, some find it easier to redraw, so horseshoe ring opens upwards (like a smiley face), rather than at an angle.

Question 18 (b)

(b) Determine the percentage yield of 1,3-dinitrobenzene.

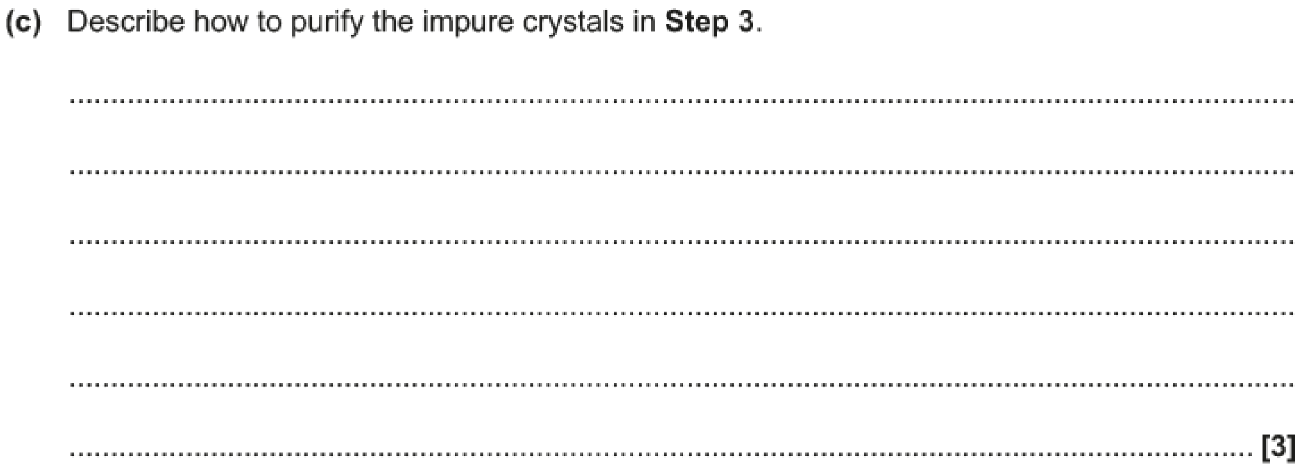
Give your answer to **3** significant figures.

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

Approximately half of the candidates scored all 3 marks and were confident calculating % yield. However, about a third did not gain any credit. A common response was 100% with both masses as 15 g. Some struggled with conversion of the volume of nitrobenzene to a mass using the density. Many candidates struggled with obtaining the correct molar mass values, especially if they were not sure on the correct structures.

As with any calculation work, clear working is vital to gain error carried forward credit here. Three significant figures were required for final answer but many also lost marks as a consequence of incorrect rounding. For example, use of 0.089 moles gave a value of 73.0%. It was not uncommon to see contradictory calculations as candidates appeared to try to find a suitable value.

Question 18 (c)



(c) Describe how to purify the impure crystals in **Step 3**.

....

....

....

....

....

.... **[3]**

About a quarter of candidates gained all 3 marks. They were able to give clear, well-structured answers with all the steps as carried out in PAG 6 practical activities. The best answers were often in the form of bullet pointed steps and often included extra details such as a hot filtration step or promoting crystallisation by scratching the surface.

Many candidates lost the first mark as their responses didn't give sufficient detail, e.g. hot solvent, not just warm and minimum volume required. Some missed the cooling step essential for formation of crystals before filtration. Some missed that the crystals need to be dried following filtration but often if only given 1 mark this was the mark given.

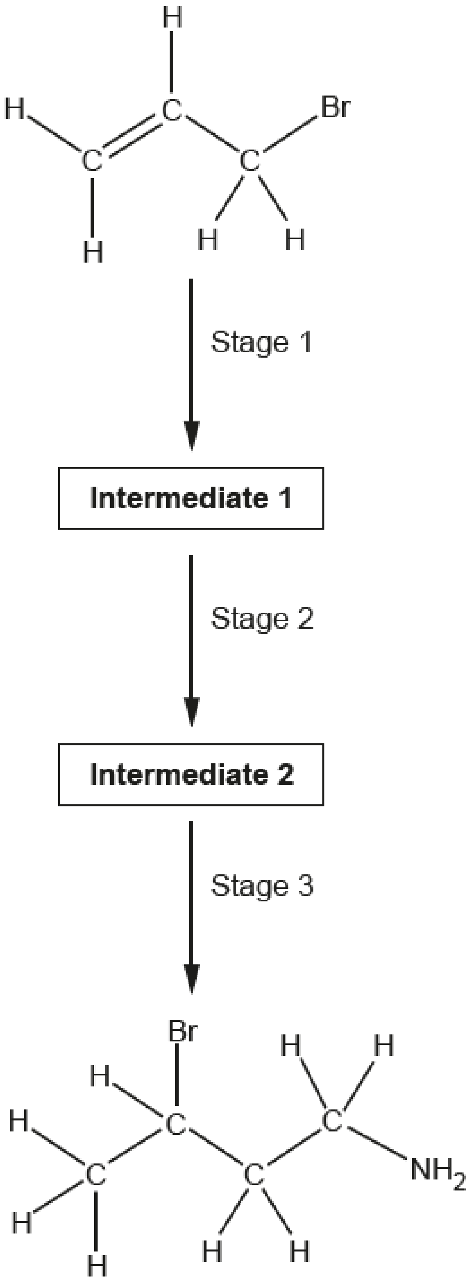
Lots of confusion with purification with organic liquid was seen, such as references to use of a separating funnel, drying agents and distillation. Some also went on to explained how to check purity using melting point determination.

OCR support

A useful resource for revising the steps for purification of an organic solid is the Topic exploration pack: Experiments on organic synthesis in Learner Activity 2.

Question 19*

19* A student intends to synthesise compound **Z**, as shown in the flowchart below.



Compound Z

Plan this synthesis showing reagents, the structures of **intermediate 1** and **intermediate 2**, and equations. **[6]**

This challenging level of response question was generally well attempted. Many candidates recognised the reagents required in this synthesis but fewer candidates were able to deduce three correct reagents in the right order with equations to achieve Level 3. Most candidates achieved Level 2 4 marks. Many correctly identified suitable reagents but carried out the stages in the wrong order. A common error was to carry out electrophilic addition with HBr first then react with cyanide ion, not realising both Br groups would react and the reaction would not be selective. Alternatively, having introduced the nitrile group then carried out the reduction first, not realising that the C=C would also be reduced.

The lowest scoring responses were often incomplete and despite identifying some reagents did not give equations. Candidates are encouraged to read the questions carefully so they can make sure their response covers all the detail required. Many candidates used molecular formula in their equations. It is usually preferrable in organic chemistry to give structures. Some gave surplus information such as the mechanisms and reaction conditions for each reaction.

The key to answering this question well was knowing reagents for different functional group interconversions as well as planning each step to make sure of a logical synthesis. Some candidates were seemingly confused by the term ‘intermediate’ and gave an intermediate as in a mechanism, e.g. carbocation.

OCR support

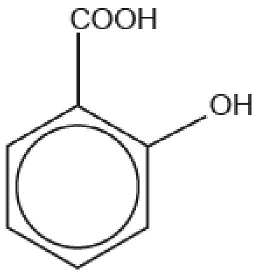
A useful resource for teaching how to identify functional groups and practice at devising synthetic routes is the Topic exploration pack on Organic synthesis.

This should be used in conjunction with the reaction pathways summaries.

Question 20 (a)

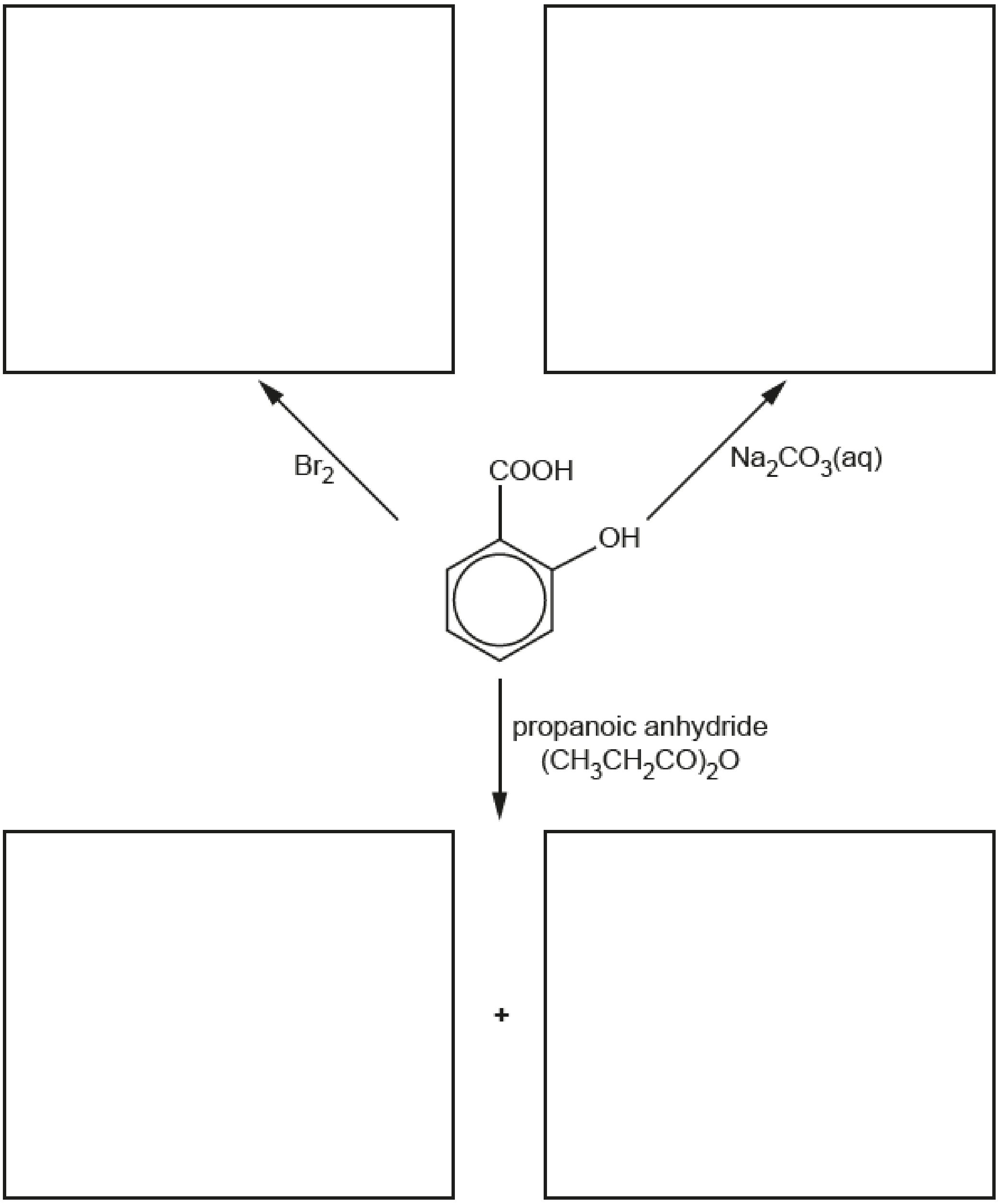
20 This question is about aromatic compounds containing the –COOH and –OH functional groups.

(a) Salicylic acid, shown below, is used in the manufacture of some important medicines.



Salicylic acid

Complete the flowchart for reactions of salicylic acid, by adding the organic products in each box.



[4]

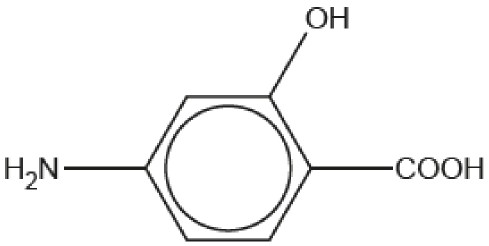
Overall, this question discriminated well with most candidates gaining some credit. Most candidates were able to suggest a correct product for the reaction of salicylic acid with bromine, with just a few candidates replacing the OH group with a Br atom. Most candidates recognised that the carboxylate salt would be produced from the reaction with Na_2CO_3 but not all were able to recall that the phenolic OH group is too weak acid to react. Some missed an O on carboxylate i.e. $-CO^-Na^+$. Some added Na or CO_3 directly to the ring.

The reaction with the anhydride proved much more challenging. All sorts of weird and wonderful structures of the main 'ester' product were given including joining the CH_3 group of propanoic anhydride to the O of the phenol group. Some used the bottom two boxes to form esters with the COOH and OH groups in turn. Many did not identify propanoic acid as a by-product even if they had correctly identified the ester product. Water was a common incorrect product.

Marks were also occasionally lost for missing the benzene ring on structures or missing the -OH or -COOH groups that were left unreacted.

Question 20 (b) (i)

(b) PAS, shown below, is an antibiotic used to treat several diseases including tuberculosis (TB).



PAS

(i) A student predicts that PAS could polymerise to form a polymer containing **both** ester and amide linkages.

Draw a section of this polymer.

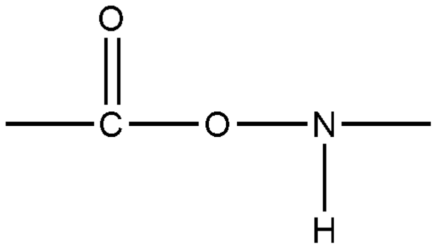
The section should contain **one** amide and **one** ester linkage, which should be displayed.

[3]

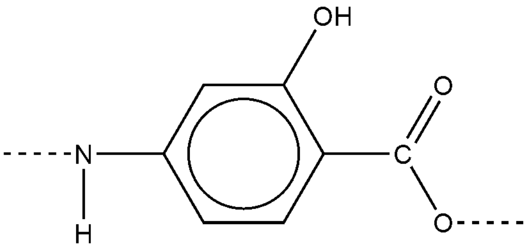
This was a demanding question with just over a third of candidates not scoring marks. However, many candidates were able to gain a mark for either showing the displayed ester or amide link between two benzene rings. Some candidates recognised that at least 3 PAS units would be needed to show both the amide and ester links appropriately. Few responses were able to show a section of polymer that contained correct amide and ester linkages, the correct substituent groups and at least one end bond. The most common reason why candidates did not secure all 3 marks was omission of the OH group on one or more benzene rings of PAS.

This question was more challenging as candidates needed to show a polymer section. Many gave 2 'end bonds' as they would for a repeat unit but this was not sufficient here due to the many different possible combinations, we could not make assumptions about what would be next.

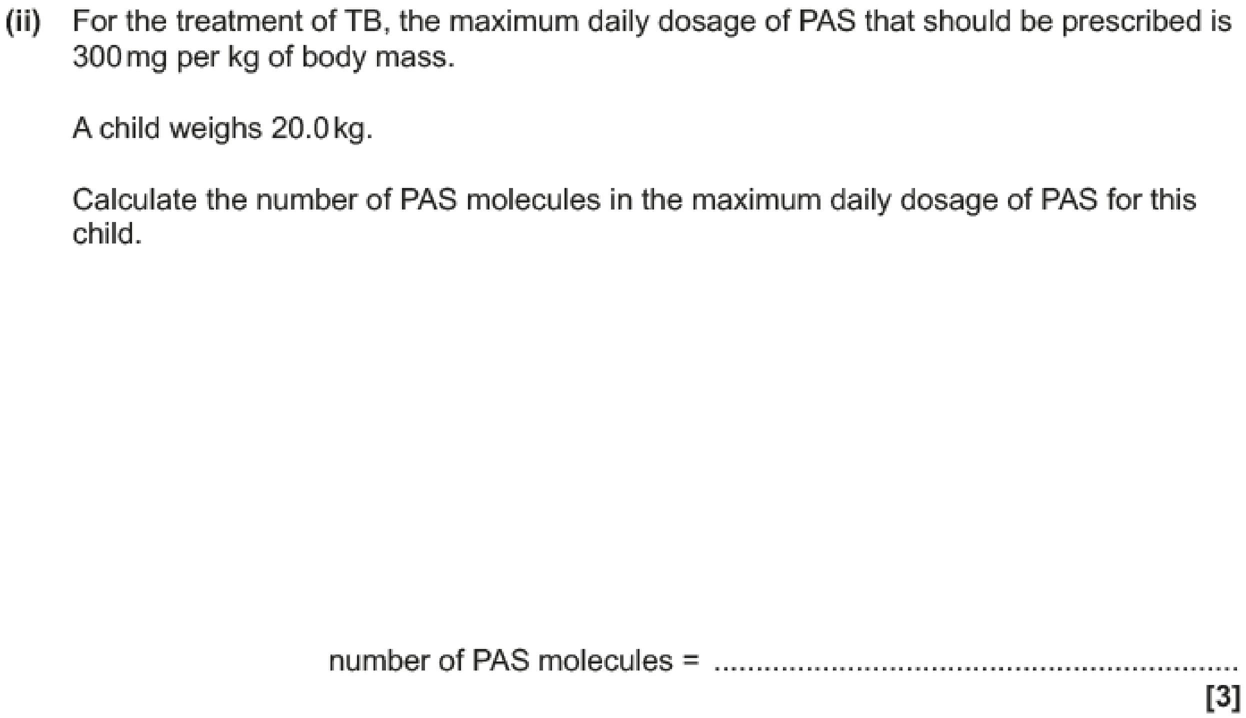
A common incorrect response was:



Furthermore, many candidates just gave 1 benzene ring, like this:



Question 20 (b) (ii)



(ii) For the treatment of TB, the maximum daily dosage of PAS that should be prescribed is 300 mg per kg of body mass.

A child weighs 20.0 kg.

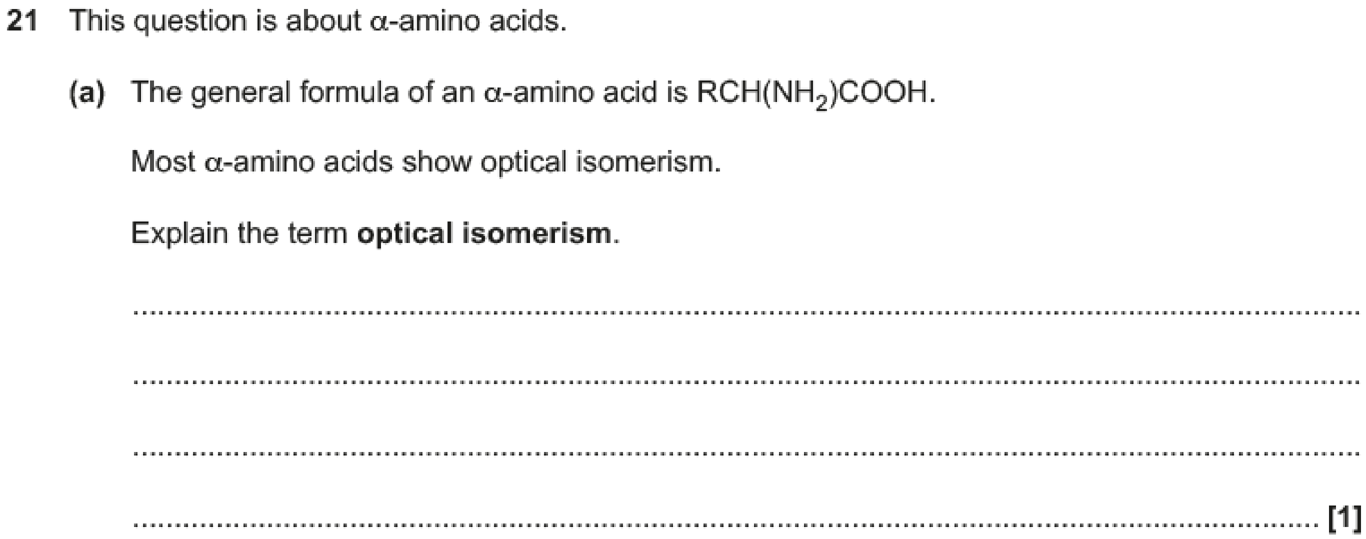
Calculate the number of PAS molecules in the maximum daily dosage of PAS for this child.

number of PAS molecules = ...

[3]

Nearly half the candidates were able to correctly calculate the number of PAS molecules in the maximum daily dosage. Some struggled with conversion from mg to g. Some made errors calculating the molar masses or did not calculate moles at all. Most were confident to multiply by N_A at the end. As with other calculations some lost marks for significant figures and rounding errors.

Question 21 (a)



21 This question is about α-amino acids.

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

Most α-amino acids show optical isomerism.

Explain the term **optical isomerism**.

....

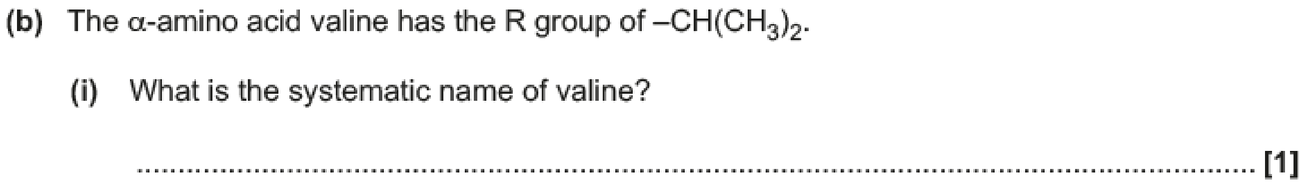
....

....

.... **[1]**

The majority of candidates were able to explain the term optical isomerism. However, it was still common to see incomplete responses such as 'mirror images' without reference to 'non-superimposable' or 'non-superimposable images' with no reference to 'mirror'. Lots gave the definitions for stereoisomerism or an explanation for how a chiral centre arises.

Question 21 (b) (i)



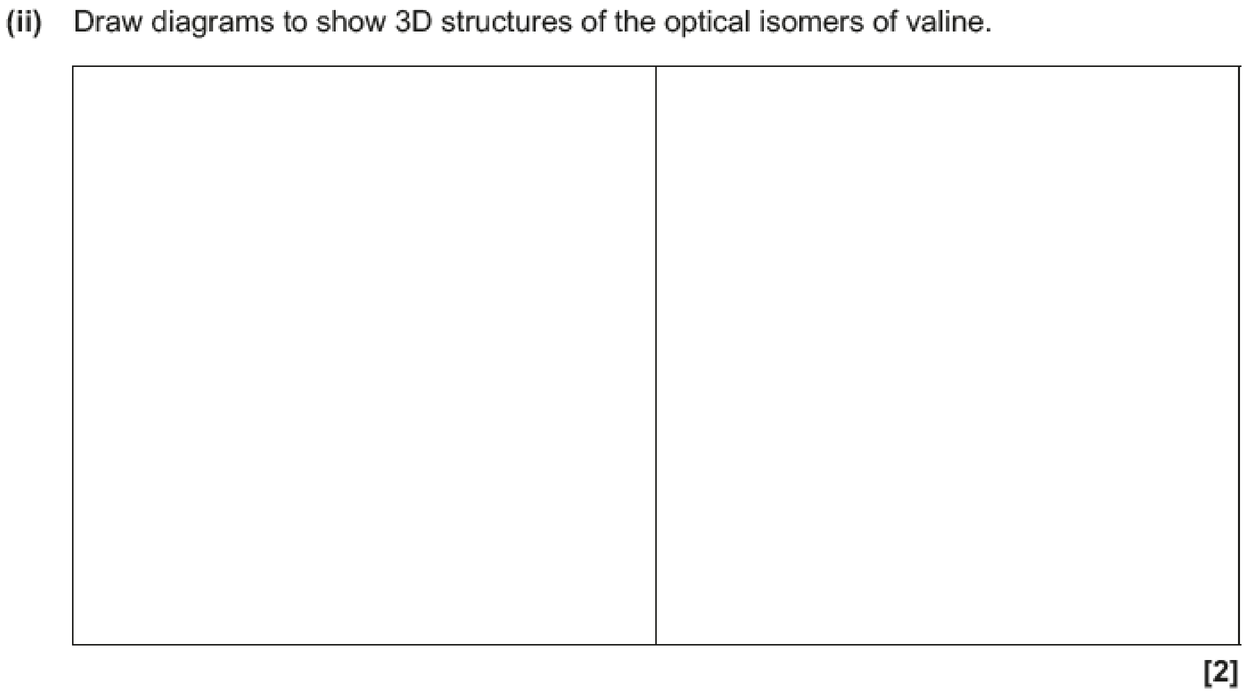
(b) The α-amino acid valine has the R group of –CH(CH$_3$)$_2$.

(i) What is the systematic name of valine?

.... **[1]**

Over half of candidates were unable to give the systematic name of valine, despite many being able to draw out a structure in the following question. A minority of candidates did not attempt the question. The best strategy was to use displayed formula, find the longest chain which included the COOH and label this as C number 1 to make sure of correct numbering. Common errors included 2-amino-3,3-dimethylpropanoic acid or 3-amino-2-methylbutanoic acid. Many candidates did not know how to name the amine functional group with errors including, amine, N-, nitro-, nitrile, etc. Some simply attempted to name the R group alone, e.g. '2-methylethyl- or 'dimethyl'.

Question 21 (b) (ii)



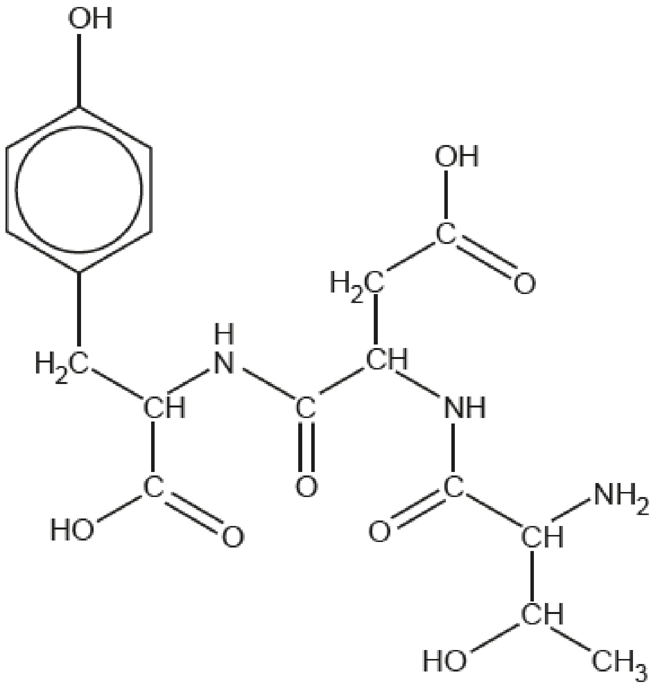
(ii) Draw diagrams to show 3D structures of the optical isomers of valine.

[2]

Most candidates (more than half) were able to score both marks here, on what was a well-practised question from previous examination series. Most were able to identify the correct chiral carbon, with four different groups attached, and draw a 3-D representation of the two optical isomers with correct connectivity. Some candidates inadvertently drew the same structure (e.g. switched groups and gave a mirror image) so if not drawn in a standard way it needed extra checking. Some lost the second mark due to incorrect connectivity or use of C$_3$H$_7$. Some attempted to write formulae out as literal mirror images, e.g. ${}_2({}_3\text{HC})\text{C}$ and need to be told that this isn't necessary as can sometime lead to connectivity errors.

Question 21 (c) (i)

(c) Three α-amino acids can react together to form compound **E**, shown below.



Compound E

(i) How many optical isomers are possible for compound **E**?

.... **[1]**

This question was challenging for even the most able candidates with very few obtaining the correct answer of 16. Many identified the four chiral centres in compound E, often labelling these with an asterisk. However, only a small proportion were able to predict that there would be 16 possible optical isomers. Most provided an answer of four corresponding to the number of chiral centres or eight considering that each chiral centre would result in two optical isomers. They struggled to see that they needed 2^n in this case where n represents the number of chiral centres. Candidates have probably seen very few, if any, examples of chiral compounds with more than two chiral centres.

Question 21 (c) (ii)

(ii) A student hydrolyses compound **E** with dilute hydrochloric acid, $HCl(aq)$.

Draw the structures of the organic products formed by this hydrolysis.

[4]

A significant number of candidates did not attempt this question despite similar questions appearing in previous exam series. However, approximately a quarter of candidates scored all 4 marks. Some lost the final mark for not protonating the amine groups as required as under acidic conditions. A very common error was to hydrolyse the amides to give acyl chlorides or even aldehydes rather than carboxylic acids. Lower scoring candidates often had incomplete hydrolysis or no hydrolysis at all with just changes to acid/amine/phenol functional groups, e.g. protonation of amine to form salts or swapping or OH groups for Cl. Candidates need to check their answers carefully for missing or extra Hs as this lost marks. It was much easier to mark candidates' work presented with structures with a similar arrangement to compound E.

Question 22 (a) (i)

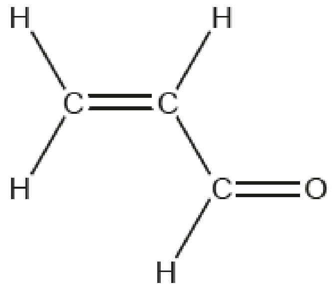
22 This question is about reactions of acrolein, $H_2C{=}CHCHO$.

(a) Acrolein reacts with sodium cyanide in acidic conditions, NaCN(aq) / H^+(aq).

(i) Outline the reaction mechanism for this reaction, showing the intermediate and the organic product.

The structure of acrolein has been provided.

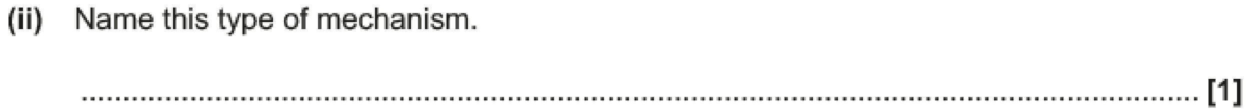
Include curly arrows and relevant dipoles.



[4]

There were many excellent examples of precisely drawn mechanisms for the reaction of acrolein with sodium cyanide in acidic conditions and so most candidates gained at least 3 marks. The importance of accuracy when drawing curly arrows needs to be emphasised when teaching mechanisms - arrows must start at lone pairs or negative charges or come from bonds. Many candidates lost marks due to incorrect arrows. Common errors included the use of NaCN or HCN rather than the cyanide ion, the first curly arrow coming from the N of CN-, omission of partial charge across the C=O double bond and addition of partially charges to hydrogen or oxygen. Lower scoring responses often included an intermediate and/or product containing sodium. Some attempted electrophilic addition using HCN across the double bond. A few gained some credit for the mechanism for a competing reaction with nucleophilic addition on CH_2 of C=C. This is not covered in the A Level specification and no candidates scored full marks for this alternative.

Question 22 (a) (ii)



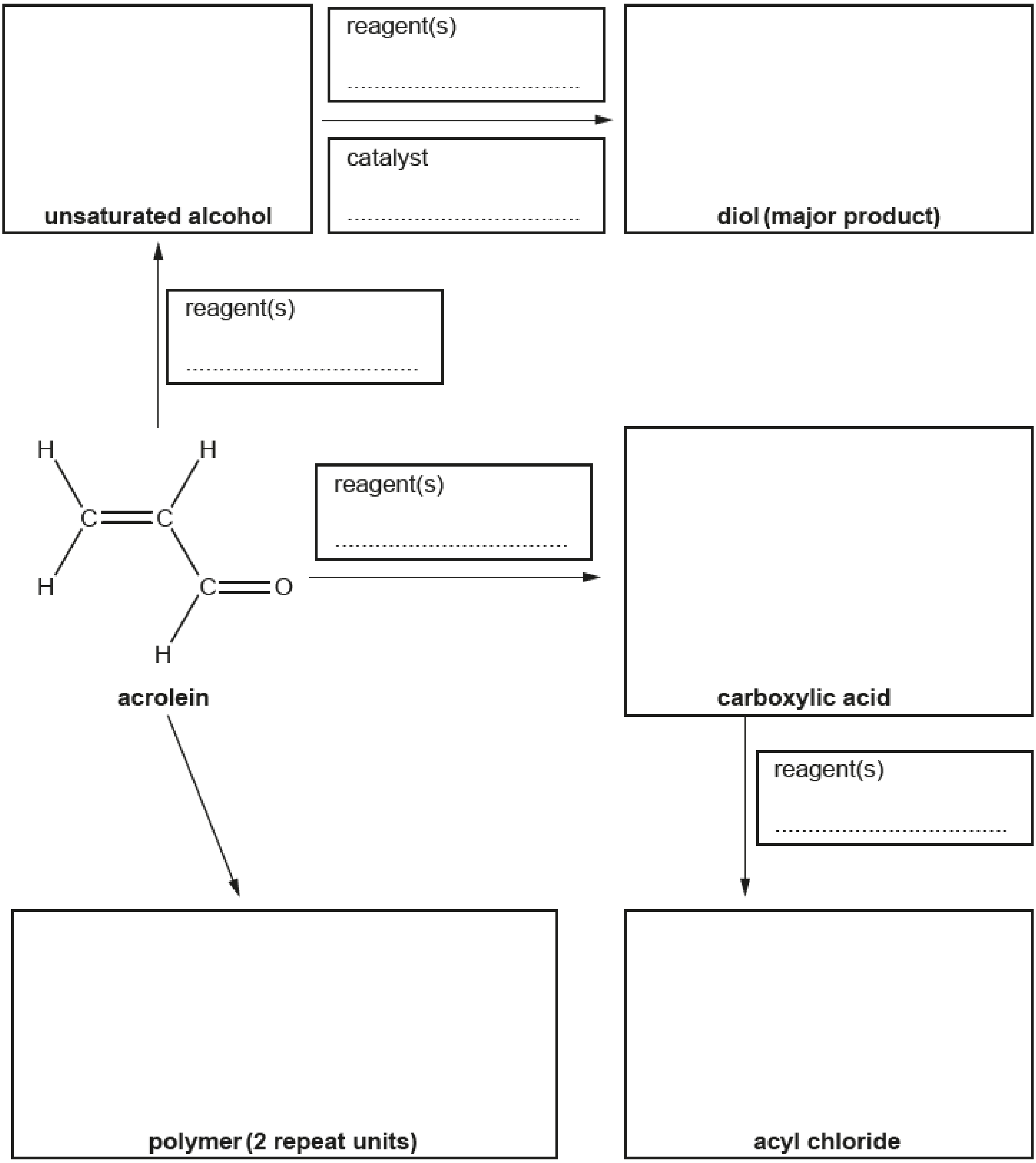
(ii) Name this type of mechanism.

.... **[1]**

Most candidates were able to recall the correct response here, especially for those more confident with drawing out the mechanism. The most common incorrect response was nucleophilic substitution. Some suggested reduction or nucleophilic addition elimination. Misspellings of ‘nucleophilic’ were often seen.

Question 22 (b)

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



[9]

This question discriminated well. Many candidates were able to demonstrate an excellent knowledge of organic reactions and it was not uncommon to see scores of at least 7 marks. This question identified which candidates had learned their synthetic routes including necessary reagents and conditions. Marks were often lost for small details such as missing Hs (check all Cs have four bonds) or not specifying that steam is required for hydration of alkenes or missing the acid needed for oxidation. Many suggested the use of NaOH or just a mixture of acids to product the diol. The minor 1,3-diol or 1,1-diol product was often seen.

The sequence leading to an acyl chloride from acrolein was usually the most well answered. However, quite a few tried to use HCl to make the acyl chloride. Many lost marks for the polymer for incorrect connectivity on the aldehyde, e.g. -COH or attempting to make a polymer via connection of the aldehyde group.

OCR support

This topic guide provides a summary of synthetic routes. Copies of the summary posters without the conditions can be found on Teach Cambridge. This should be used in conjunction with the organic synthesis topic exploration pack.

Question 23*

23* An unknown organic compound is analysed.

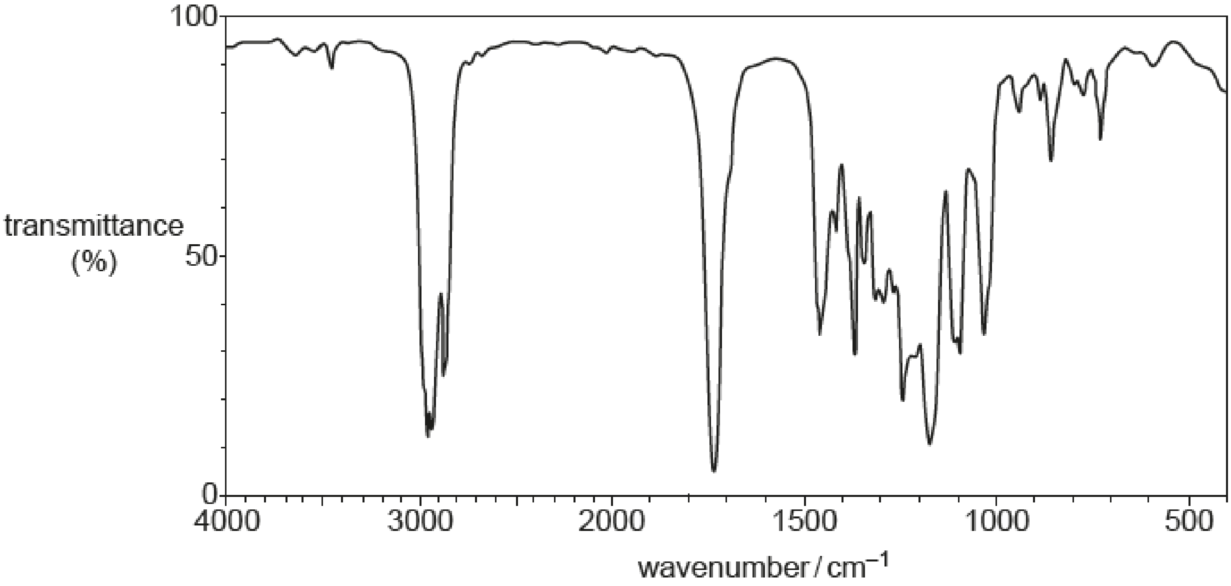
The results are shown below.

Addition of 2,4-DNP
No visible change

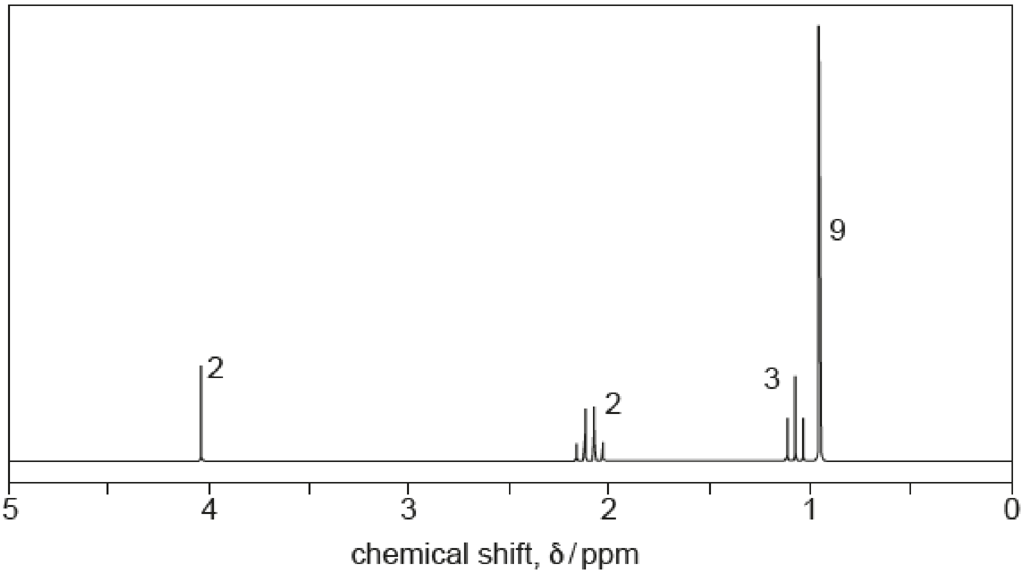
Elemental analysis by mass
C, 66.63%; H, 11.18%; O, 22.19%

Mass spectrum
Molecular ion peak at $m/z = 144.0$

IR spectrum



Proton NMR spectrum
The numbers by each peak are the relative peak areas.



Use the information to identify the organic compound.

Show **all** your reasoning.

....

....

....

....

....

.... **[6]**

Most candidates were able to deduce the empirical and/or molecular formula of the organic compound. Analysis of the IR spectrum was also well attempted, but some candidates assumed the unknown was a carboxylic acid, attributing the sharp peak just below 3000 cm^{-1} to an OH group. Others misidentified the C=O peak as a C=C group suggesting alkene or arene structure. They were often led to this conclusion as they believed no precipitate with 2,4-DNP suggested no C=O rather than no aldehyde or ketone.

Good analysis of the NMR data was crucial for deducing the correct ester. Some candidates opted to annotate the proton NMR spectrum, some produced tables and others gave written details for each peak. It was vital that they were able to interpret all information for each peak i.e. number of proton environments, the type of environment from chemical shift, the number of protons in each environment from relative peak areas and use of splitting patterns to find information about adjacent protons. Many tried to make the data fit their proposed structure rather than the other way round. Some suggested structures that were only partially consistent with the data such as $CH_3CH_2CH_2COOC(CH_3)_3$ and were awarded Level 2. Others did not take full note of all the information provided, for example omitting the 2,4-DNP observations, giving the ketone $(CH_3)_3COCH_2COCH_2CH_3$ or not checking it matched the molecular formula $CH_3CH_2COOC(CH_3)_3$ so only achieved Level 1.

Candidates need to be encouraged to draw a structure as without they can only achieve a maximum of 2 marks despite some excellent analysis of the data. Conversely, it is not sufficient to just give a structure, candidates must give analysis of the data provided.

Exemplar 3

C $66.63/12$ H $11.18/1$ O $22.19/16$

= $\frac{5.553}{1.387}$ $\frac{11.18}{1.387}$ $\frac{1.387}{1.387}$

= 4 : 8 : 1 empirical formula = C_4H_8O

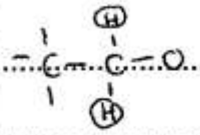
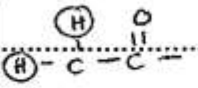
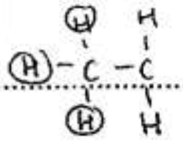
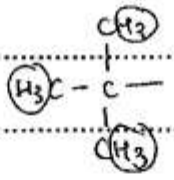
mr = 72

$144/72 = 2$ molecular formula = $C_8H_{16}O_2$

because mr = m/z peak which is furthest to right.

IR spectrum: C=O peak at around 1700 cm^{-1}

C-O peak at around 1300 cm^{-1}

shift	proton type	relative peak area	splitting	no. adjacent protons	deductions.
4.0	HC–O	2	singlet	0	
2.1	HC–C=O	2	quartet	3	
1.1	HC–R	3	triplet	2	
0.9	HC-R	9	singlet	0	

[6]

Additional answer space if required.

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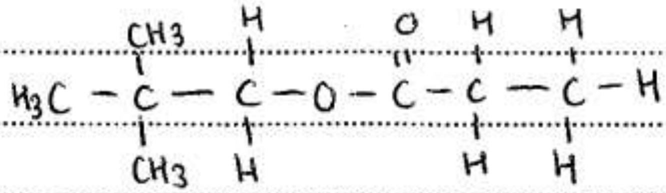
(23)



$C_8H_{16}O_2$

This is a good Level 3 6 mark response. As well as this clearly laid out analysis they also had details written on the question, e.g. no aldehyde or ketone due to no reaction with 2,4-DNP. This response has been selected due to the detailed analysis of NMR data that has been summarised in a table.

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