

OCR A-Level Chemistry A

Module 6: Organic chemistry and analysis

Questions only

All 93 questions in Module 6: Organic chemistry and analysis

Questions

93

Total marks

549

Name

Class or teacher

Date

Instructions

- Answer all questions in the spaces provided.
- Use black ink. Show your working for every calculation.
- You may use a scientific calculator and the OCR Data Sheet.
- Print the separate mark scheme when you are ready to mark your answers.

For marking

Total _____ / 549 Percentage _____ %

Questions from OCR past papers, 2017–2025, reproduced for revision. Practise these topics online, with instant marking:

whiteboardchemistry.com/revision/exam-questions/ocr-a-level-chemistry/?[topics=amines-amino-acids-and-polymers,aromatic-compounds,carbon-carbon-bond-formation-and-synthesis,carbonyls-carboxylic-acids-and-esters,chromatography-and-functional-group-tests,nmr-spectroscopy&len=0](https://whiteboardchemistry.com/revision/exam-questions/ocr-a-level-chemistry/?topics=amines-amino-acids-and-polymers,aromatic-compounds,carbon-carbon-bond-formation-and-synthesis,carbonyls-carboxylic-acids-and-esters,chromatography-and-functional-group-tests,nmr-spectroscopy&len=0)

Questions

6 topics · 93 questions · 549 marks

Q1 · Amines, amino acids and polymers · June 2017 · Paper 2 (Synthesis and analytical techniques) · Q18 · [14 marks]

This question also needs Alcohols and haloalkanes, Alkenes and addition polymers, Atomic structure and isotopes and Basic concepts of organic chemistry.

This question is about organic compounds containing nitrogen.

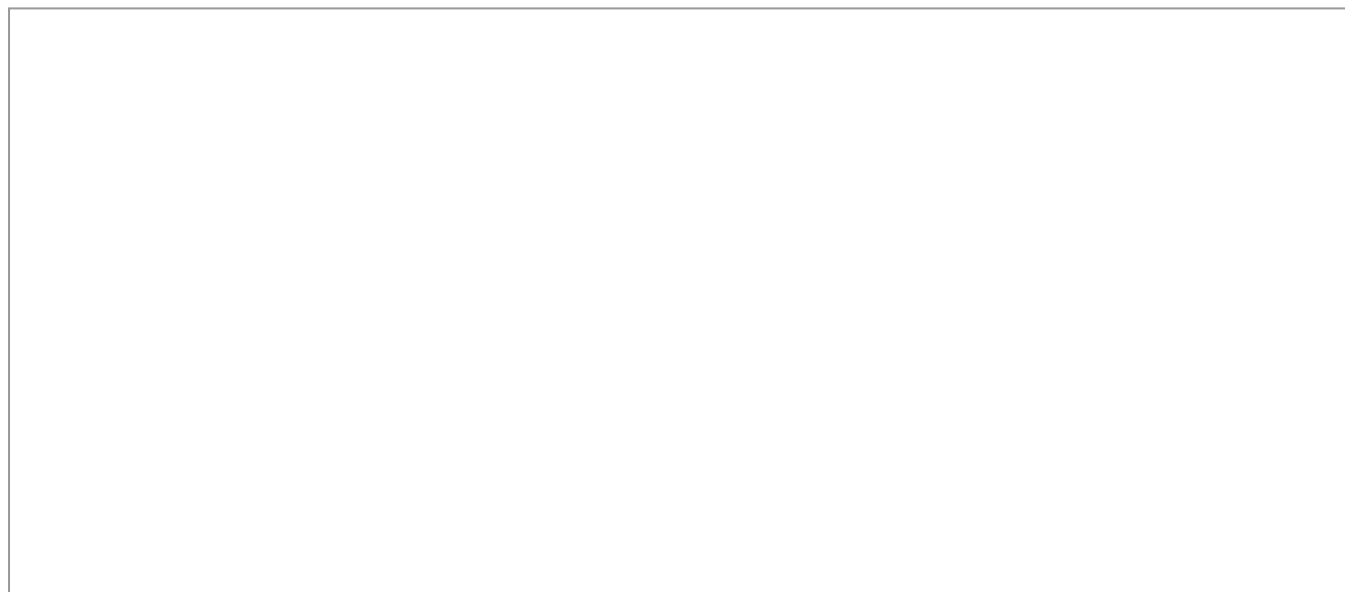
Sodium cyanide, NaCN, can be reacted with many organic compounds to increase the length of a carbon chain.

18(a)(i) 1-Chloropropane, $\text{CH}_3\text{CH}_2\text{CH}_2\text{Cl}$, reacts with ethanolic sodium cyanide by nucleophilic substitution.

Outline the mechanism for this reaction.

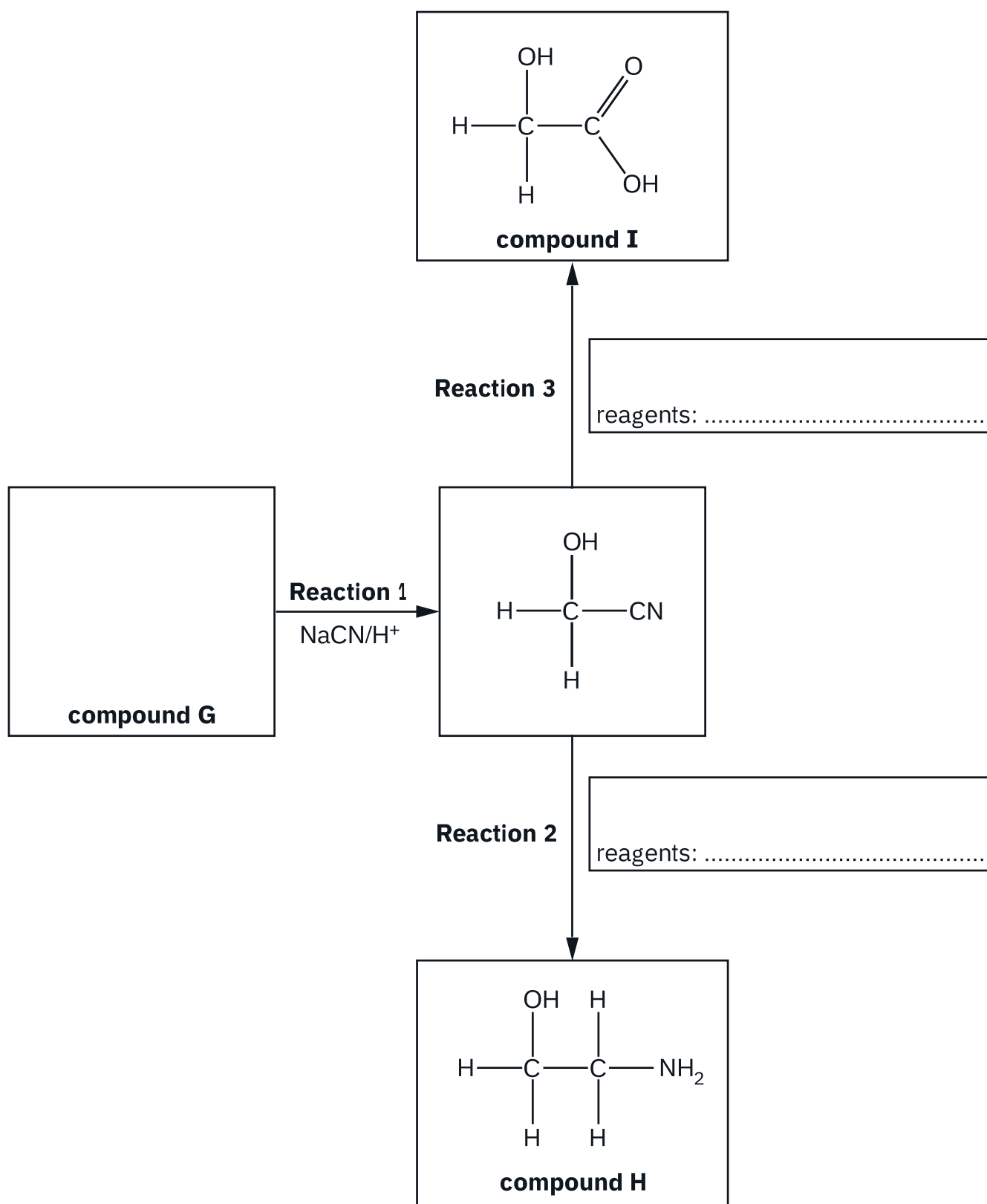
Include curly arrows, relevant dipoles and the structure of the organic product.

[3 marks]



18(a)(ii) Compound G is used to synthesise compounds H and I as shown in the flowchart below.

Complete the flowchart showing the structure of compound G and the formulae of the reagents for Reaction 2 and Reaction 3.



[3 marks]

Draw your answer on the figure above.

18(a)(iii) Compound H reacts with dilute hydrochloric acid to form a salt.

Explain why compound H can react with dilute hydrochloric acid and suggest a structure for the salt formed.

[2 marks]

Explanation

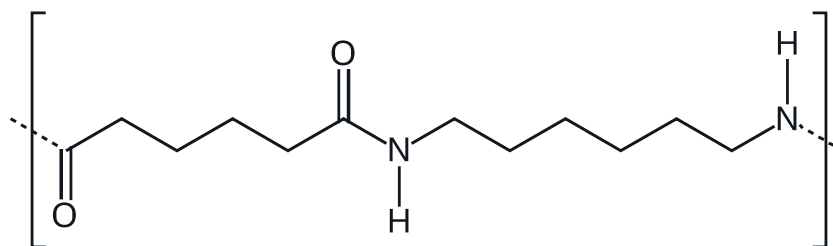
Structure

18(a)(iv) Compound I is the monomer for the biodegradable polymer J.

Draw two repeat units of polymer J and suggest a reason why it is biodegradable.

[3 marks]

The repeat unit of Nylon 6,6 is shown below.



Nylon 6,6

18(b)(i) Draw the structures of two monomers that can be used to form Nylon 6,6.

[2 marks]

18(b)(ii) A sample of Nylon 6,6 has a relative molecular mass of 21500.

Estimate the number of repeat units in the sample.

Give your answer as a whole number.

number of repeat units =

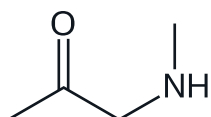
[1 mark]

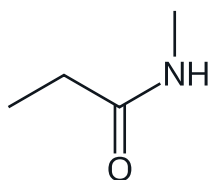
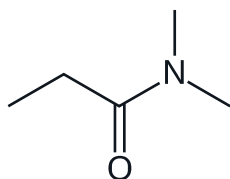
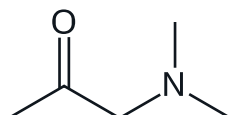
Q2 • Amines, amino acids and polymers • June 2017 • Paper 2 (Synthesis and analytical techniques) • Q7 • [1 mark]

Which molecule is a secondary amine?

Tick (✓) one box.

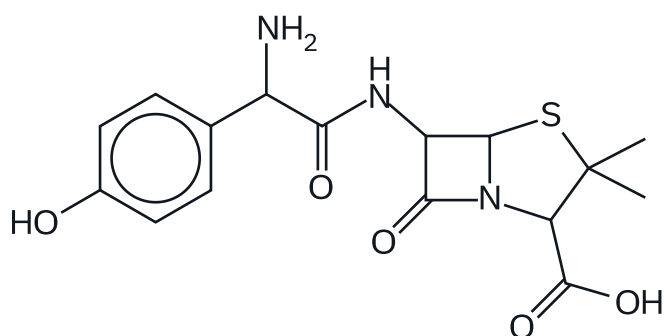
☐ **A**



☐ B☐ C☐ D

Q3 · Amines, amino acids and polymers · June 2017 · Paper 2 (Synthesis and analytical techniques) · Q8 · [1 mark]

What is the number of chiral centres in the molecule below?



Tick (✓) one box.

☐ A 2☐ B 3☐ C 4☐ D 5

Q4 · Amines, amino acids and polymers · June 2018 · Paper 2 (Synthesis and analytical techniques) · Q17 · [7

marks]

This question also needs Basic concepts of organic chemistry.

The general formula of an α -amino acid is $\text{RCH}(\text{NH}_2)\text{COOH}$.

17(a) The α -amino acid cysteine ($\text{R} = \text{CH}_2\text{SH}$) shows optical isomerism.

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

[2 marks]

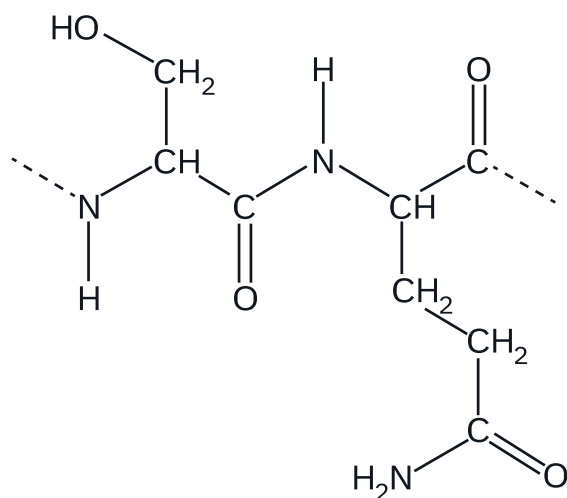
17(b) The α -amino acid lysine ($\text{R} = (\text{CH}_2)_4\text{NH}_2$) reacts with an excess of dilute hydrochloric acid to form a salt.

Draw the structure of the salt formed in this reaction.

[2 marks]

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

A short section of a protein chain is shown below.



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

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

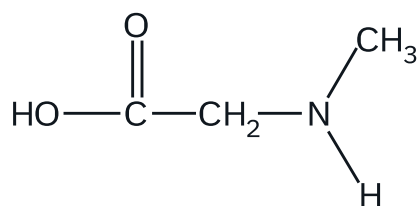
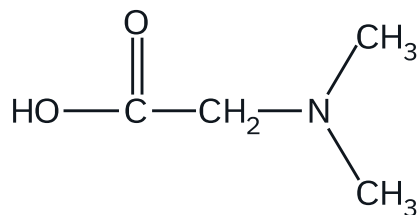
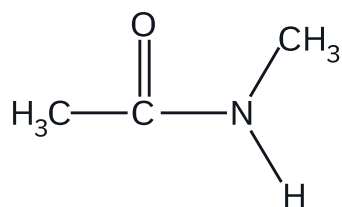
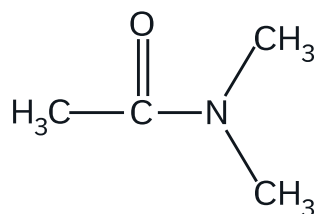
[3 marks]

Blank area for drawing the structures of the organic products.

mark]

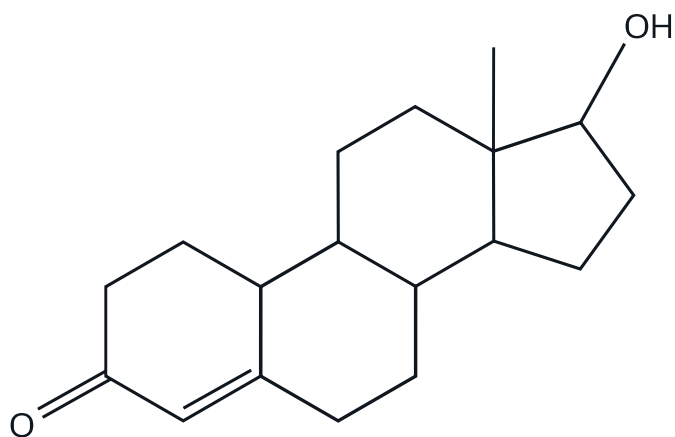
Which compound is a secondary amide?

Tick (✓) one box.

☐ **A**☐ **B**☐ **C**☐ **D**

Q6 · Amines, amino acids and polymers · June 2019 · Paper 2 (Synthesis and analytical techniques) · Q7 · [1 mark]

What is the number of chiral carbon atoms in the steroid molecule below?



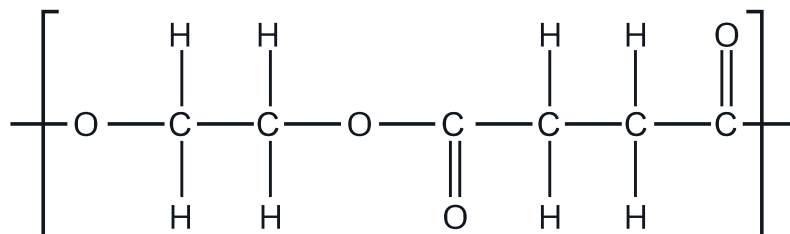
Tick (✓) one box.

- ☐ **A** 5
- ☐ **B** 6
- ☐ **C** 7
- ☐ **D** 8

Q7 • Amines, amino acids and polymers • June 2019 • Paper 2 (Synthesis and analytical techniques) • Q9 • [1 mark]

This question also needs Alkenes and addition polymers.

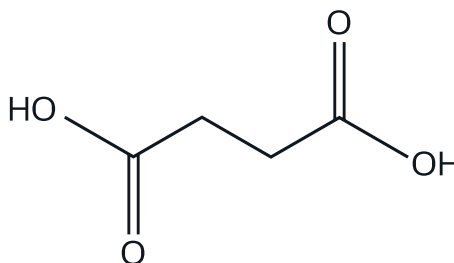
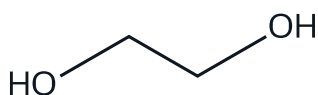
The repeat unit of a polymer is shown below.



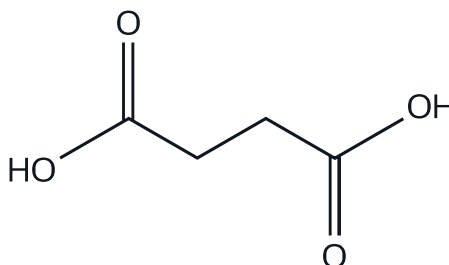
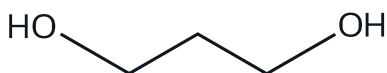
Which monomers could form this polymer?

Tick (✓) one box.

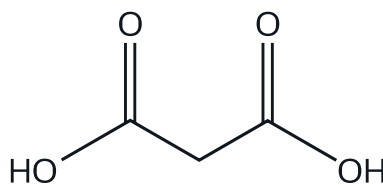
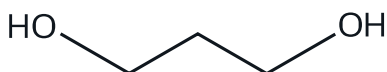
☐ **A**



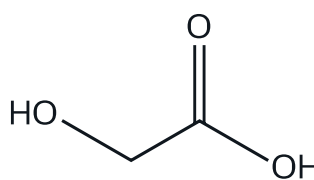
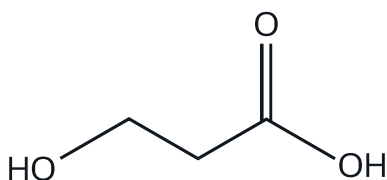
☐ **B**



☐ **C**

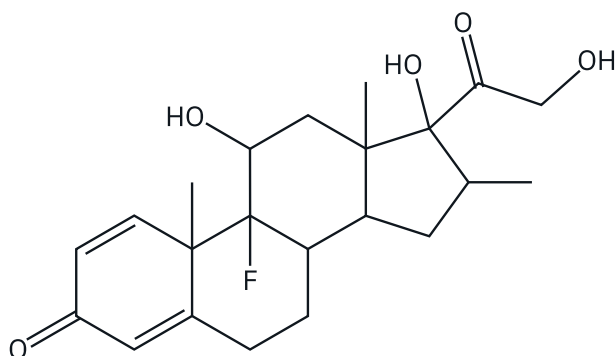


☐ **D**

**Q8 • Amines, amino acids and polymers • June 2022 • Paper 2 (Synthesis and analytical techniques) • Q5 • [1**

mark]

The structure of a drug is shown below:



How many chiral carbon atoms are there in a molecule of the drug?

Tick (✓) one box.

- ☐ **A** 5
- ☐ **B** 6
- ☐ **C** 7
- ☐ **D** 8

Q9 • Amines, amino acids and polymers • June 2023 • Paper 2 (Synthesis and analytical techniques) • Q21 • [9 marks]

This question is about α -amino acids.

21(a) The general formula of an α -amino acid is $\text{RCH}(\text{NH}_2)\text{COOH}$.

Most α -amino acids show optical isomerism.

Explain the term **optical isomerism**.

[1 mark]

The α -amino acid valine has the R group of $-\text{CH}(\text{CH}_3)_2$.

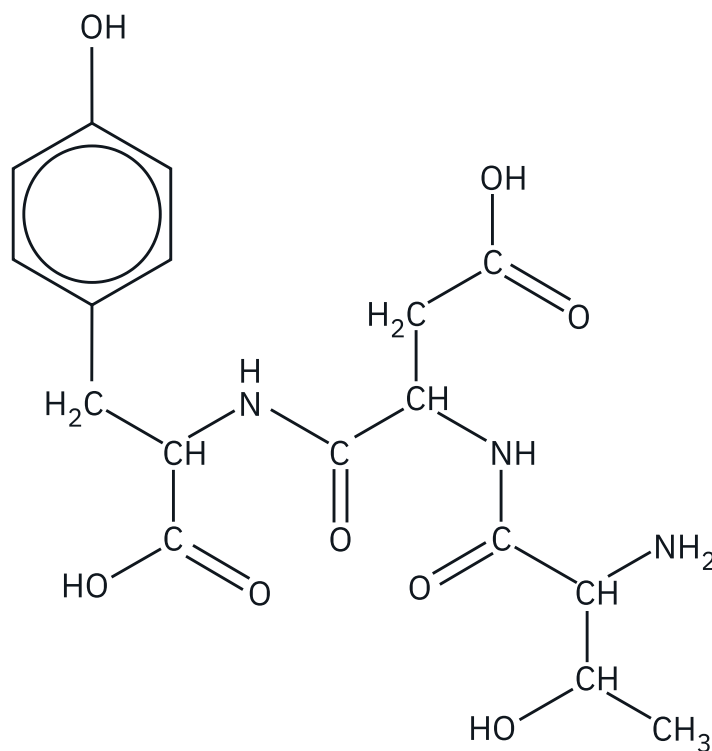
21(b)(i) What is the systematic name of valine?

[1 mark]

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

[2 marks]

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



Compound E

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

[1 mark]

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

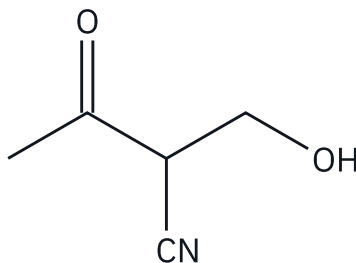
Draw the structures of the organic products formed by this hydrolysis.

[4 marks]

Q10 · Amines, amino acids and polymers · June 2023 · Paper 3 (Unified chemistry) · Q3 · [6 marks]

This question also needs Alcohols and haloalkanes.

3 A chemist is investigating compound A, shown below, as a potential organic intermediate.



Compound A

Describe the type of stereoisomerism shown by compound A and suggest **three** reactions of compound A, one for each of the three functional groups using reagents of your choice.

In your answer, show stereoisomers of compound A, your chosen reactants and conditions, and the structures for the organic products produced.

Mechanisms and equations are **not** required.

[6 marks]

Q11 · Amines, amino acids and polymers · June 2024 · Paper 2 (Synthesis and analytical techniques) · Q12 · [1 mark]

1,6-Diaminohexane, $\text{H}_2\text{N}(\text{CH}_2)_6\text{NH}_2$, reacts with hexanedioyl dichloride, $\text{ClOC}(\text{CH}_2)_4\text{COCl}$ to form a polyamide and one other product.

What is the other product formed in this reaction?

Tick (✓) one box.

☐ **A** HCl

☐ **B** H_2O

☐ **C** CO

☐ **D** NH_3

Q12 · Amines, amino acids and polymers · June 2024 · Paper 2 (Synthesis and analytical techniques) · Q22 · [6 marks]

This question also needs Alkenes and addition polymers.

α -Amino acids have the general formula $\text{RCH}(\text{NH}_2)\text{COOH}$.

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} .

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

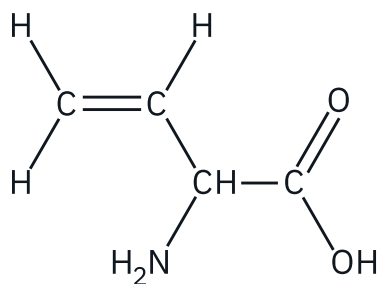
Determine the molar mass of this polymer.

Give your answer to the nearest whole number.

molar mass of polymer = g mol^{-1}

[3 marks]

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

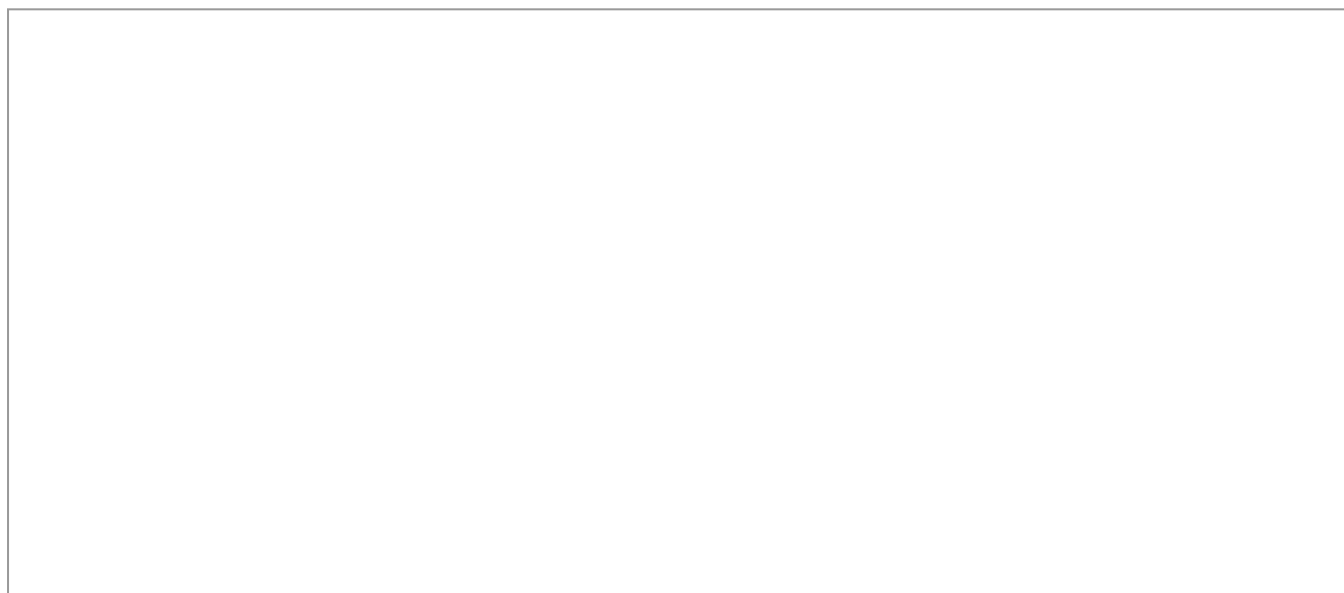


Draw **2** repeat units of these polymers.

Display the sections linking the monomers together.

[3 marks]

addition polymer (2 repeat units)



condensation polymer (2 repeat units)

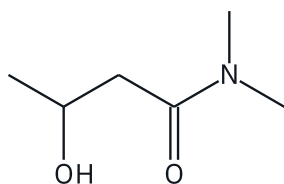
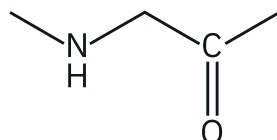
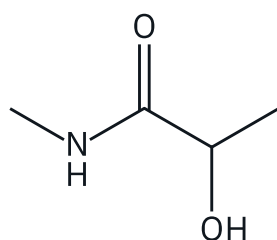
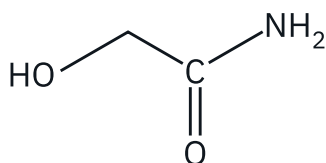


Q13 · Amines, amino acids and polymers · June 2024 · Paper 2 (Synthesis and analytical techniques) · Q9 · [1

mark]

Which compound is a secondary amide?

Tick (✓) one box.

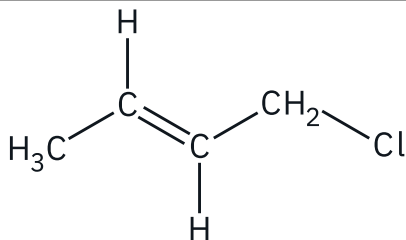
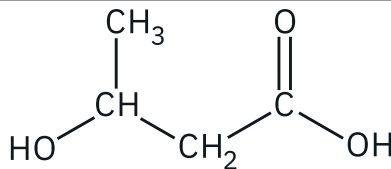
☐ **A**☐ **B**☐ **C**☐ **D**

Q14 · Amines, amino acids and polymers · June 2025 · Paper 2 (Synthesis and analytical techniques) · Q18 · [8 marks]

This question also needs Alkenes and addition polymers.

This question is about polymers.

The structures of 1-chlorobut-2-ene and 3-hydroxybutanoic acid are shown.

**1-Chlorobut-2-ene****3-Hydroxybutanoic acid**

18(a) 1-Chlorobut-2-ene and 3-hydroxybutanoic acid can both form polymers.

Draw **two** repeat units of each of the polymers formed.

State the type of polymerisation reaction that takes place for each compound.

[4 marks]

Two repeat units of polymer of 1-chlorobut-2-ene

Type of polymerisation

Two repeat units of polymer of 3-hydroxybutanoic acid

Type of polymerisation

The disposal of polymers containing chlorine is a major challenge.

18(b)(i) Suggest why a polymer made from monomers containing chlorine, such as 1-chlorobut-2-ene, is difficult to dispose of by incineration.

[1 mark]

18(b)(ii) The polymer formed from 3-hydroxybutanoic acid can be hydrolysed. This makes the polymer biodegradable.

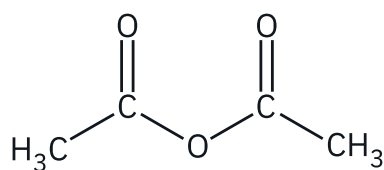
Suggest what feature in the structure of this polymer allows this hydrolysis.

[1 mark]

18(c) 3-Hydroxybutanoic acid reacts with ethanoic anhydride, $(\text{CH}_3\text{CO})_2\text{O}$.

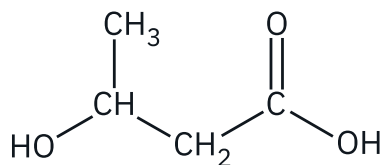
Complete the equation for this reaction.

Show the structures of the organic compounds.

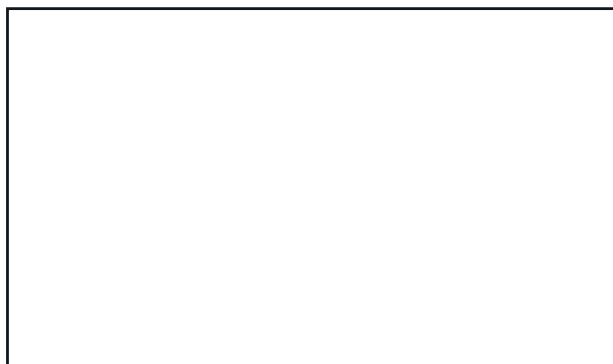


Ethanoic anhydride

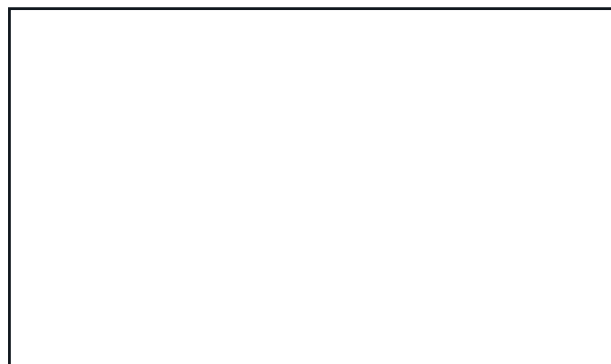
+



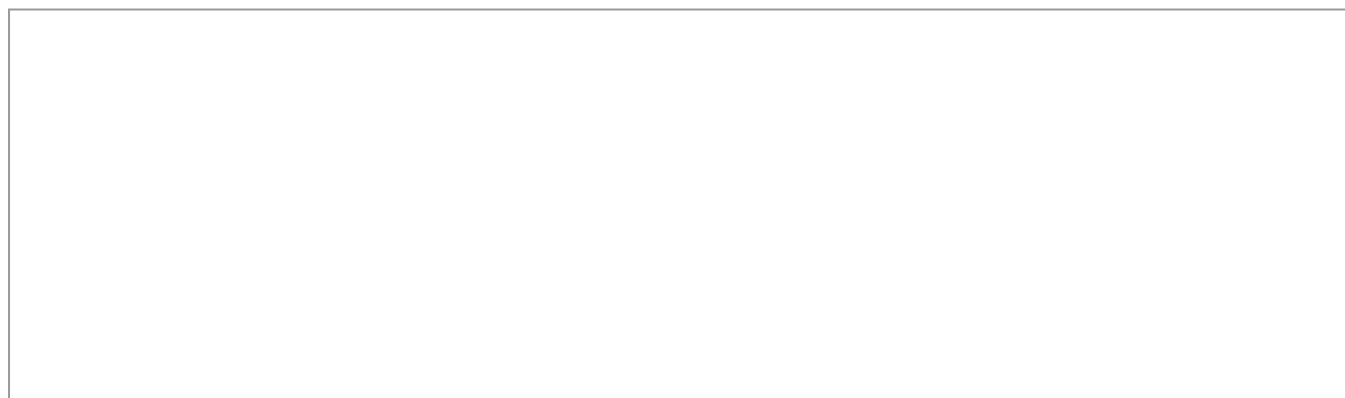
3-Hydroxybutanoic acid



+



[2 marks]



[15 marks]

This question also needs Alcohols and haloalkanes and Basic concepts of organic chemistry.

This question is about organic compounds containing nitrogen.

21(a) Salt H, $(\text{CH}_3)_2\text{CHNH}_3\text{Cl}$, is used in the manufacture of garden weedkillers.

The flowchart shows the synthesis of the salt H from propanone.

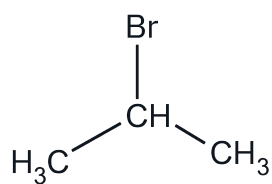
Complete the flowchart.

Show structures for organic compounds.

propanone

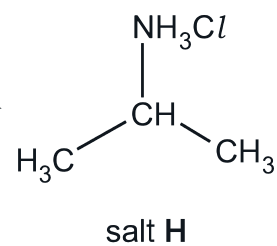
NaBH₄

reagent:



reagent:

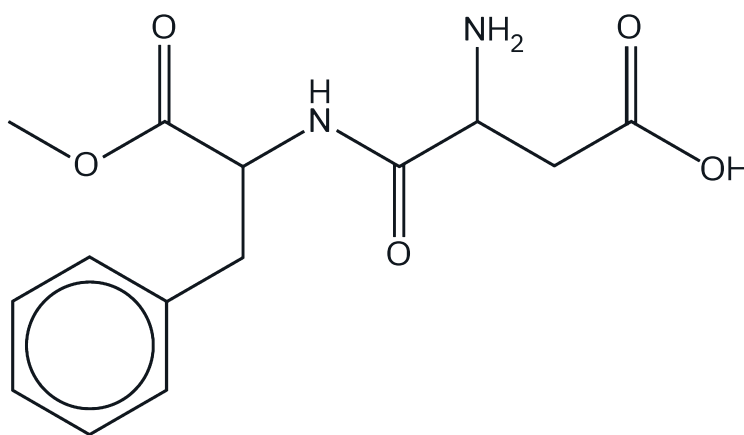
reagent:



[5 marks]



Aspartame, shown below, is an artificial sweetener commonly used as a sugar substitute.



aspartame

21(b)(i) Aspartame contains several functional groups.

Apart from the benzene ring, name the functional groups in aspartame.

[3 marks]

21(b)(ii) A sample of aspartame is hydrolysed with aqueous acid.

Draw the structures of the three organic products of the complete acid hydrolysis of aspartame.

[4 marks]

21(b)(iii) Some people are concerned that aspartame, $C_{14}H_{18}N_2O_5$, may have adverse health effects.

Research shows that the safe maximum daily intake of aspartame is $1.7 \times 10^{-4} \text{ mol kg}^{-1}$.

- A typical UK adult has a mass of 75 kg.
- A can of a diet drink contains 167 mg of aspartame.

How many cans of this diet drink is it safe for a typical adult to drink in one day?

Number of cans =

[3 marks]

Q16 • Amines, amino acids and polymers • November 2021 • Paper 2 (Synthesis and analytical techniques) • Q18 •

[18 marks]

This question also needs Alcohols and haloalkanes and Amount of substance.

This question is about organic acids.

Table 18.1 shows the R groups in four amino acids.

Amino acid	R group
alanine	CH_3-
valine	$(\text{CH}_3)_2\text{CH}-$
threonine	$\text{CH}_3\text{CH}(\text{OH})-$
lysine	$\text{H}_2\text{N}(\text{CH}_2)_4-$

Table 18.1

Most amino acids show optical isomerism.

18(a)(i) Explain the term optical isomerism.

[1 mark]

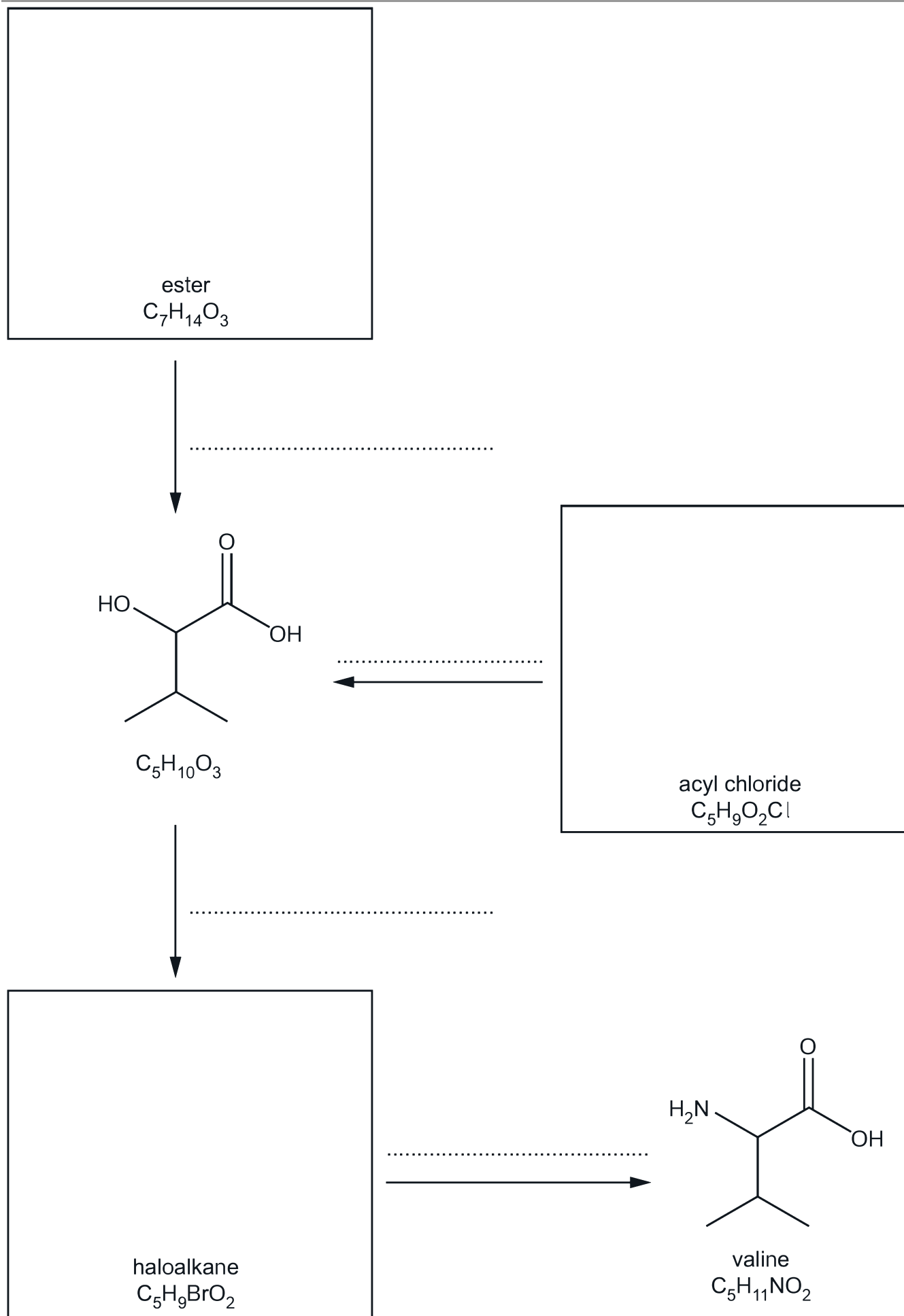
18(a)(ii) Draw 3-D diagrams to show the optical isomers of alanine.

[2 marks]

18(a)(iii) How many optical isomers does threonine have?

[1 mark]

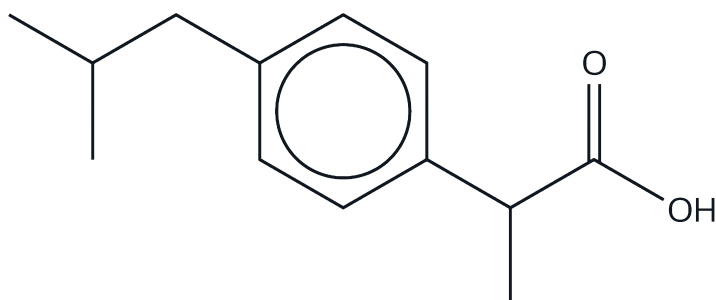
18(b) Complete the flowchart for two synthetic routes to the amino acid valine.



[7 marks]

Draw your answer on the figure above.

Ibuprofen, shown below, is used as a painkiller.



ibuprofen

18(c)(i) What is the molecular formula of ibuprofen?

[1 mark]

18(c)(ii) One ibuprofen tablet contains 400 mg of ibuprofen.

Calculate the number of ibuprofen molecules in one ibuprofen tablet.

Give your answer to 3 significant figures.

number of ibuprofen molecules =

[3 marks]

Tablets based on ibuprofen and lysine are now available from pharmacies.

These tablets are claimed to act faster than ibuprofen by being absorbed into the body more quickly than ibuprofen alone.

One type of these tablets contains a salt of ibuprofen and the amino acid lysine ($R = -(CH_2)_4NH_2$) in a 1:1 molar proportion.

18(d)(i) Suggest the structure of each ion in this lysine salt of ibuprofen, including the position of any charges.

- ion	+ ion
-------	-------

[2 marks]

18(d)(ii) Suggest why tablets based on a salt of ibuprofen should act faster in the body than ibuprofen.

[1 mark]

Q17 · Amines, amino acids and polymers · November 2021 · Paper 2 (Synthesis and analytical techniques) · Q2 · [1 mark]

Which type(s) of stereoisomerism is/are shown by 2,4-dimethylhex-2-ene?

Tick (✓) one box.

- ☐ **A** E / Z isomerism only.
- ☐ **B** Optical isomerism only.
- ☐ **C** Both E / Z isomerism and optical isomerism.
- ☐ **D** Neither E / Z isomerism nor optical isomerism.

Q18 · Amines, amino acids and polymers · November 2021 · Paper 2 (Synthesis and analytical techniques) · Q9 · [1 mark]

Which reaction is not a reduction?

Tick (✓) one box.

- ☐ **A** $\text{C}_6\text{H}_5\text{NO}_2 \rightarrow \text{C}_6\text{H}_5\text{NH}_2$
- ☐ **B** $\text{CH}_3\text{CN} \rightarrow \text{CH}_3\text{CH}_2\text{NH}_2$
- ☐ **C** $\text{CH}_3\text{CH}_2\text{Cl} \rightarrow \text{CH}_3\text{CH}_2\text{NH}_2$
- ☐ **D** $\text{CH}_3\text{COCH}_3 \rightarrow \text{CH}_3\text{CHOHCH}_3$

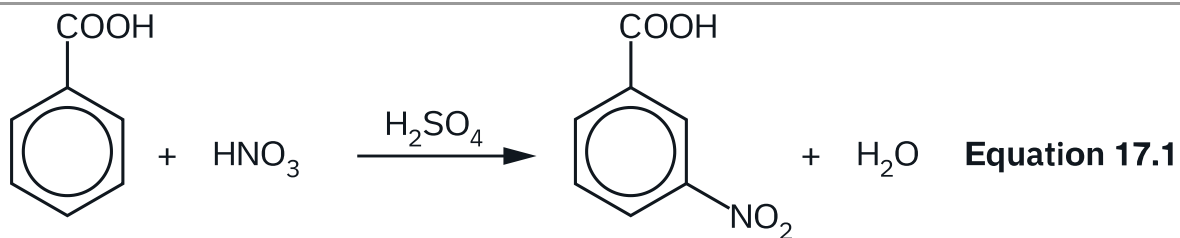
Q19 · Aromatic compounds and phenols · June 2017 · Paper 2 (Synthesis and analytical techniques) · Q17 · [21 marks]

This question also needs Alkenes and addition polymers, Amount of substance, Basic concepts of organic chemistry and Reaction rates and equilibrium.

This question is about the chemistry of aromatic compounds.

Benzoic acid can be nitrated by concentrated nitric acid in the presence of concentrated sulfuric acid as a catalyst, as shown in Equation 17.1.

The organic product of this reaction is 3-nitrobenzoic acid.

**benzoic acid****3-nitrobenzoic acid**

17(a)(i) Outline the mechanism for this nitration of benzoic acid.

Show how H_2SO_4 behaves as a catalyst.

[5 marks]

17(a)(ii) A chemist carries out the reaction in Equation 17.1 using 4.97 g of benzoic acid.

The chemist obtains 3-nitrobenzoic acid as an impure solid.

The chemist purifies the solid to obtain 4.85 g of 3-nitrobenzoic acid.

Describe a method to obtain a pure sample of 3-nitrobenzoic acid from the impure solid, determine the percentage yield and check its purity.

[6 marks]

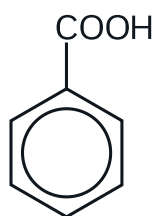
A student investigates the relative ease of nitration of phenol, benzene, and benzoic acid.



phenol



benzene



benzoic acid

The student finds that the conditions required for the nitration of each compound are different, as shown in Table 17.1.

Compound	phenol	benzene	benzoic acid
Conditions required for nitration	Dilute HNO_3 20 °C No catalyst	Concentrated HNO_3 55 °C H_2SO_4 catalyst	Concentrated HNO_3 100 °C H_2SO_4 catalyst

Table 17.1

17(b)(i) State the trend in the relative ease of nitration of phenol, benzene, and benzoic acid.

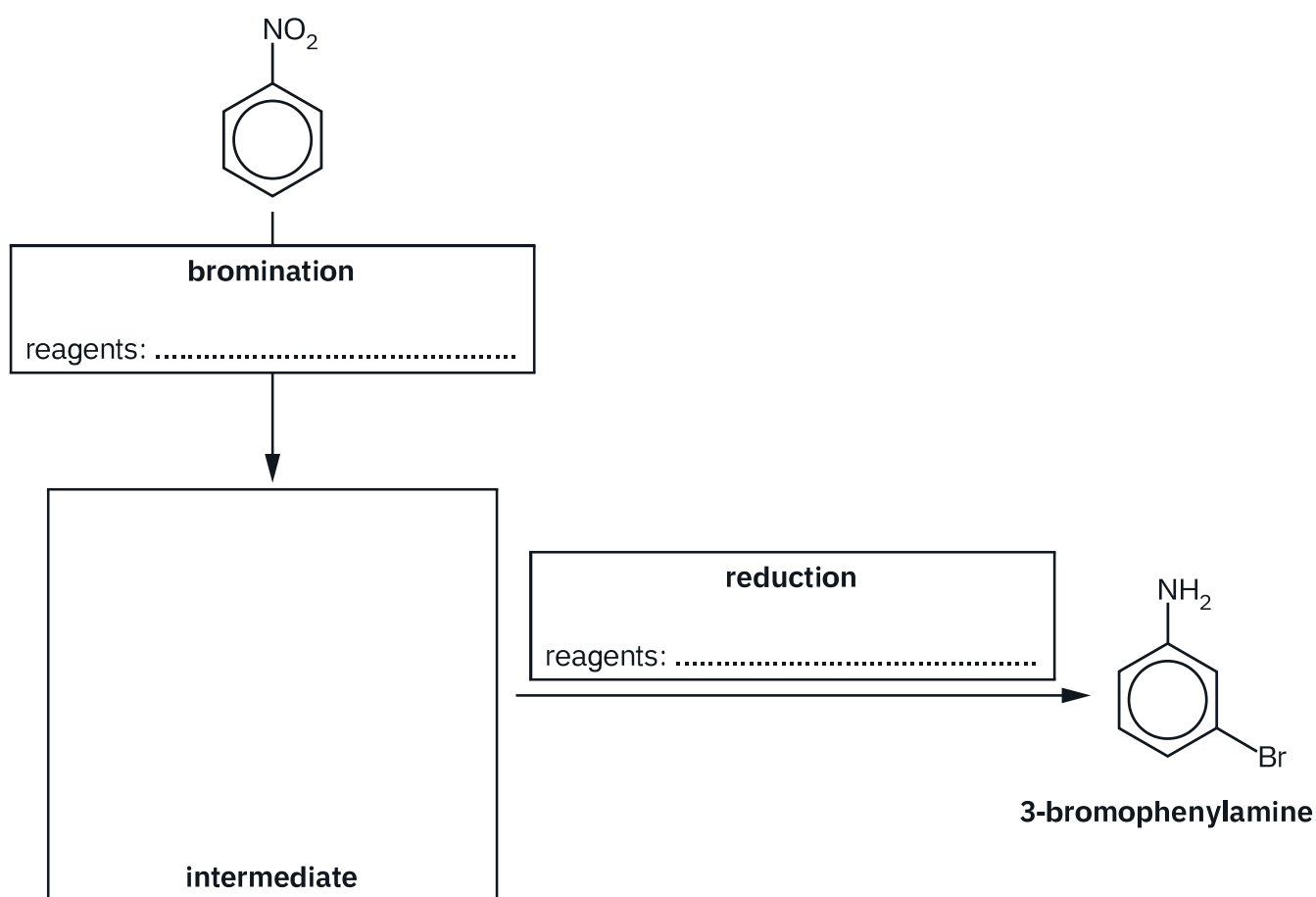
[1 mark]

17(b)(ii) Apply your knowledge of the bonding in arenes to explain the trend in part (b)(i).

[3 marks]

A student synthesises 3-bromophenylamine, shown below, starting from nitrobenzene.

17(c)(i) Complete the flowchart showing the structure of the intermediate and the formulae of the reagents for each stage.



[3 marks]

Draw your answer on the figure above.

17(c)(ii) Another student attempts the same synthesis but carries out reduction before bromination.

The student was surprised to find that two structural isomers of 3-bromophenylamine had been formed instead of the desired organic product.

Explain this result and suggest the structures of the two isomers that formed.

[3 marks]

Explanation

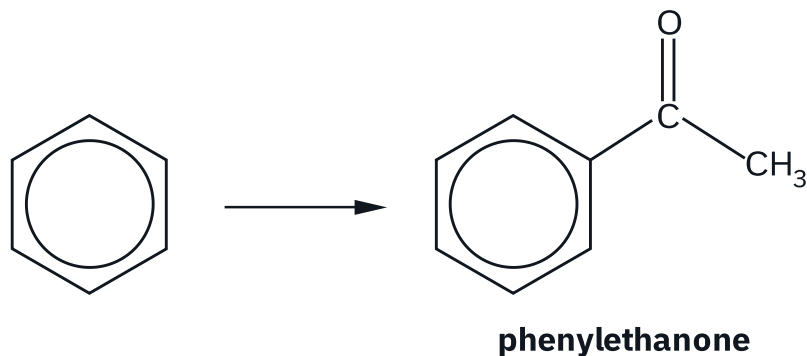
Structures

Q20 · Aromatic compounds and phenols · June 2018 · Paper 2 (Synthesis and analytical techniques) · Q10 · [1

mark]

This question also needs Group 2 and the halogens.

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



Which organic reagent is required?

Tick (✓) one box.

- ☐ **A** CH₃CH₂OH
- ☐ **B** CH₃CHO
- ☐ **C** CH₃COCl
- ☐ **D** CH₃COOH

Q21 · Aromatic compounds and phenols · June 2018 · Paper 2 (Synthesis and analytical techniques) · Q13 · [1 mark]

This question also needs Enthalpy changes.

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

- 1 All carbon–carbon bonds have the same length.
- 2 The enthalpy change of hydrogenation of benzene is less exothermic than expected.
- 3 Bromine reacts with benzene less readily than with cyclohexene.

Tick (✓) one box.

- ☐ **A** 1, 2 and 3
- ☐ **B** Only 1 and 2
- ☐ **C** Only 2 and 3
- ☐ **D** Only 1

Q22 · Aromatic compounds and phenols · June 2018 · Paper 2 (Synthesis and analytical techniques) · Q18 · [9 marks]

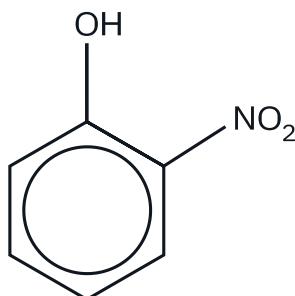
This question also needs Alkenes and addition polymers and Basic concepts of organic chemistry.

This question is about aromatic compounds.

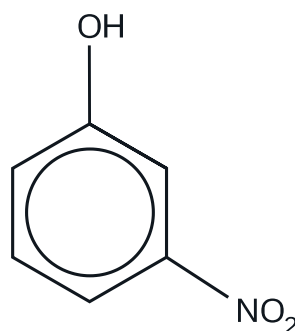
Phenol undergoes nitration more readily than benzene.

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

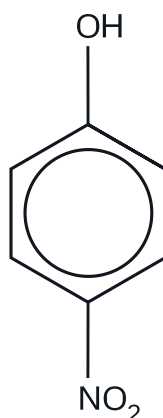
A small amount of 3-nitrophenol is also produced.



2-nitrophenol



3-nitrophenol



4-nitrophenol

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

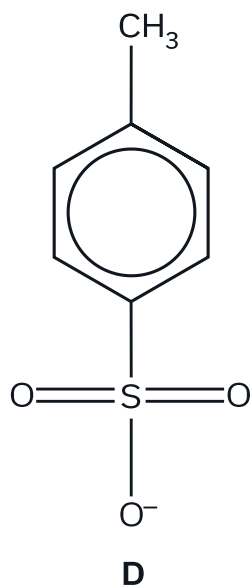
Explain whether the student is correct.

[3 marks]

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

[3 marks]

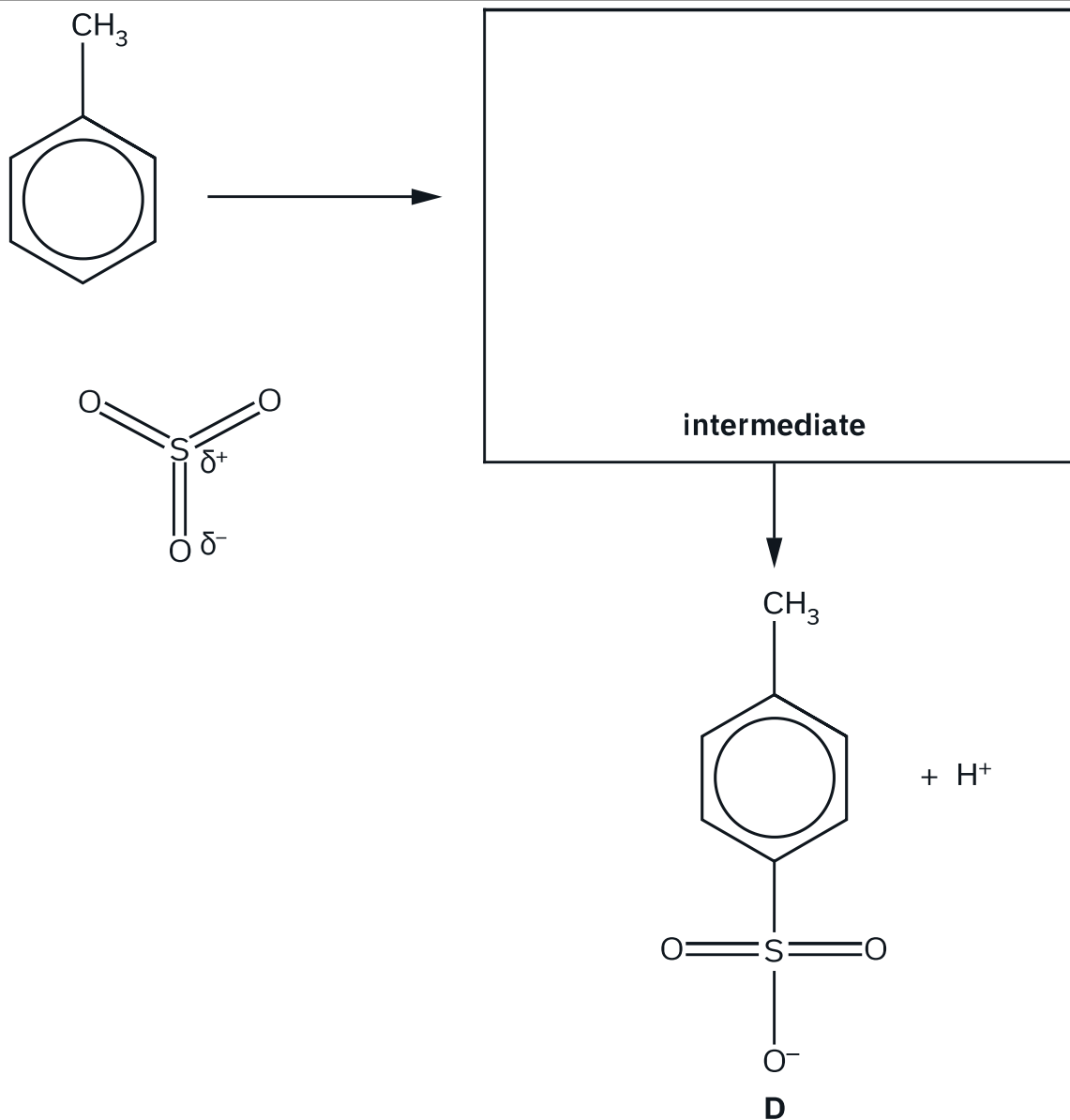
18(b) Methylbenzene reacts with sulfur trioxide, SO_3 , to form D, shown below.



The electrophile in this reaction is SO_3 .

Complete the mechanism for the formation of D.

Show curly arrows and the structure of the intermediate.

**[3 marks]**

Draw your answer on the figure above.

Q23 · Aromatic compounds and phenols · June 2019 · Paper 2 (Synthesis and analytical techniques) · Q14 · [1 mark]

Which chemical(s) can react with phenol?

1 Potassium hydroxide

2 Ethanoyl chloride

3 Nitric acid

Tick (✓) one box.

- ☐ **A** 1, 2 and 3
- ☐ **B** Only 1 and 2
- ☐ **C** Only 2 and 3
- ☐ **D** Only 1

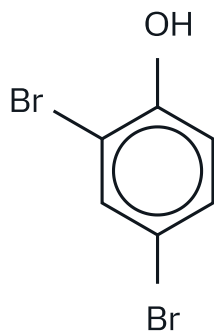
Q24 · Aromatic compounds and phenols · June 2019 · Paper 2 (Synthesis and analytical techniques) · Q8 · [1 mark]

Phenol reacts with bromine.

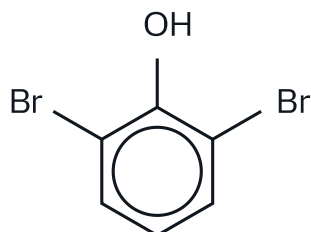
Which is the least likely organic product?

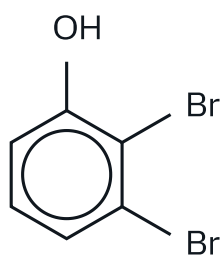
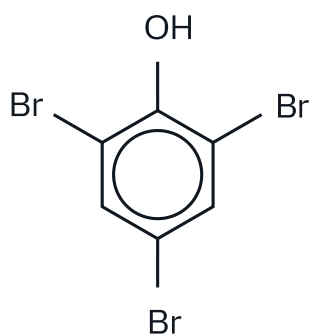
Tick (✓) one box.

☐ **A**



☐ **B**



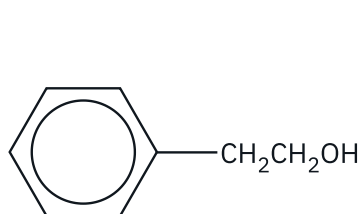
☐ **C**☐ **D**

Q25 · Aromatic compounds and phenols · June 2022 · Paper 2 (Synthesis and analytical techniques) · Q20 · [22 marks]

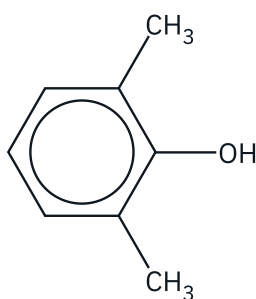
This question also needs Alkenes and addition polymers.

This question is about the chemistry of aromatic compounds.

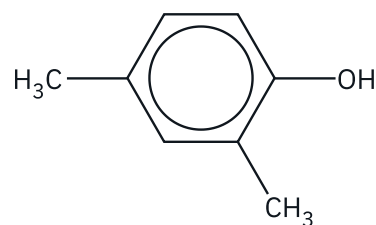
Compounds J, K and L, shown below, are structural isomers.



Compound J



Compound K



Compound L

20(a)(i) What chemical test(s) could be used to confirm the presence of the phenol group in compounds K and L?

[1 mark]

20(a)(ii) A student thought that ^{13}C NMR spectroscopy could be used to distinguish between compounds J, K and L.

Explain, with reasoning, whether the student is correct.

[3 marks]

20(a)(iii) Compound J is substituted at the 2- and 4- positions by chlorine in the presence of a catalyst.

Outline the mechanism for the 4 substitution of compound J by chlorine in the presence of a catalyst.

Show the role of the catalyst.

[4 marks]

20(b) Compounds K and L react with chlorine much more readily than compound J.

Explain why.

[3 marks]

20(c) Compound J, $\text{C}_6\text{H}_5\text{CH}_2\text{CH}_2\text{OH}$, is reacted with acidified potassium dichromate(VI) under reflux to form organic product M.

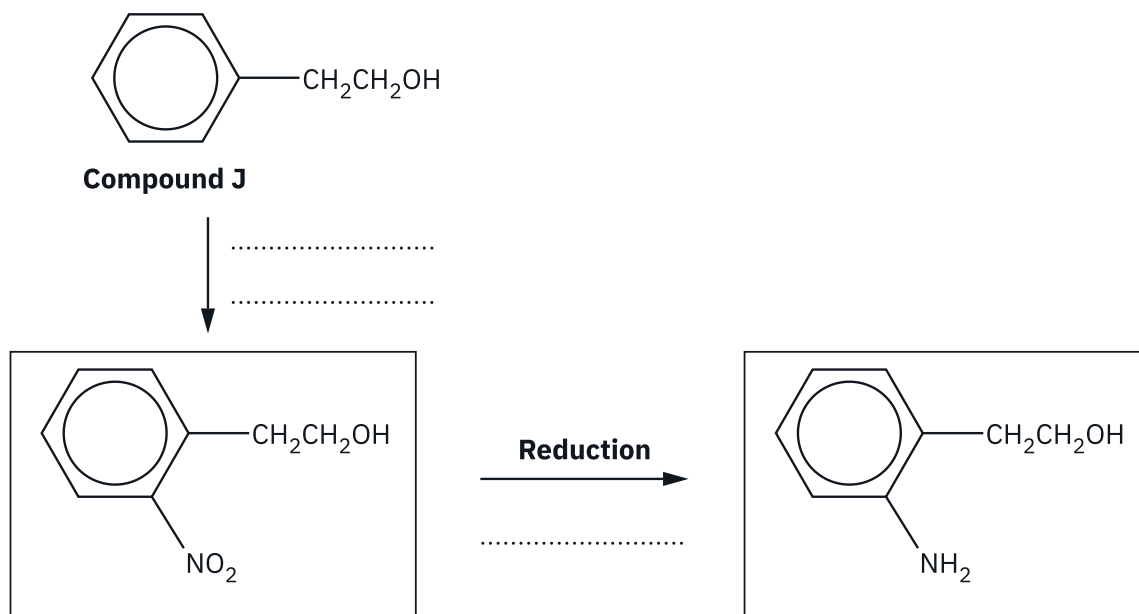
Write an equation for this reaction.

Use [O] to represent the oxidising agent and show the structure of M.

[2 marks]

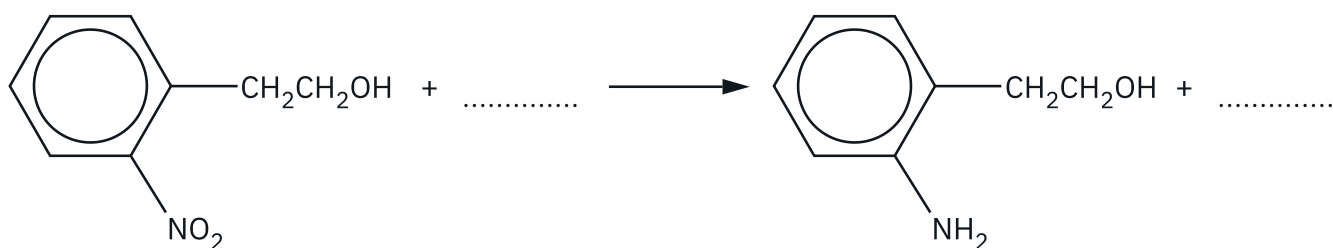
A two-stage synthesis of an amine from compound J is shown below.

20(d)(i) Add the reagents for each stage of this synthesis.



[2 marks]

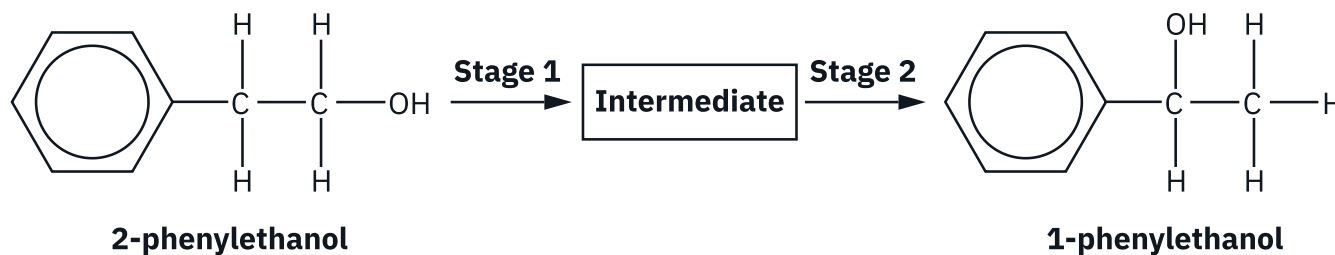
20(d)(ii) Fill in the equation for the reduction stage of this synthesis.



[1 mark]

20(e) 1-phenylethanol is a naturally occurring compound found in many vegetables and flowers.

1-phenylethanol can be synthesised from 2-phenylethanol in two stages.



Suggest reagents, conditions and equations for each stage in the synthesis.

Show structures for organic compounds.

Stage 1

reagents and conditions

equation:

[4 marks]

Stage 2

reagents and conditions

equation:

20(f) Acid anhydrides react in a similar way to acyl chlorides with phenols.

Benzoic anhydride is the acid anhydride of benzoic acid, $\text{C}_6\text{H}_5\text{COOH}$.

Benzoic anhydride reacts with butan-2-ol to form an ester.

Suggest an equation for this reaction. Show structures for organic compounds. Use C_6H_5 for any phenyl groups.

[2 marks]

Q26 · Aromatic compounds and phenols · June 2022 · Paper 2 (Synthesis and analytical techniques) · Q3 · [1 mark]

What is the number of sigma bonds in a molecule of methylbenzene?

Tick (✓) one box.

- ☐ **A** 7
- ☐ **B** 10
- ☐ **C** 12
- ☐ **D** 15

Q27 · Aromatic compounds and phenols · June 2023 · Paper 2 (Synthesis and analytical techniques) · Q18 · [11 marks]

This question also needs Amount of substance and Organic synthesis, IR and mass spectra.

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.

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

[5 marks]

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

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

percentage yield = %

[3 marks]

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

[3 marks]

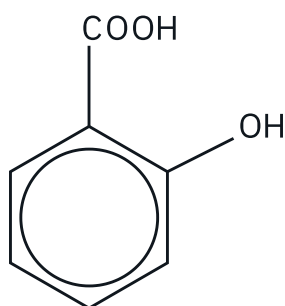
Q28 · Aromatic compounds and phenols · June 2023 · Paper 2 (Synthesis and analytical techniques) · Q20 · [10

marks]

This question also needs Amount of substance.

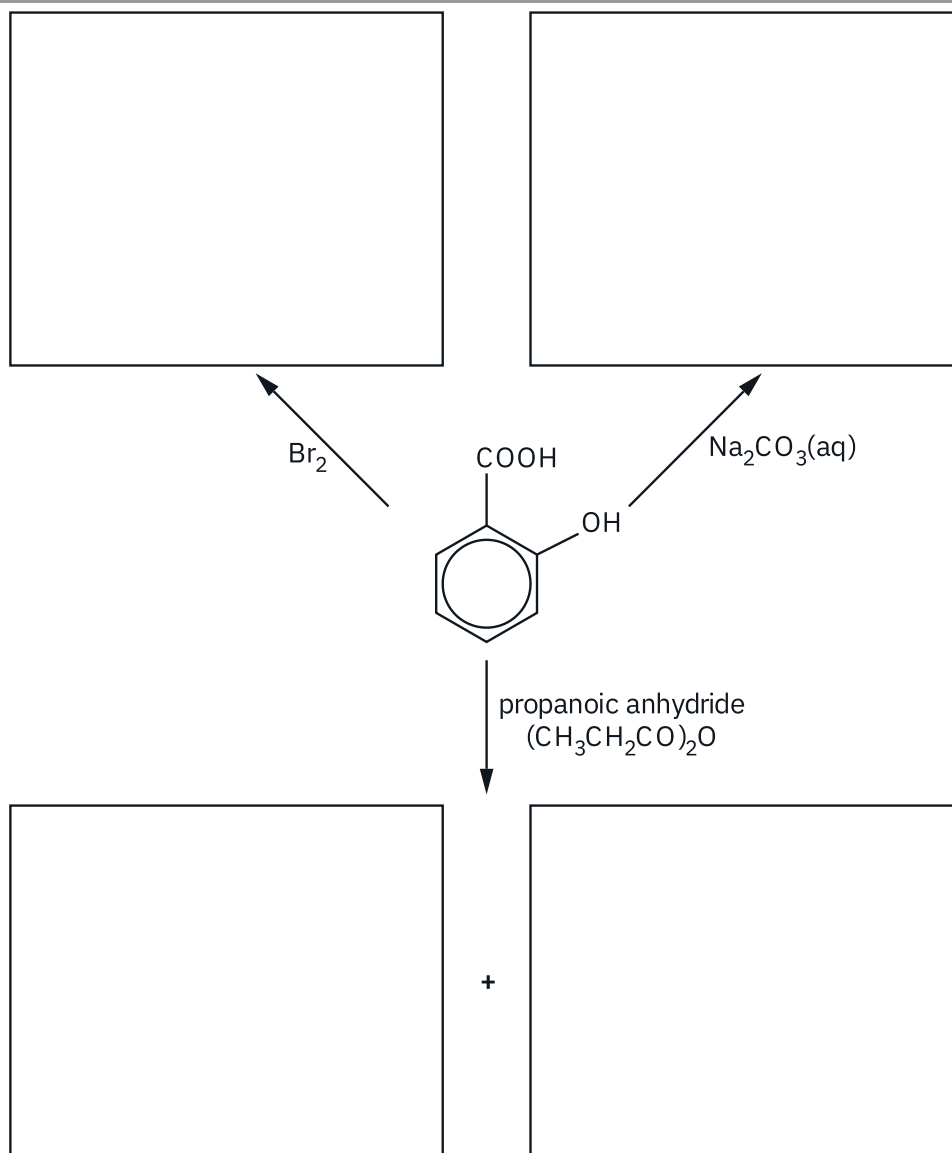
This question is about aromatic compounds containing the -COOH and -OH functional groups.

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

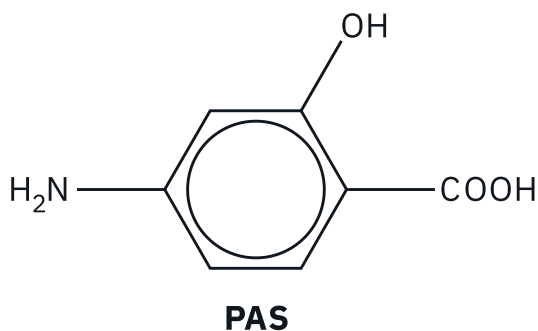


Salicylic acid

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

**[4 marks]**

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



20(b)(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 marks]

20(b)(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.

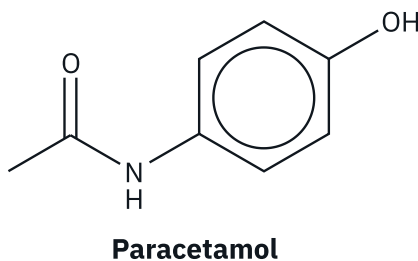
Calculate the number of PAS molecules in the maximum daily dosage of PAS for this child.

number of PAS molecules =

[3 marks]

Q29 · Aromatic compounds and phenols · June 2023 · Paper 2 (Synthesis and analytical techniques) · Q4 · [1 mark]

The structure of the painkiller paracetamol is shown below.



Which functional groups are present in paracetamol?

Tick (✓) one box.

- ☐ **A** alcohol, amide
- ☐ **B** alcohol, arene, ketone, amine
- ☐ **C** phenol, amide
- ☐ **D** phenol, ketone, amine

Q30 · Aromatic compounds and phenols · June 2023 · Paper 2 (Synthesis and analytical techniques) · Q6 · [1

mark]

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

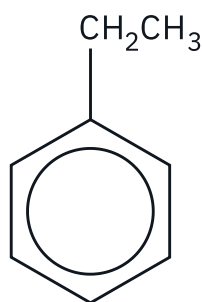
Tick (✓) one box.

- ☐ **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.

Q31 • Aromatic compounds and phenols • June 2024 • Paper 2 (Synthesis and analytical techniques) • Q21 • [14 marks]

This question is about aromatic compounds.

Ethylbenzene, $\text{C}_6\text{H}_5\text{CH}_2\text{CH}_3$, can be prepared by reacting benzene with chloroethane, $\text{CH}_3\text{CH}_2\text{Cl}$, 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.

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

[1 mark]

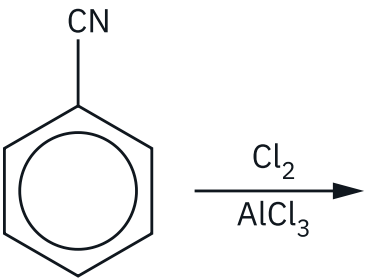
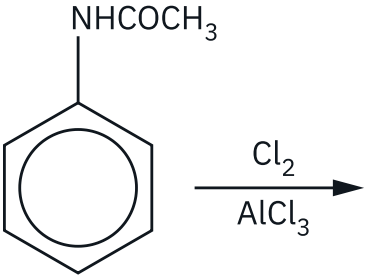
21(a)(ii) Outline the mechanism for this reaction, including the role of AlCl_3 as a halogen carrier.

[5 marks]

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

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

Reaction	Monosubstituted Product(s)
 Reaction of benzonitrile (a benzene ring with a -CN group) with Cl₂ and AlCl₃ catalyst.	
 Reaction of N-phenylacetamide (a benzene ring with an -NHCOCH₃ group) with Cl₂ and AlCl₃ catalyst.	

[3 marks]

21(b)(ii) The reactions of $\text{C}_6\text{H}_5\text{NH}_2$ are similar to the reactions of phenol.

Write an equation for the tri-substitution of $\text{C}_6\text{H}_5\text{NH}_2$ with chlorine.

[2 marks]

21(b)(iii) Explain why chlorine reacts much more readily with $\text{C}_6\text{H}_5\text{NH}_2$ than with benzene.

[3 marks]

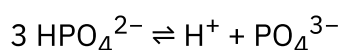
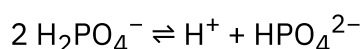
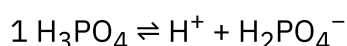
Q32 · Aromatic compounds and phenols · June 2024 · Paper 3 (Unified chemistry) · Q4 · [16 marks]

This question also needs Acids and redox reactions, Amount of substance and Electrons, bonding and structure.

This question is about the chemistry of compounds containing phosphorus.

Phosphorus forms several acids including H_3PO_4 and H_3PO_3 .

H_3PO_4 is a tribasic acid. The equilibria for the dissociations are shown below.



4(a)(i) During the equilibria, H_2PO_4^- behaves both as an acid and as a base.

Explain this statement, using the equilibria **1**, **2** and **3**, as required.

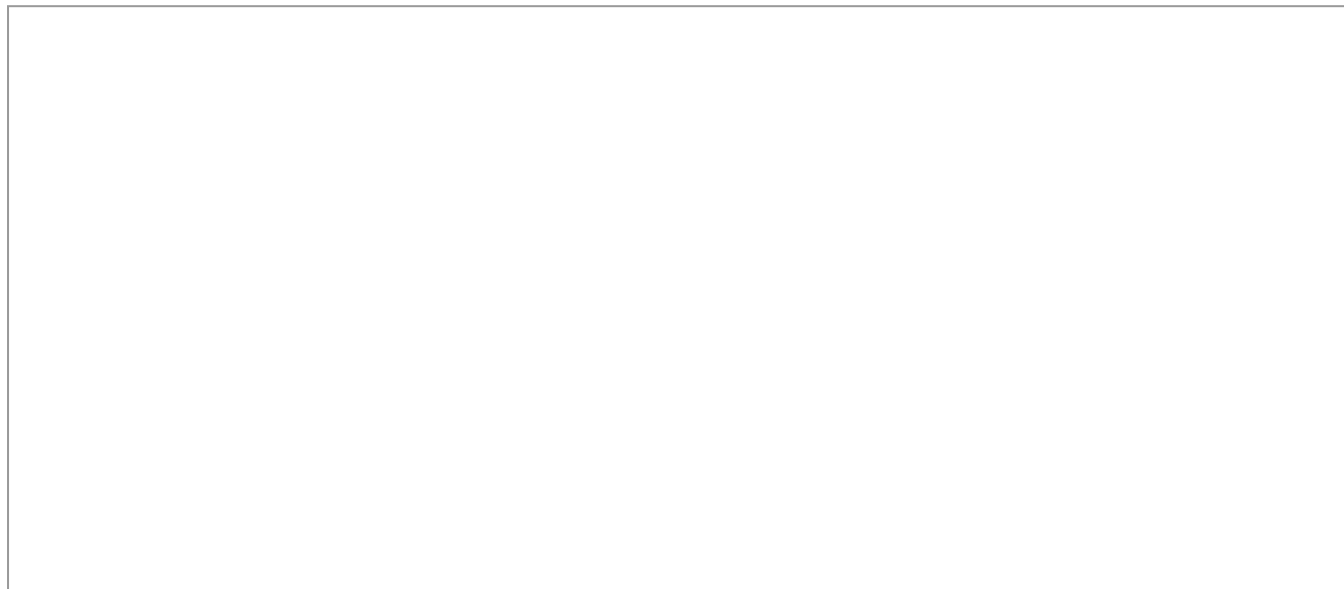
[2 marks]

4(a)(ii) In a H_3PO_3 molecule, the O atoms are covalently bonded to the P atom. The H atoms are bonded to the O atoms.

Draw the structure of a H_3PO_3 molecule, showing all the bonds.

On your diagram, add the values for the O–P–O and P–O–H bond angles.

[3 marks]



4(a)(iii) The systematic name of H_3PO_4 is phosphoric(V) acid.

What is the systematic name of H_3PO_3 ?

[1 mark]

Phosphine, PH_3 , is a poisonous gas.

4(b)(i) Phosphine reacts with oxygen gas to form phosphorus(V) oxide and water.

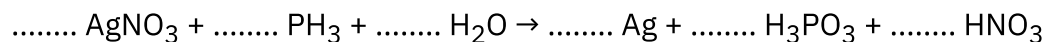
Write the equation for this reaction.

[1 mark]

4(b)(ii) Aqueous silver nitrate, AgNO_3 , is reduced by PH_3 .

The unbalanced equation is shown below.

Balance the equation and use oxidation numbers to explain why this is a redox reaction.



Explanation

[3 marks]

When phosphorus(V) chloride, PCl_5 , and ammonium chloride are heated together, the compound $\text{P}_3\text{N}_3\text{Cl}_6$ is formed, together with HCl gas.

$\text{P}_3\text{N}_3\text{Cl}_6$ has a cyclic structure, like the Kekulé structure of benzene.

4(c)(i) Write an equation for the reaction of PCl_5 and ammonium chloride to form $\text{P}_3\text{N}_3\text{Cl}_6$.

[1 mark]

4(c)(ii) Calculate the percentage by mass of P in $\text{P}_3\text{N}_3\text{Cl}_6$.

Give your answer to **2** decimal places.

percentage by mass of P = %

[2 marks]

4(c)(iii) Suggest **one** example of evidence that could show that $\text{P}_3\text{N}_3\text{Cl}_6$ has a Kekulé structure rather than a delocalised structure.

[1 mark]

4(c)(iv) In a molecule of $\text{P}_3\text{N}_3\text{Cl}_6$ all the N and Cl atoms are bonded to P atoms.

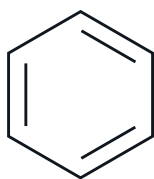
Suggest a possible structure for a molecule of $\text{P}_3\text{N}_3\text{Cl}_6$.

[2 marks]

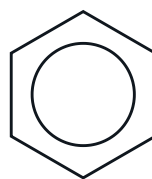
Q33 · Aromatic compounds and phenols · June 2025 · Paper 2 (Synthesis and analytical techniques) · Q20 · [17 marks]

This question is about aromatic compounds.

20(a) The diagrams show the Kekulé and delocalised models of benzene.



Kekulé



Delocalised

One piece of evidence for the delocalised model is that benzene does **not** decolourise aqueous bromine.

Suggest **two other** pieces of evidence which support the delocalised model of benzene.

[2 marks]

A student investigates the reactions of benzene and phenol with excess bromine.

The student's observations are given in Table 20.1.

Table 20.1

Compound	Benzene	Phenol
Observation with excess bromine	no change	decolourises and forms a white precipitate

20(b)(i) Explain the difference in the relative reactivities of benzene and phenol with bromine.

[3 marks]

20(b)(ii) The white precipitate has a relative molecular mass of 330.7.

Construct an equation for the reaction of phenol with excess bromine shown in Table 20.1.

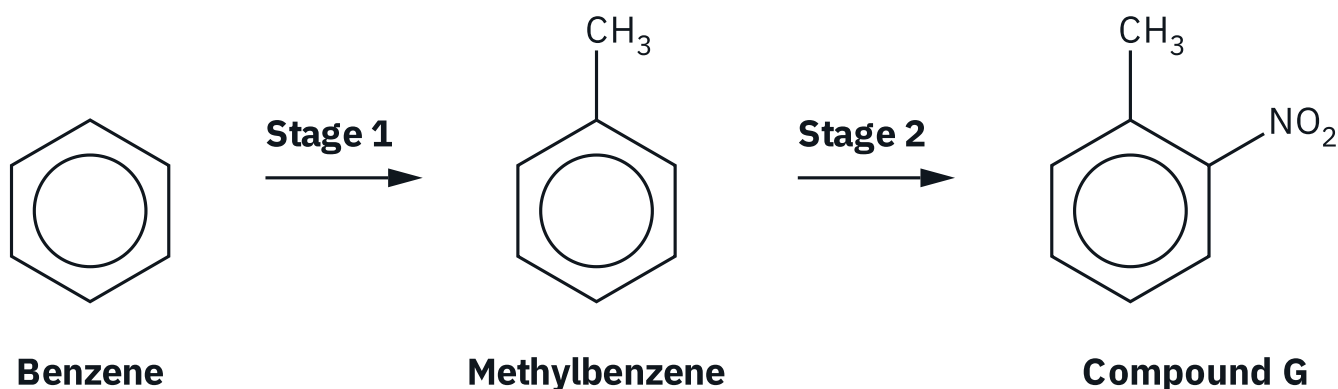
Show the structure of the organic species.

[2 marks]

Compound G is an organic compound used in the production of pesticides.

Compound G can be synthesised from benzene in the two-stage process shown.

Synthesis 1



20(c)(i) Suggest a reagent and halogen carrier that could be used in Stage 1 of Synthesis 1.

[1 mark]

20(c)(ii) Stage 2 of Synthesis 1 is the conversion of methylbenzene to compound G.

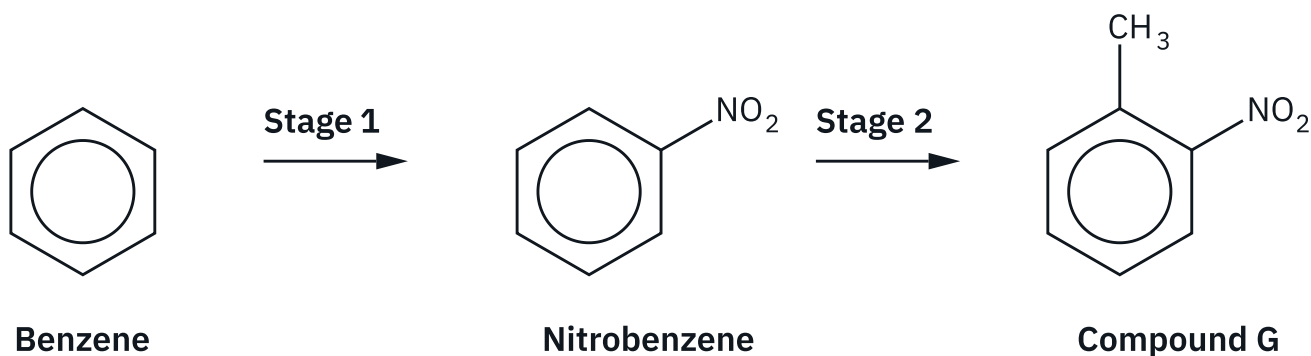
Outline the mechanism for the reaction in Stage 2.

Show the role of H_2SO_4 as a catalyst.

[5 marks]

20(c)(iii) A student suggested an alternative two-stage synthesis of compound G from benzene.

Synthesis 2



When Synthesis 2 is attempted, the synthesis is **not** successful and a different organic compound from compound G is produced.

- Suggest why Synthesis 1 is successful but Synthesis 2 is **not** successful.
- Suggest the structure of the different organic compound that is formed in Synthesis 2.

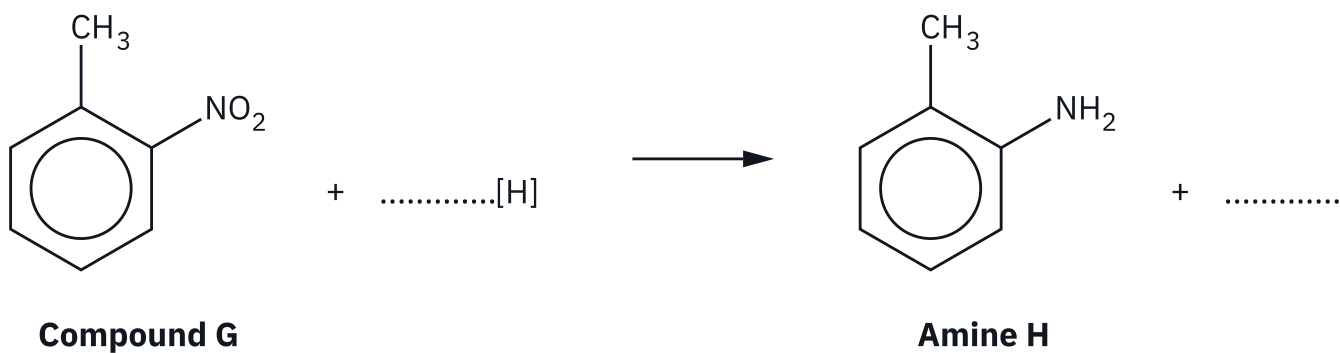
[2 marks]

20(c)(iv) In the production of a pesticide, compound G is reduced to amine H.

Suggest suitable reagents and complete the equation for this reduction.

Reagents

Equation:

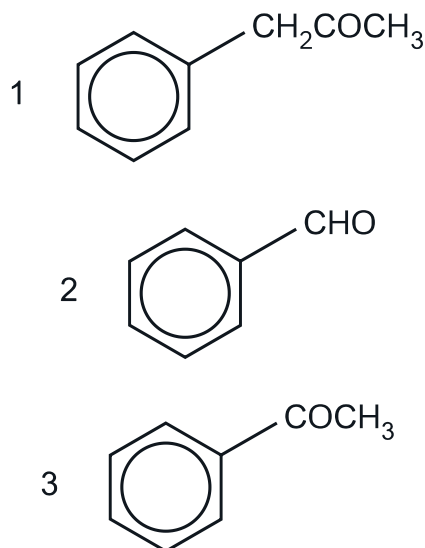


[2 marks]

Q34 · Aromatic compounds and phenols · November 2020 · Paper 2 (Synthesis and analytical techniques) · Q15 · [1 mark]

This question also needs Group 2 and the halogens.

Which compound(s) could be prepared by reacting benzene with an acyl chloride in the presence of a halogen carrier?



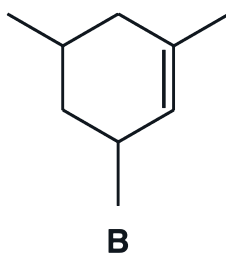
Tick (✓) one box.

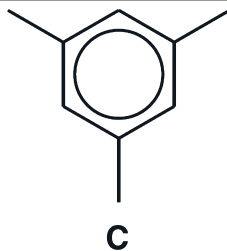
- ☐ **A** 1, 2 and 3
- ☐ **B** Only 1 and 2
- ☐ **C** Only 2 and 3
- ☐ **D** Only 1

Q35 · Aromatic compounds and phenols · November 2020 · Paper 2 (Synthesis and analytical techniques) · Q17 · [20 marks]

This question also needs Alkenes and addition polymers, Basic concepts of organic chemistry, Group 2 and the halogens and Reaction rates and equilibrium.

Compounds B and C, shown below, are unsaturated hydrocarbons containing nine carbon atoms.





Compound B reacts with chlorine at room temperature, but compound C requires the presence of a halogen carrier.

In both reactions, the organic compound reacts with chlorine in a 1:1 molar ratio.

17(a)(i) Draw the structures of the organic product of each reaction.

Organic product with B

Organic product with C

[2 marks]

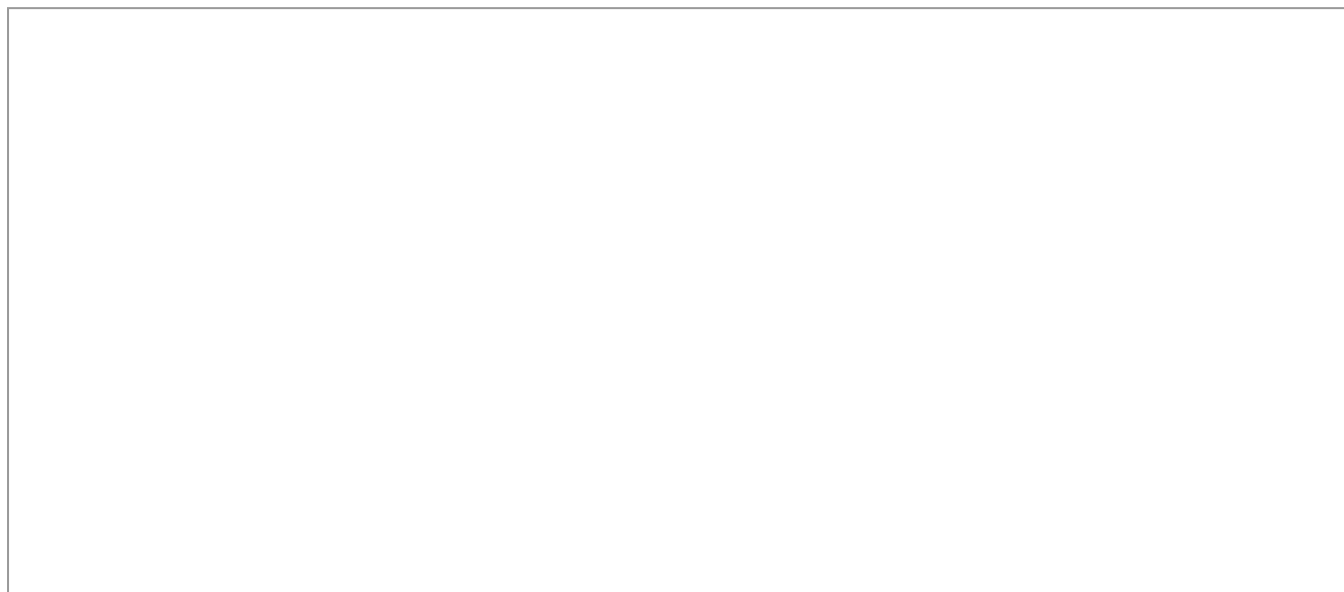
17(a)(ii) Explain the relative resistance to chlorination of compound C compared with compound B.

[3 marks]

17(a)(iii) Outline the mechanism for the reaction of compound C with chlorine.

Show the role of the halogen carrier.

[5 marks]



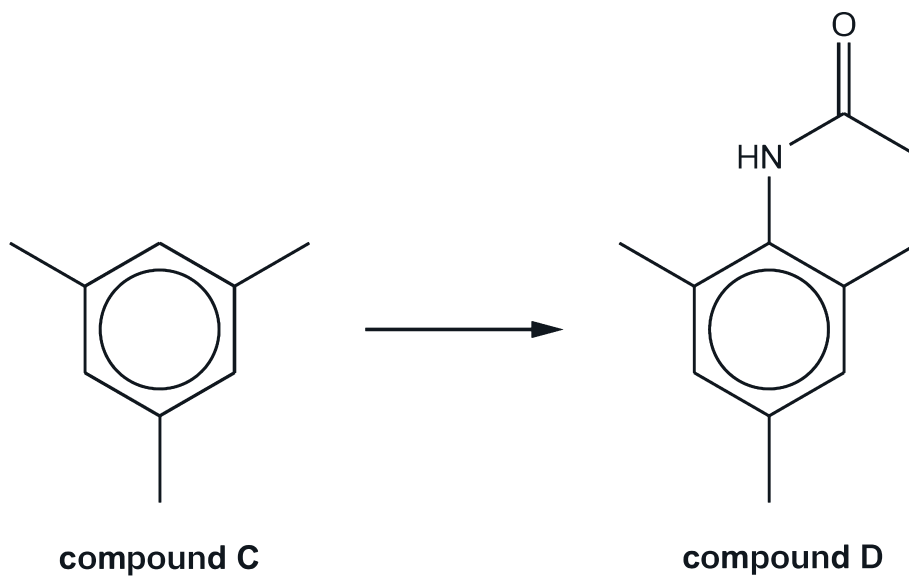
17(b) Compound C can be prepared by 'trimerisation' of propanone using concentrated sulfuric acid as a catalyst.

Suggest an equation for this reaction, using molecular formulae.

[3 marks]

An organic chemist is investigating compound D for possible use as a medicine.

The chemist proposes a synthesis of compound D from compound C.



17(c)(i) Predict the number of peaks in the ^{13}C NMR spectra of compounds C and D.

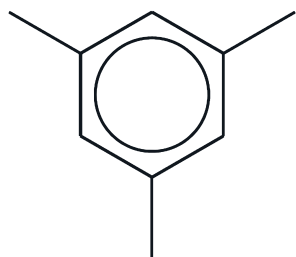
Compound C	Compound D
Number of peaks	

[2 marks]

17(c)(ii) The chemist develops a three-stage synthesis of compound D from compound C.

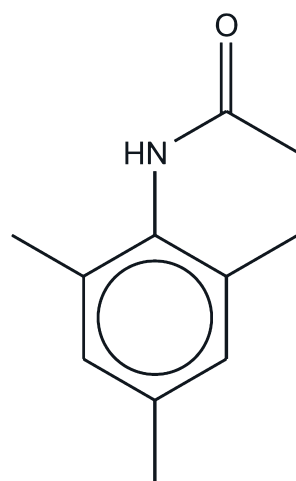
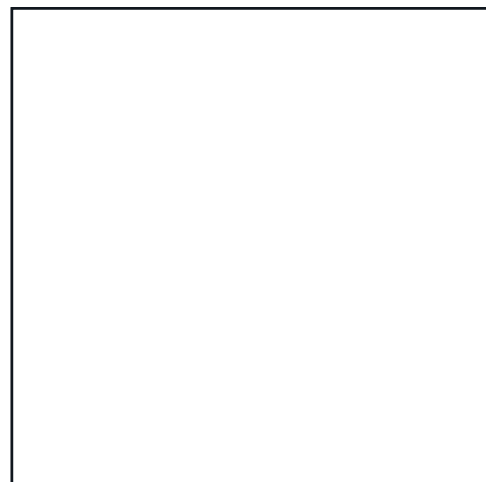
Complete the flowchart.

Show structures for organic compounds.

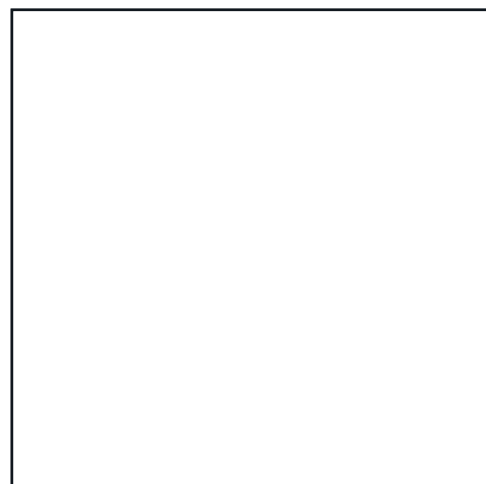
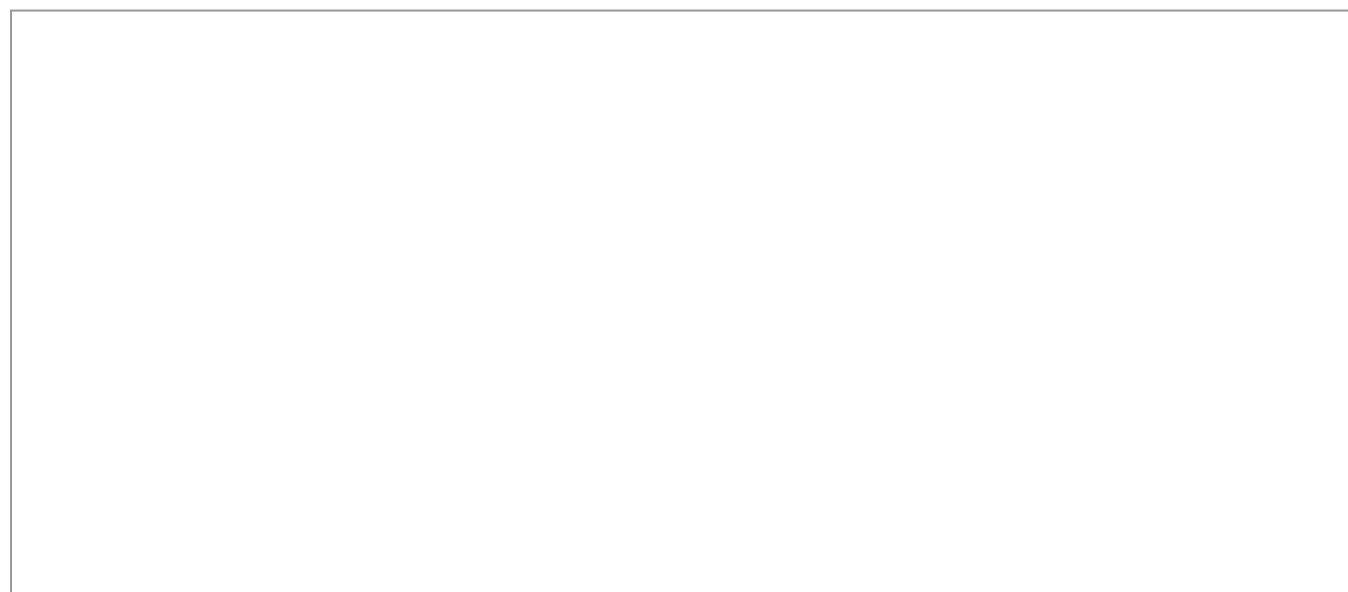
**compound C**

reagent:

catalyst:

**compound D**

reagent:

1. Sn + HCl
2. Neutralise**[5 marks]**

Q36 · Aromatic compounds and phenols · November 2020 · Paper 2 (Synthesis and analytical techniques) · Q7 · [1 mark]

This question also needs Acids and redox reactions and Reaction rates and equilibrium.

Which one of the following reacts with ethanoic acid and with phenol?

Tick (✓) one box.

- ☐ **A** Aqueous potassium hydroxide
- ☐ **B** Bromine
- ☐ **C** Calcium carbonate
- ☐ **D** Methanol and an acid catalyst

Q37 · Aromatic compounds and phenols · November 2021 · Paper 2 (Synthesis and analytical techniques) · Q14 · [1 mark]

This question also needs Enthalpy changes and Group 2 and the halogens.

Which of the following statement(s) provide(s) evidence for the delocalised model of benzene rather than the Kekulé model?

- 1 The enthalpy change of hydrogenation is more exothermic than expected.
- 2 Benzene only reacts with bromine in the presence of a halogen carrier.
- 3 The carbon-carbon bonds all have the same length.

Tick (✓) one box.

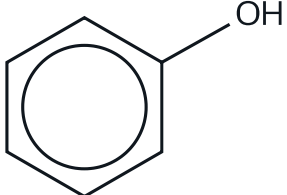
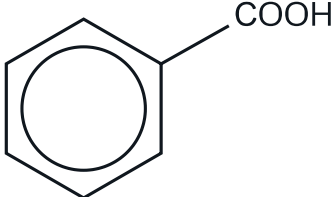
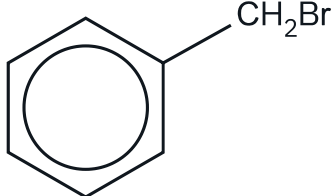
- ☐ **A** 1, 2 and 3
- ☐ **B** Only 1 and 2
- ☐ **C** Only 2 and 3
- ☐ **D** Only 1

Q38 · Aromatic compounds and phenols · November 2021 · Paper 2 (Synthesis and analytical techniques) · Q15 ·

[1 mark]

Compounds 1, 2 and 3 are heated with NaOH(aq).

Which compound(s) react(s)?

1	
2	
3	

Tick (✓) one box.

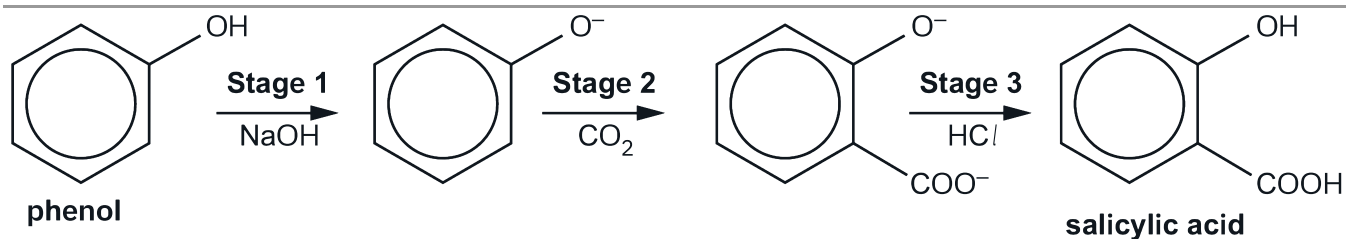
- ☐ **A** 1, 2 and 3
- ☐ **B** Only 1 and 2
- ☐ **C** Only 2 and 3
- ☐ **D** Only 1

Q39 · Aromatic compounds and phenols · November 2021 · Paper 2 (Synthesis and analytical techniques) · Q20 · [20 marks]

This question also needs Alkenes and addition polymers, Amount of substance, Atomic structure and isotopes and 3 other topics.

This question is about reactions of phenol.

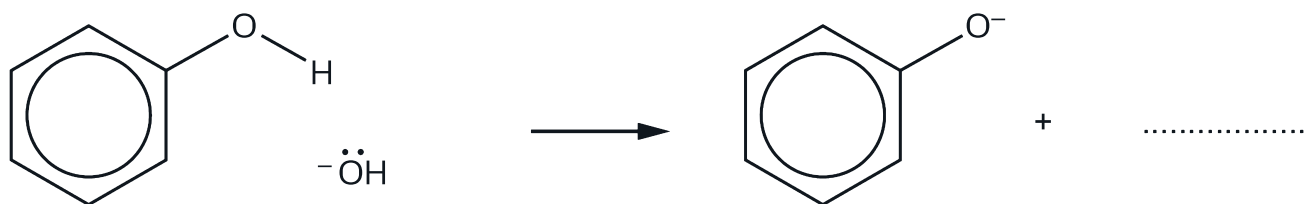
Salicylic acid can be prepared from phenol as shown below.



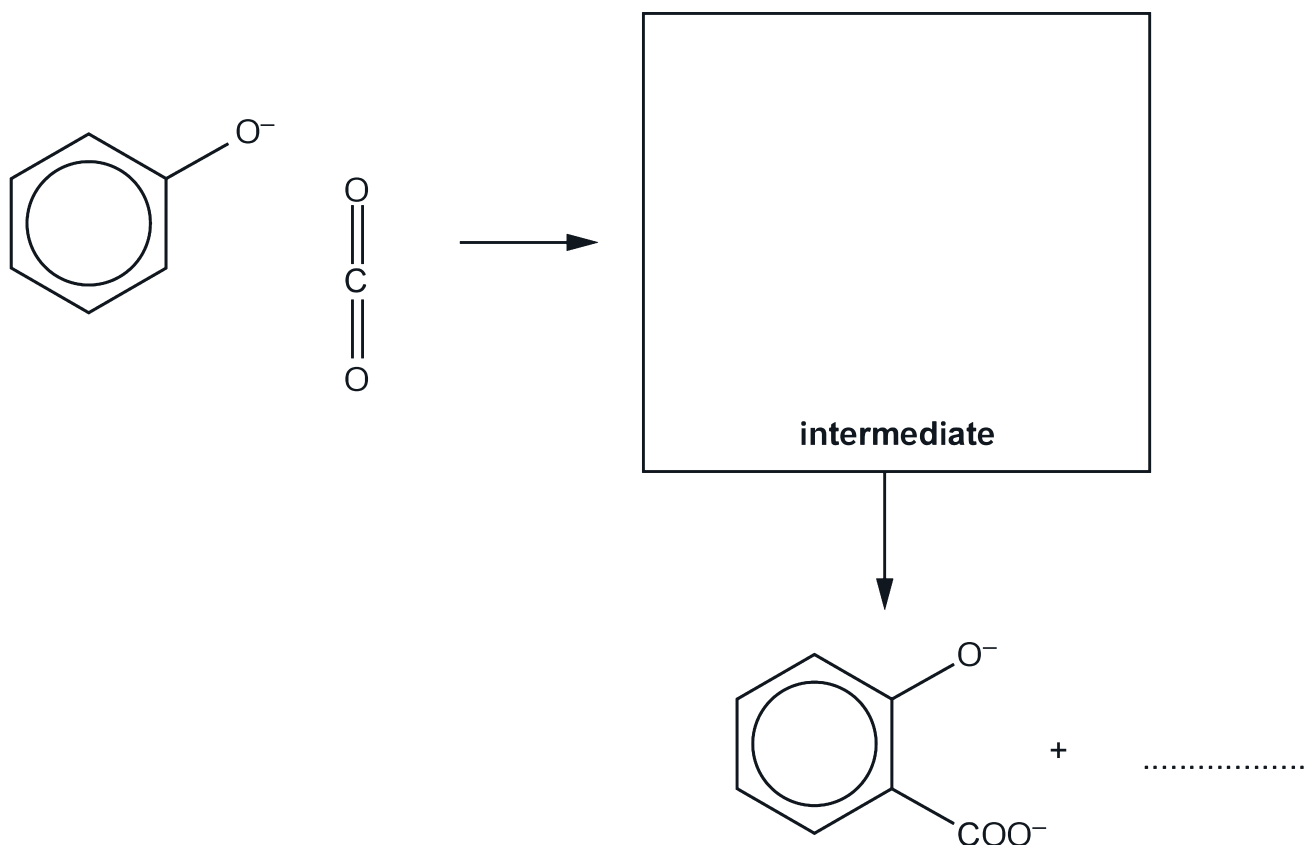
20(a)(i) Complete the mechanism below for Stage 1 and Stage 2.

Show curly arrows, the structure of the intermediate and the missing formulae on the dotted lines.

Stage 1



Stage 2



[6 marks]

Draw your answer on the figure above.

20(a)(ii) What are the roles of OH^- and CO_2 in the mechanism?

[2 marks]

OH^-

CO_2

20(a)(iii) Two molecules of salicylic acid can react together in the presence of an acid catalyst to form compound B.

Compound B has three rings and a molecular formula of $\text{C}_{14}\text{H}_8\text{O}_4$.

Write the equation for this reaction showing the structures of organic compounds.

[3 marks]

A student reacts phenol with nitric acid and sulfuric acid at 100°C to form impure crystals of an organic compound, C. The student purifies the crystals by recrystallisation.

20(b)(i) Describe how the student could recrystallise the impure crystals to obtain a pure sample of C.

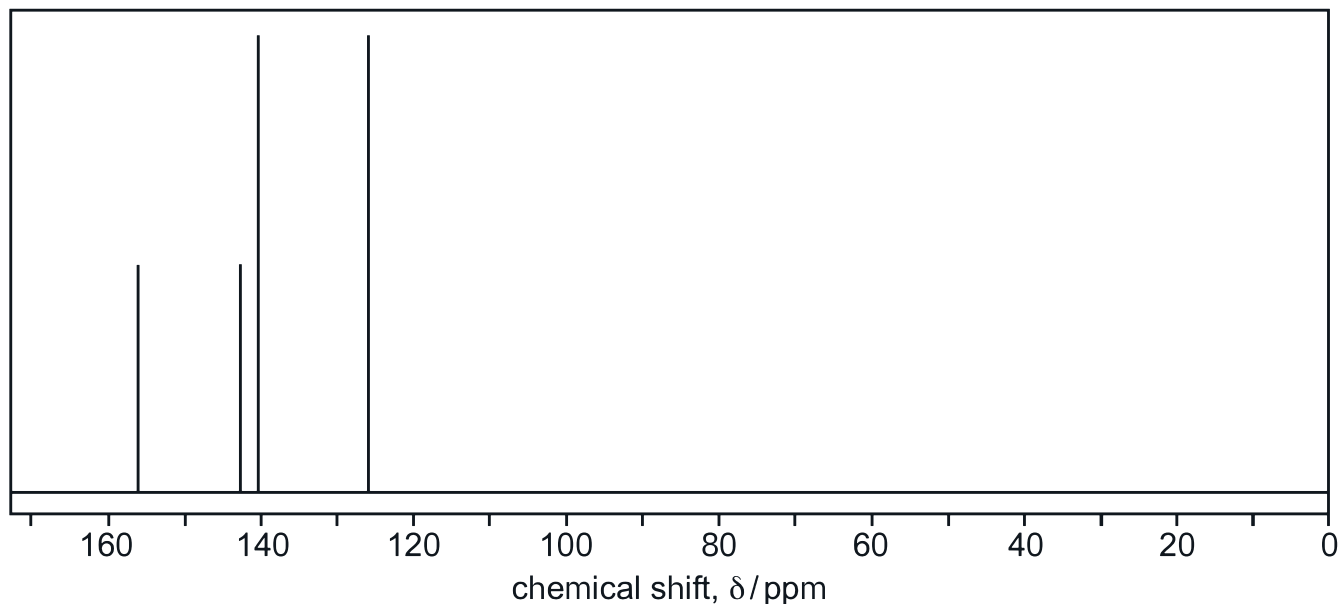
[3 marks]

20(b)(ii) The pure sample of C is analysed to give the following results.

Percentage composition by mass: C, 31.44%; H, 1.31%; N, 18.34%; O, 48.91%.

The mass spectrum of C shows a molecular ion peak at $m/z = 229.0$

The ^{13}C NMR spectrum of C is shown below.



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	

Analyse all the information to suggest the structure for C.

Show all your reasoning.

compound C

[6 marks]

Q40 · Carbon–carbon bond formation and synthesis · June 2018 · Paper 2 (Synthesis and analytical techniques) · Q14 · [1 mark]

A solid organic compound can be purified by recrystallisation.

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

- 1 The organic compound is more soluble in hot solvent.
- 2 The hot solution is cooled before the purified organic compound is collected.
- 3 The melting point of the purified organic compound is lower than the impure compound.

Tick (✓) one box.

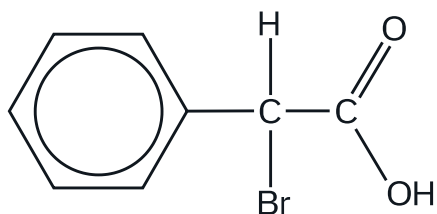
- ☐ **A** 1, 2 and 3
- ☐ **B** Only 1 and 2
- ☐ **C** Only 2 and 3
- ☐ **D** Only 1

Q41 · Carbon–carbon bond formation and synthesis · June 2018 · Paper 2 (Synthesis and analytical techniques) ·

Q15 · [1 mark]

This question also needs Alcohols and haloalkanes.

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



1 CH_3Cl and AlCl_3

2 KCN in ethanol

3 CH_3OH and H_2SO_4

Tick (✓) one box.

☐ **A** 1, 2 and 3

☐ **B** Only 1 and 2

☐ **C** Only 2 and 3

☐ **D** Only 1

Q42 · Carbon–carbon bond formation and synthesis · June 2018 · Paper 3 (Unified chemistry) · Q4 · [11 marks]

This question also needs Acids and redox reactions, Amount of substance, Basic concepts of organic chemistry and 2 other topics.

This question is about two compounds used in medicine.

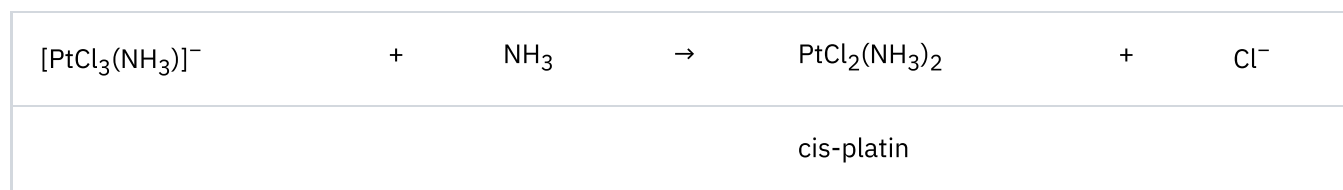
Cis-platin, $\text{PtCl}_2(\text{NH}_3)_2$, is a complex of platinum which is used in cancer treatment.

4(a)(i) What is the oxidation number of platinum in cis-platin?

[1 mark]

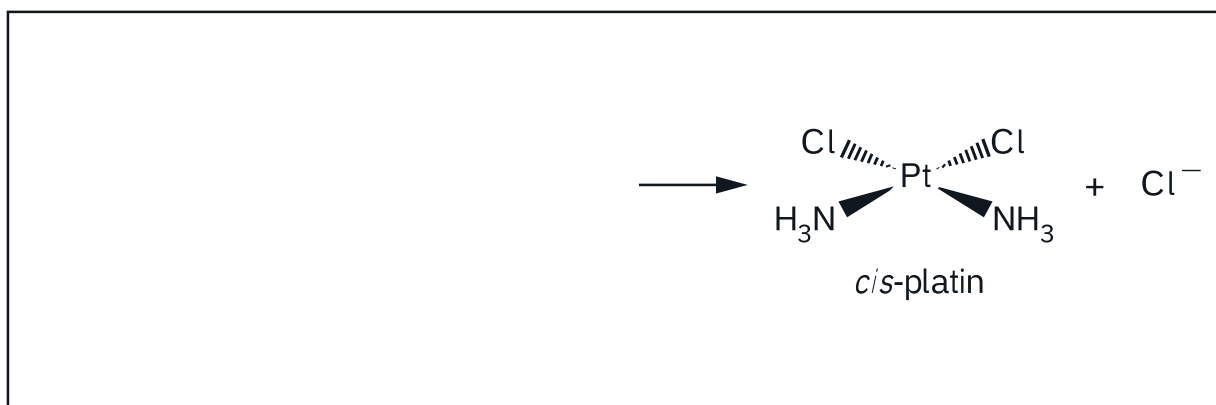
4(a)(ii) Cis-platin is prepared in a ligand substitution reaction which takes place in multiple steps.

The equation for the final step forming cis-platin is shown below.



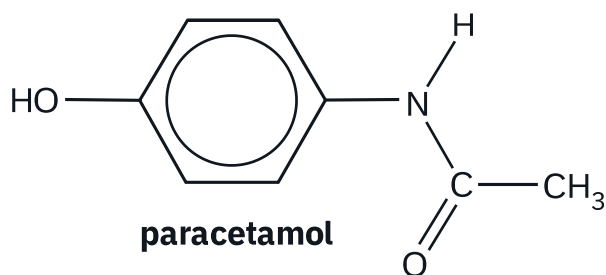
In the box, outline the mechanism for the formation of cis-platin from $[\text{PtCl}_3(\text{NH}_3)]^-$.

Use curly arrows and lone pairs where appropriate.



[2 marks]

Paracetamol is a solid organic compound used in tablets as a painkiller.



4(b)(i) Name the functional groups present in paracetamol.

[2 marks]

4(b)(ii) A chemist prepares a pure solid sample of paracetamol from 4-nitrophenol in two stages:



Describe a two-stage synthesis of 5.00 g of pure paracetamol from 4-nitrophenol. The overall percentage yield of paracetamol from 4-nitrophenol is 40.0%.

In your answer, include the mass of 4-nitrophenol required, the reagents and intermediate, and details of the purification of paracetamol.

[6 marks]

Q21 · [6 marks]

21 Carbon-carbon bond formation is used in synthesis to increase the length of a carbon chain.

Describe the formation of carbon-carbon bonds in aliphatic compounds by **two** different mechanisms.

Your answer should include mechanisms for each aliphatic compound.

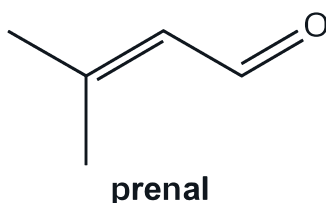
[6 marks]

Q44 · Carbon-carbon bond formation and synthesis · November 2021 · Paper 2 (Synthesis and analytical techniques) · Q19 · [14 marks]

This question also needs Alcohols and haloalkanes, Amount of substance, Basic concepts of organic chemistry and 2 other topics.

This question is about organic synthesis.

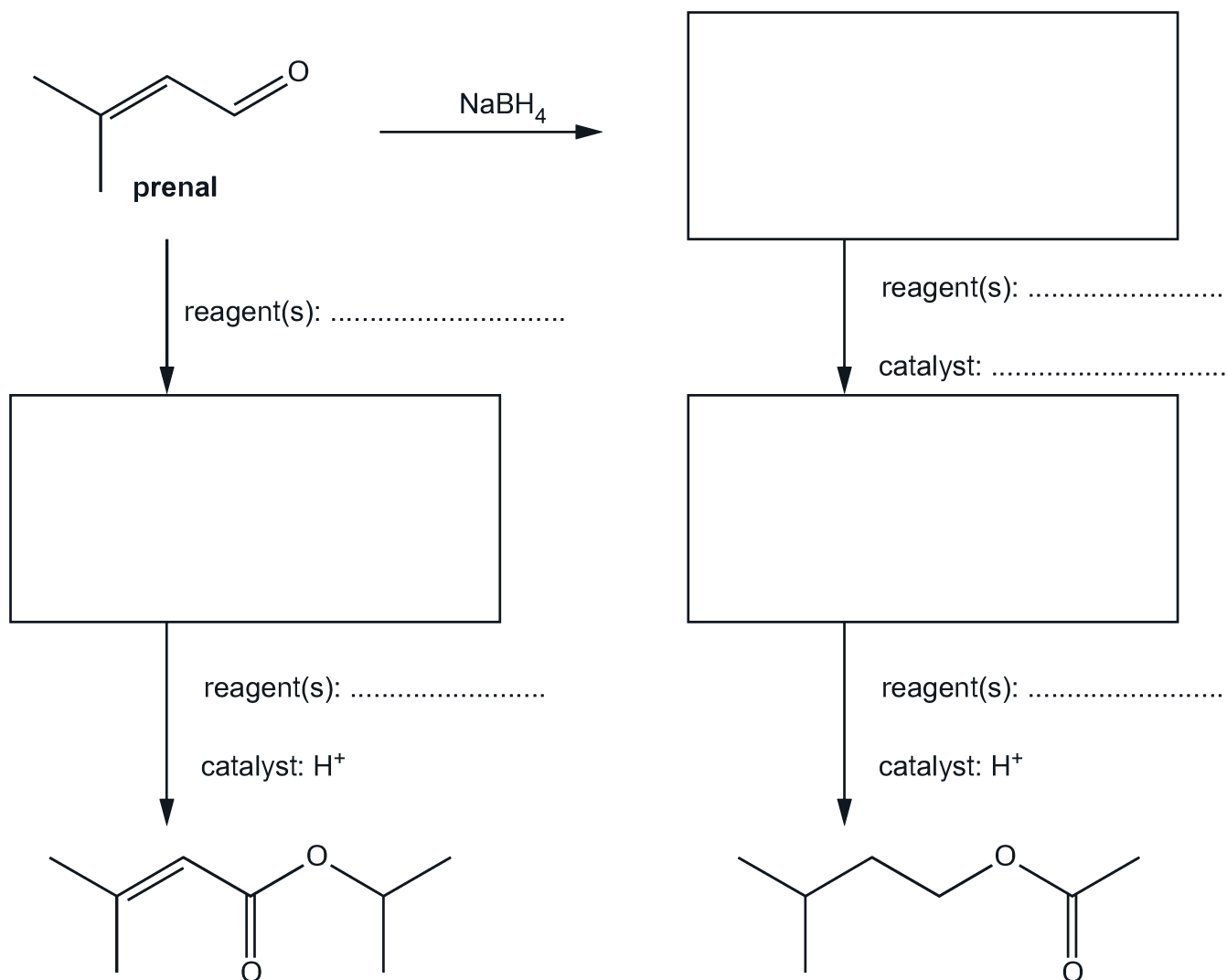
Prenal, shown below, is used in the synthesis of some pharmaceuticals.



19(a)(i) What is the systematic name for prenal?

[1 mark]

19(a)(ii) Complete the flowchart below for the synthesis of two compounds starting from prenal.



[7 marks]

Draw your answer on the figure above.

19(b) A student intends to synthesise compound A using the two-stage route below.



Plan a two-stage synthesis to prepare 5.44 g of compound A starting from (chloromethyl)benzene, $\text{C}_6\text{H}_5\text{CH}_2\text{Cl}$. Assume that the overall percentage yield of compound A from (chloromethyl)benzene is 25%.

In your answer, include the mass of $\text{C}_6\text{H}_5\text{CH}_2\text{Cl}$ required, reagents, and equations where appropriate.

Purification details are not required.

[6 marks]

Q45 • Carbonyls, carboxylic acids and esters • June 2017 • Paper 2 (Synthesis and analytical techniques) • Q10 • [1 mark]

Equal amounts of the four compounds are added to the same volume of water.

Which compound would produce the most acidic solution?

Tick (✓) one box.

- ☐ **A** CH_3CONH_2
☐ **B** CH_3COOH
☐ **C** $\text{CH}_3\text{COOCH}_3$
☐ **D** CH_3COCl

Q46 · Carbonyls, carboxylic acids and esters · June 2017 · Paper 2 (Synthesis and analytical techniques) · Q13 · [1 mark]

Which reagents could be used to prepare $\text{CH}_3\text{CH}_2\text{CONHCH}_3$?

Tick (✓) one box.

- ☐ **A** $\text{CH}_3\text{CH}_2\text{COCl} + \text{CH}_3\text{NH}_2$
- ☐ **B** $\text{CH}_3\text{CH}_2\text{CONH}_2 + \text{CH}_3\text{Br}$
- ☐ **C** $\text{CH}_3\text{CH}_2\text{COONa} + \text{CH}_3\text{NH}_2$
- ☐ **D** $\text{CH}_3\text{CH}_2\text{COCH}_3 + \text{NH}_3$

Q47 · Carbonyls, carboxylic acids and esters · June 2018 · Paper 2 (Synthesis and analytical techniques) · Q21 · [12 marks]

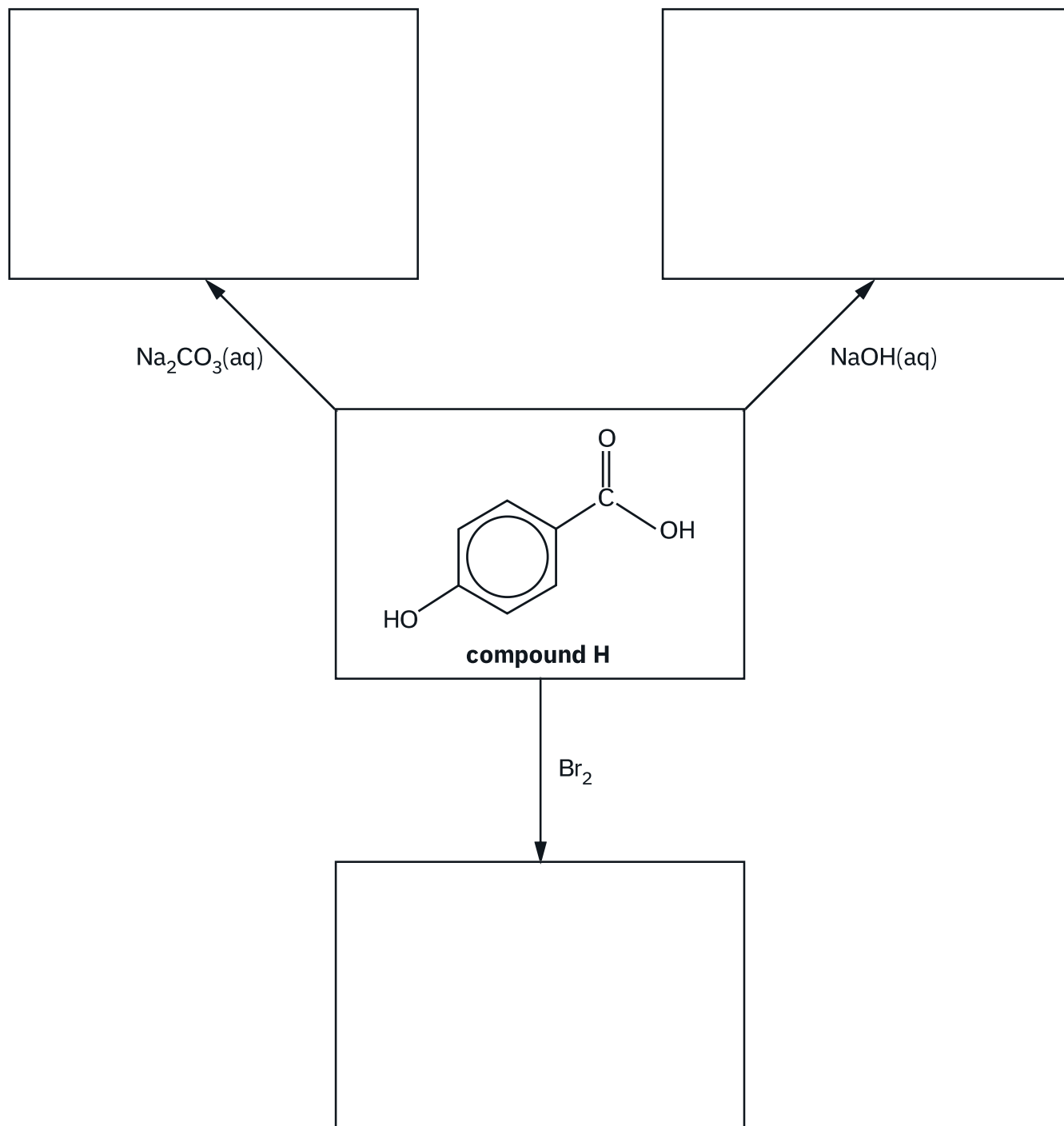
This question also needs Alkenes and addition polymers, Amount of substance, Atomic structure and isotopes

and Basic concepts of organic chemistry.

This question is about aromatic carboxylic acids and their derivatives.

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

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

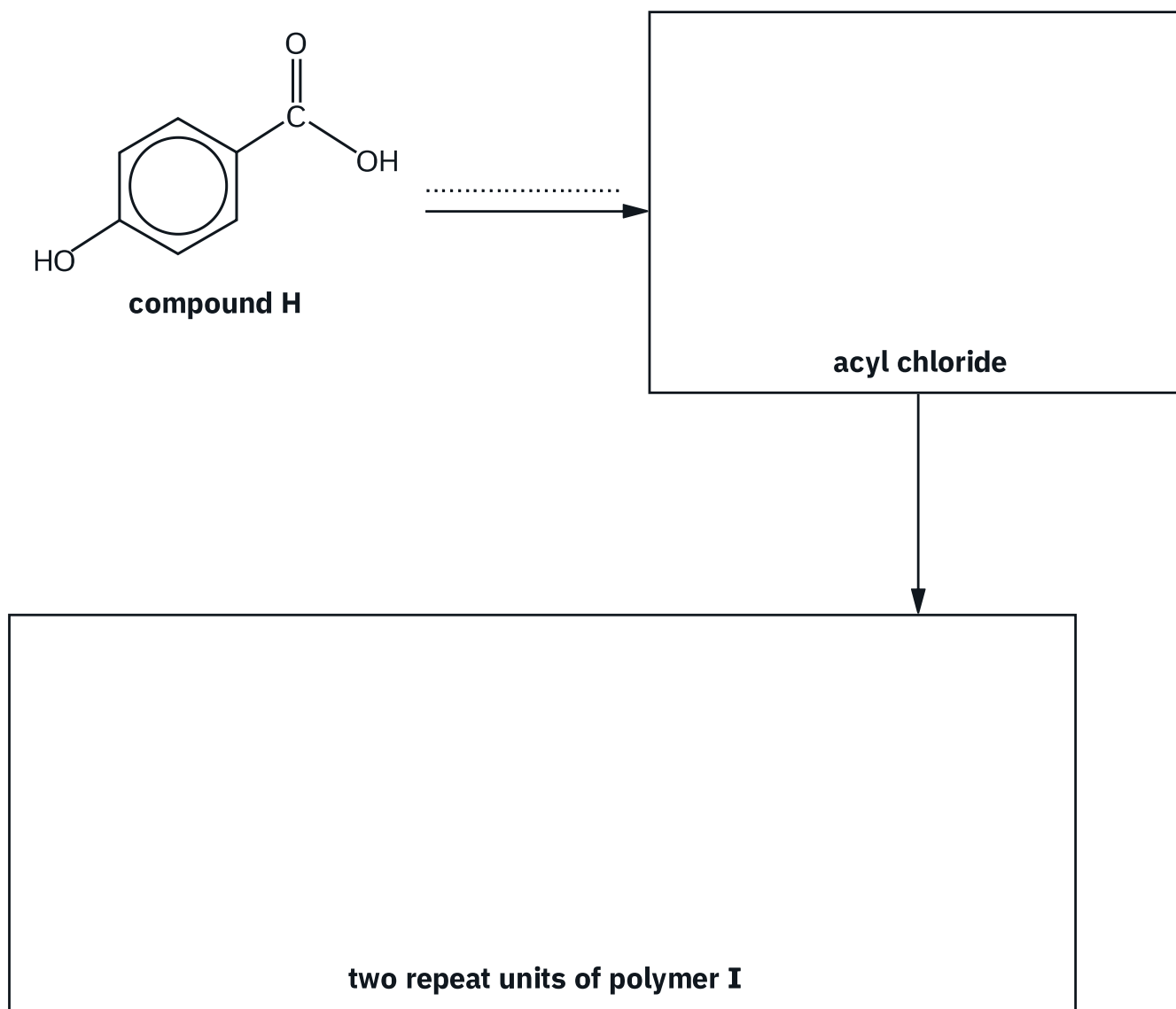


[3 marks]

Draw your answer on the figure above.

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

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

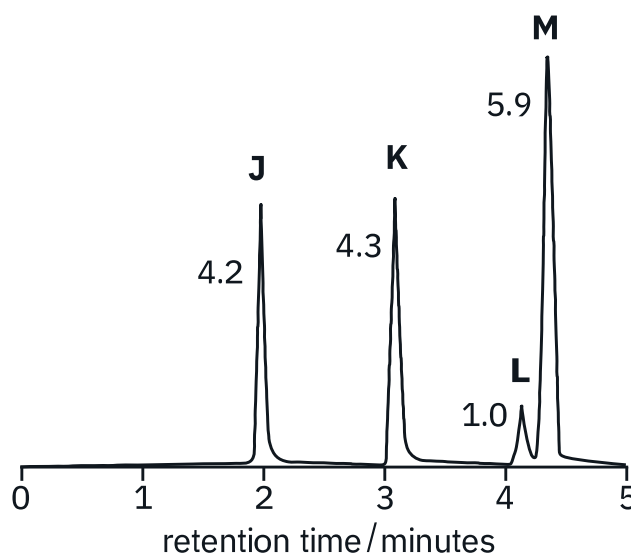


[4 marks]

Draw your answer on the figure above.

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

Gas chromatogram



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

Mass spectrometry

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

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

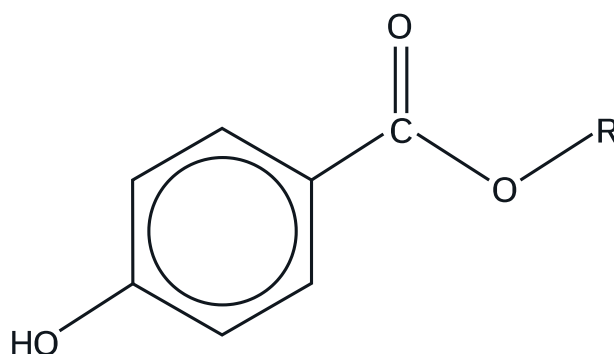
Using the results, calculate the concentration, in mol dm^{-3} , of ester M in the cosmetic product.

Give your answer to two significant figures.

concentration of ester M = mol dm⁻³

[2 marks]

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



Where 'R' is an alkyl group.

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

J L M

[3 marks]

[1 mark]

A carbonyl compound is reacted with NaBH_4 .

Which compound(s) could be formed?

1 2-Methylpentan-2-ol

2 2-Methylpentan-1-ol

3 3-Methylpentan-2-ol

Tick (✓) one box.

☐ **A** 1, 2 and 3

☐ **B** Only 1 and 2

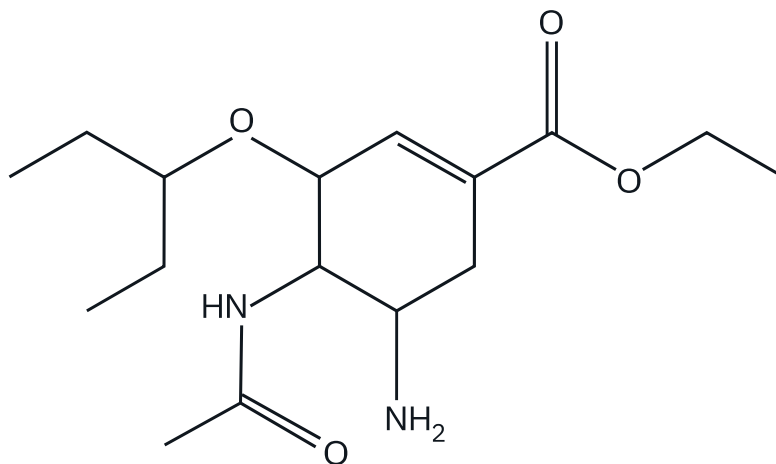
☐ **C** Only 2 and 3

☐ **D** Only 1

Q49 · Carbonyls, carboxylic acids and esters · June 2019 · Paper 2 (Synthesis and analytical techniques) · Q15 · [1 mark]

This question also needs Basic concepts of organic chemistry.

The structure of a compound used to treat influenza is shown below.



Which functional group(s) is/are in a molecule of the compound?

1 Ester

2 Secondary amide

3 Ketone

Tick (✓) one box.

- ☐ **A** 1, 2 and 3
- ☐ **B** Only 1 and 2
- ☐ **C** Only 2 and 3
- ☐ **D** Only 1

Q50 • Carbonyls, carboxylic acids and esters • June 2022 • Paper 2 (Synthesis and analytical techniques) • Q10 • [1 mark]

Butyl propanoate is hydrolysed by aqueous sodium hydroxide.

Which compound is one of the products of this hydrolysis?

Tick (✓) one box.

☐ **A** $\text{C}_3\text{H}_7\text{ONa}$

☐ **B** $\text{C}_3\text{H}_5\text{O}_2\text{Na}$

☐ **C** $\text{C}_4\text{H}_9\text{ONa}$

☐ **D** $\text{C}_4\text{H}_7\text{O}_2\text{Na}$

Q51 • Carbonyls, carboxylic acids and esters • June 2022 • Paper 2 (Synthesis and analytical techniques) • Q18 • [12 marks]

This question also needs Organic synthesis, IR and mass spectra.

This question is about carbonyl compounds.

18(a)(i) Describe a chemical test to confirm the presence of a carbonyl group.

How could the product of this test be used to identify the carbonyl compound?

Your answer should **not** include spectroscopy.

[3 marks]

18(a)(ii) Describe a chemical test that would identify whether a carbonyl compound is an aldehyde.

Your answer **should** include the reagent and observations.

[1 mark]

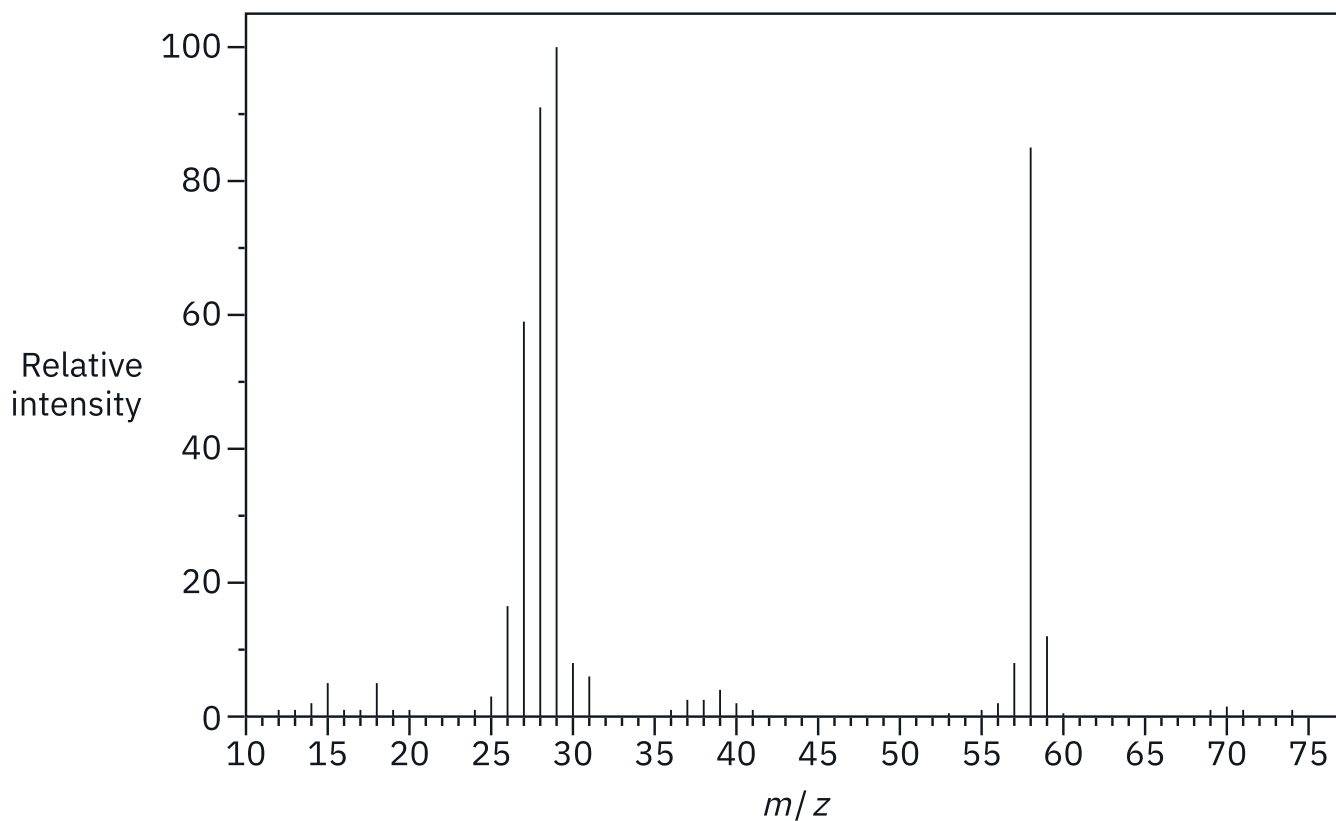
18(b) A student is provided with two unknown carbonyl compounds, F and G.

The compounds are analysed and found to have identical percentage compositions by mass:

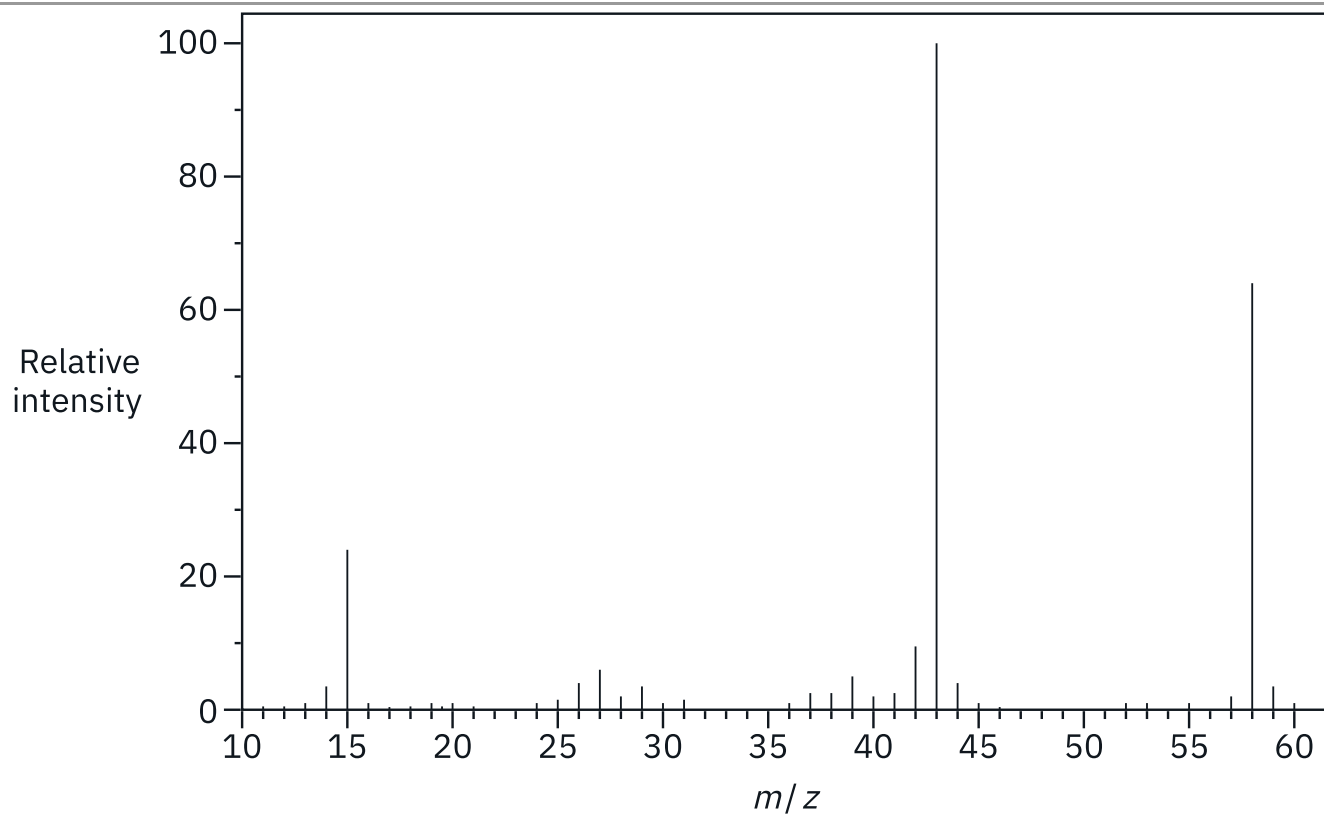
C: 62.07%; H: 10.34%; O: 27.59%

The mass spectra of the two compounds are shown below.

Mass spectrum of F



Mass spectrum of G



Use the results to identify the structures of the two compounds.

Include relevant peaks present in the mass spectrum of each compound.

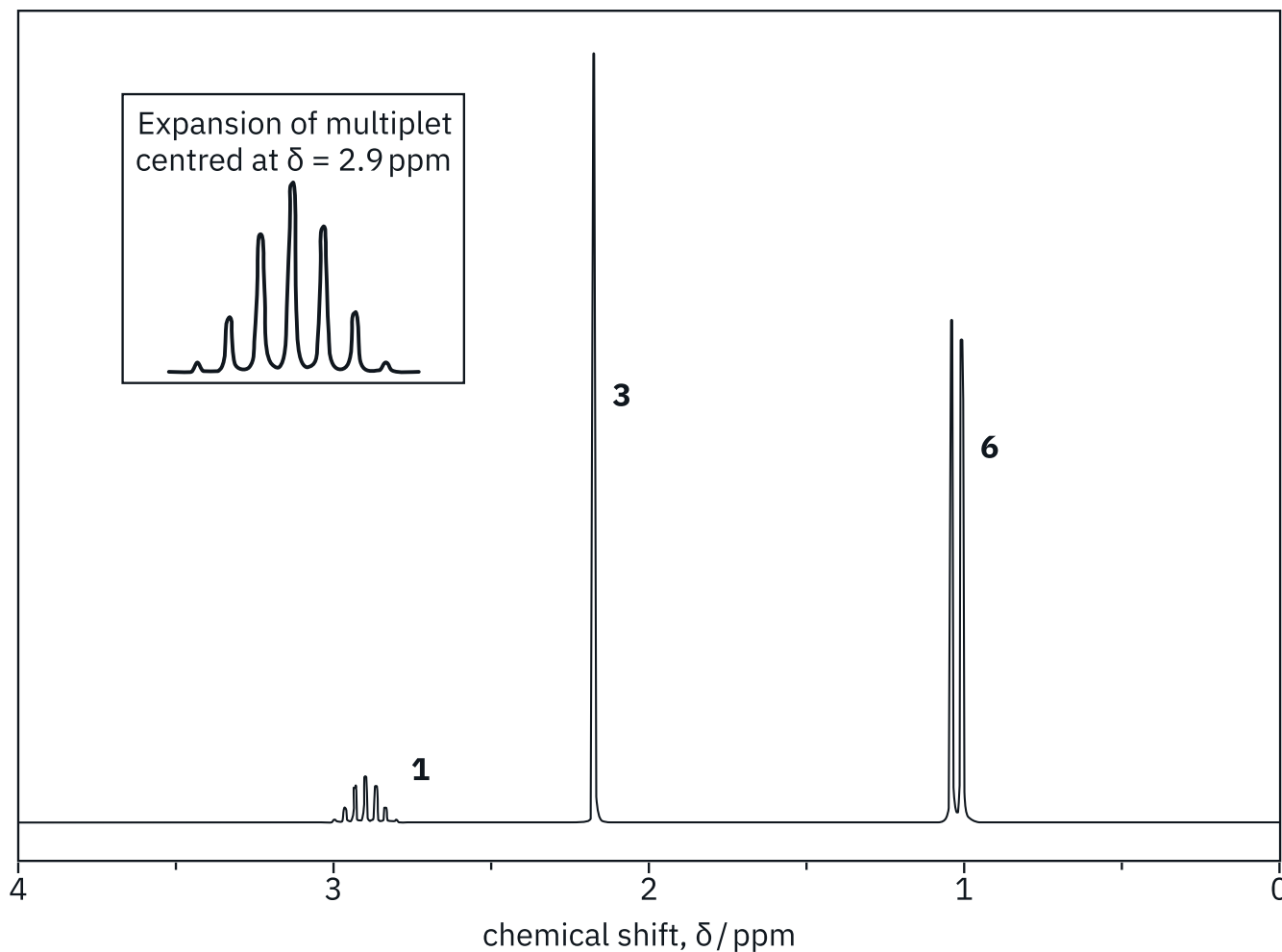
F	G
---	---

[4 marks]

18(c) The organic compound H contains carbon, hydrogen and oxygen only and has an M_r of 114.0.

Compound H has two carbonyl groups and no other functional groups.

The ^1H NMR spectrum of organic compound H is shown below.



The numbers by the peaks are the relative peak areas.

Analyse the spectrum to suggest a possible structure for compound H.

Show all your reasoning.

Compound H

[4 marks]

Q52 • Carbonyls, carboxylic acids and esters • June 2022 • Paper 2 (Synthesis and analytical techniques) • Q19 • [22 marks]

This question also needs Alkenes and addition polymers.

This question is about compounds that contain the carboxylic acid functional group.

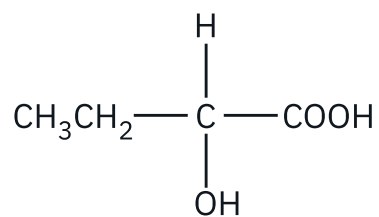
19(a) Carboxylic acids react with alkalis, metals and carbonates to form salts.

Write full equations for the following **three** reactions. Show structures for organic compounds.

- the reaction of propanoic acid with aqueous potassium hydroxide:
- the reaction of aqueous methanoic acid with magnesium:
- the reaction of the α -amino acid, aspartic acid ($R=CH_2COOH$), with an excess of aqueous sodium carbonate, Na_2CO_3 :

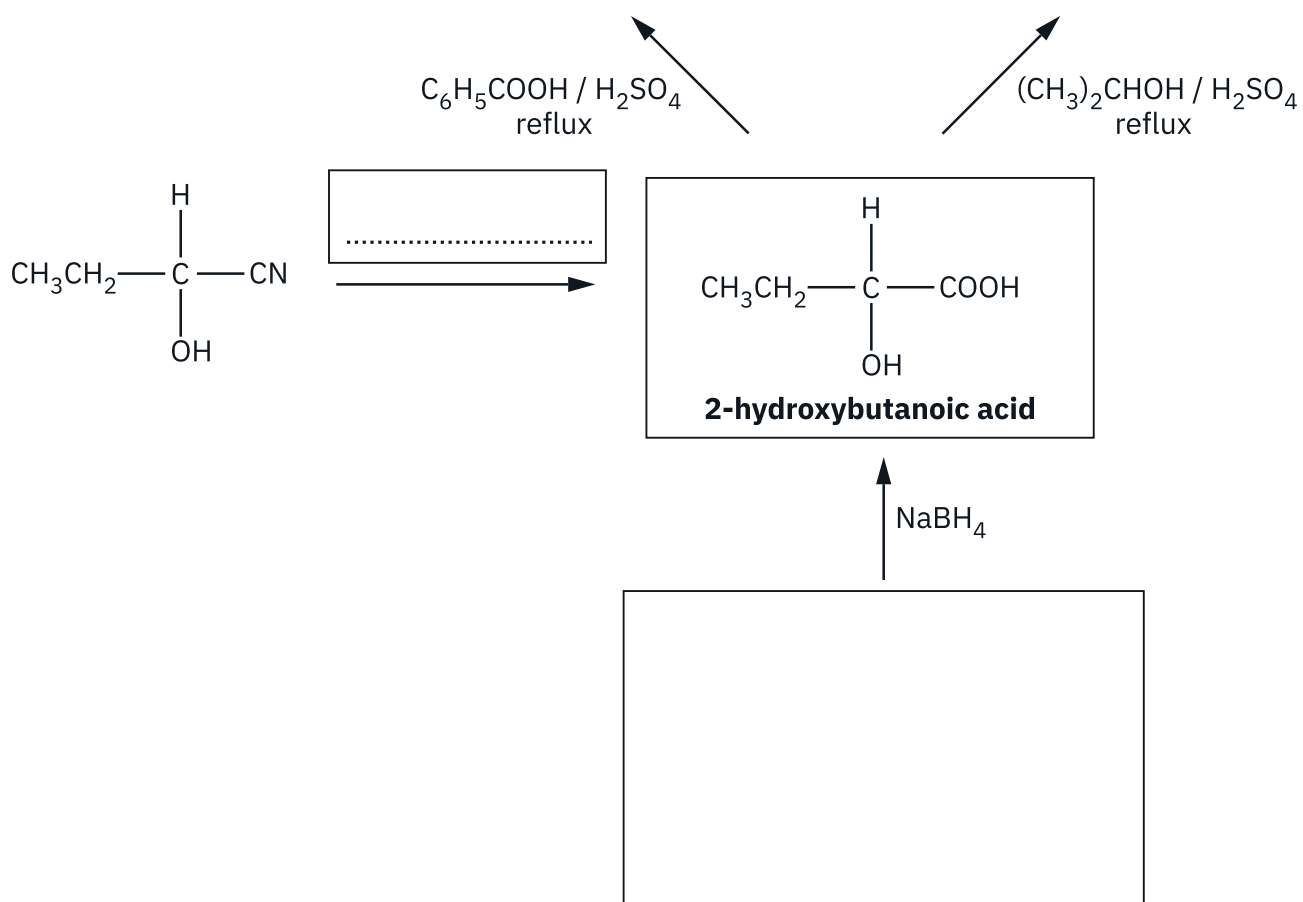
[4 marks]

19(b) The structure of 2-hydroxybutanoic acid is shown below.



2-hydroxybutanoic acid

Fill in the flowchart for reactions involving 2-hydroxybutanoic acid.



[4 marks]

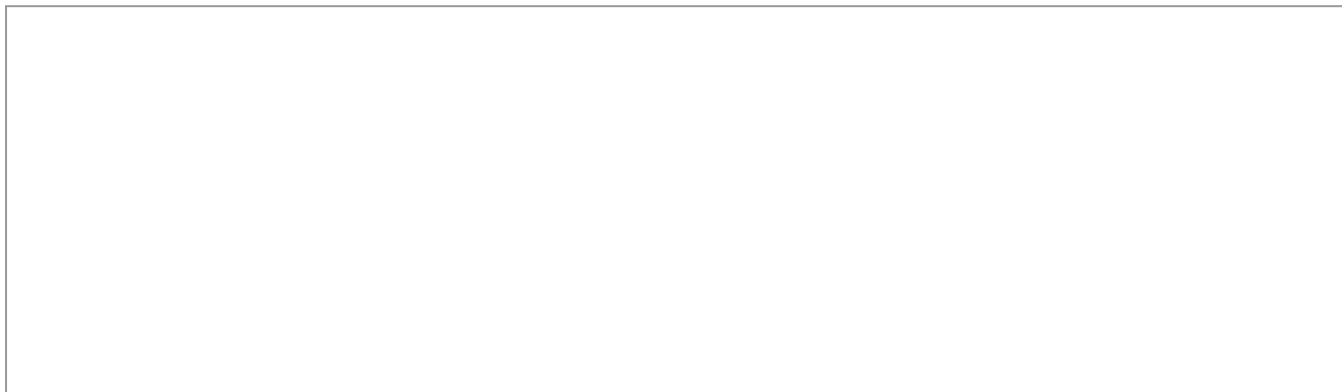
This part is about polymers derived from carboxylic acid monomers.

19(c)(i) Poly(pent-3-enoic acid) is an addition polymer.

Draw the structure of pent-3-enoic acid and **two** repeat units of this polymer.

[2 marks]

Pent-3-enoic acid



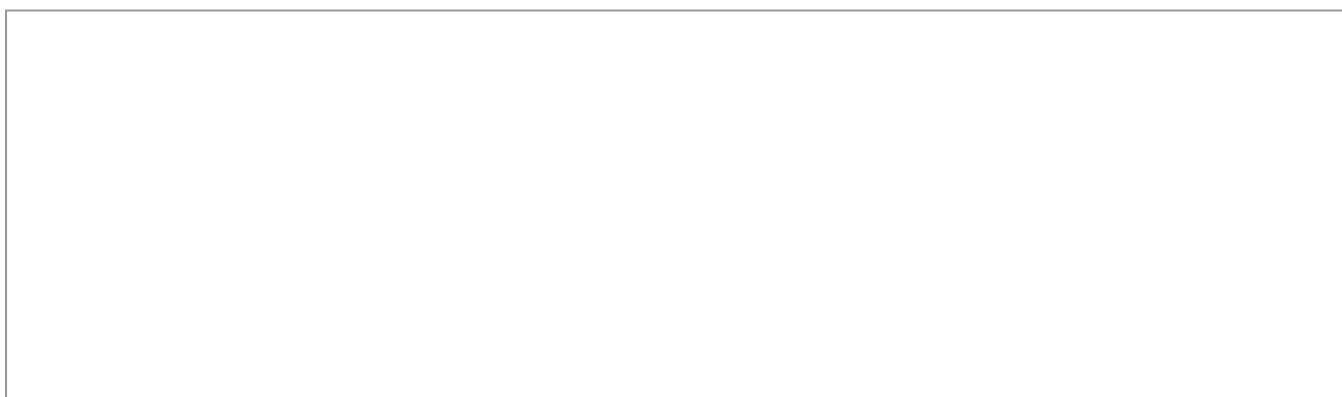
Two repeat units of poly(pent-3-enoic acid)



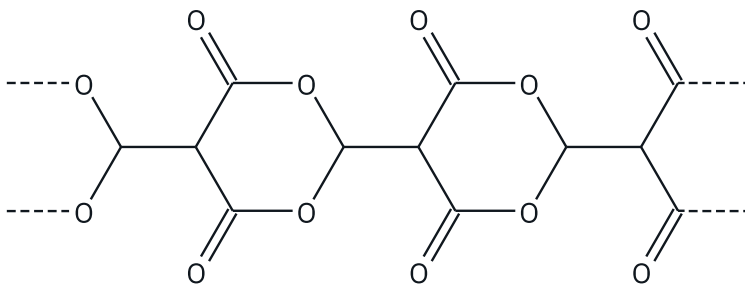
19(c)(ii) Butanedicarboxylic acid and 1,4-dihydroxy-2-methylbenzene react to form a condensation polymer.

Draw **one** repeat unit of this condensation polymer.

[2 marks]



19(c)(iii) Three repeat units of a condensation polymer are shown below.



Draw the structure of the monomer required to form this polymer.

[1 mark]

A polymer is formed from 400 molecules of 2-aminopropanoic acid.

19(d)(i) Draw **one** repeat unit of this polymer.

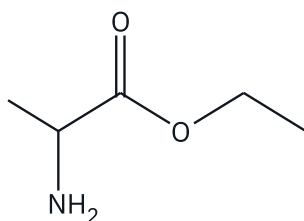
[1 mark]

19(d)(ii) What is the relative molecular mass, M_r , of the polymer?

$M_r =$

[2 marks]

19(e) A student intends to synthesise compound I.



Compound I

Plan a synthesis to prepare 9.36 g of compound I starting from 2-chloropropanoic acid, $\text{CH}_3\text{CHClCOOH}$. The overall percentage yield of compound I from 2-chloropropanoic acid is 64%.

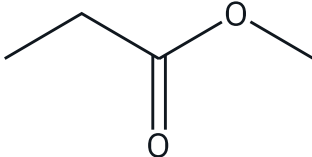
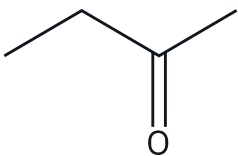
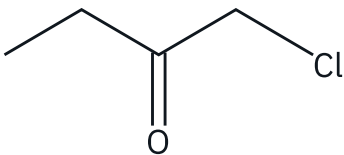
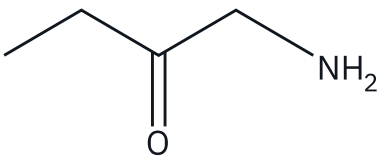
In your answer, include starting mass of 2-chloropropanoic acid, reagents, conditions and equations where appropriate.

[6 marks]

[1 mark]

Which compound reacts with ethanoyl chloride?

Tick (✓) one box.

- ☐ **A** 
- ☐ **B** 
- ☐ **C** 
- ☐ **D** 

Q54 · Carbonyls, carboxylic acids and esters · June 2023 · Paper 2 (Synthesis and analytical techniques) · Q14 · [1 mark]

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

1 $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOCH}_3$

2 $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CN}$

3 $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Cl}$

Tick (✓) one box.

- ☐ **A** 1, 2 and 3
- ☐ **B** Only 1 and 2
- ☐ **C** Only 2 and 3
- ☐ **D** Only 1

Q55 · Carbonyls, carboxylic acids and esters · June 2023 · Paper 2 (Synthesis and analytical techniques) · Q2 · [1

mark]

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

Tick (✓) one box.

- ☐ **A** $\text{C}_6\text{H}_5\text{COCOOH}$
- ☐ **B** $\text{C}_6\text{H}_5\text{CH}(\text{OH})\text{CHO}$
- ☐ **C** CH_3COCHO
- ☐ **D** $\text{CH}_3\text{CH}_2\text{CH}(\text{OH})\text{CH}_3$

Q56 · Carbonyls, carboxylic acids and esters · June 2023 · Paper 2 (Synthesis and analytical techniques) · Q22 · [14 marks]

This question also needs Alkenes and addition polymers.

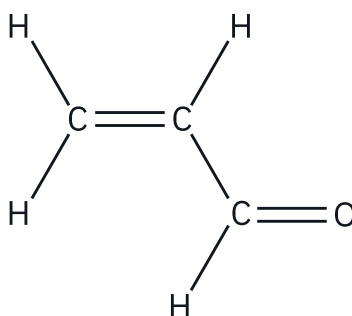
This question is about reactions of acrolein, $\text{H}_2\text{C}=\text{CHCHO}$.

Acrolein reacts with sodium cyanide in acidic conditions, $\text{NaCN}(\text{aq}) / \text{H}^+(\text{aq})$.

22(a)(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 marks]

22(a)(ii) Name this type of mechanism.

[1 mark]

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

Flowchart structure:

- unsaturated alcohol** (top left box) has two outgoing arrows:
 - One arrow points to **diol (major product)** (top right box). Above this arrow is a box for **reagent(s)** and below it is a box for **catalyst**.
 - One arrow points up to a box for **reagent(s)**.
- acrolein** (bottom left, with structural formula) has two outgoing arrows:
 - One arrow points up to the **reagent(s)** box above the **unsaturated alcohol**.
 - One arrow points right to a box for **reagent(s)**, which then points to **carboxylic acid** (middle right box).
- carboxylic acid** (middle right box) has one outgoing arrow pointing down to **acyl chloride** (bottom right box). Above this arrow is a box for **reagent(s)**.
- acrolein** (bottom left) has one outgoing arrow pointing down to **polymer (2 repeat units)** (bottom left box).

Structural formula for acrolein:

$$\begin{array}{c} \text{H} & & \text{H} \\ & \backslash & / \\ & \text{C} = \text{C} \\ & / & \backslash \\ \text{H} & & \text{C} = \text{O} \\ & & | \\ & & \text{H} \end{array}$$

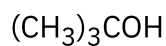
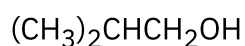
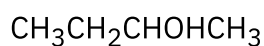
[9 marks]

Q57 · Carbonyls, carboxylic acids and esters · June 2024 · Paper 2 (Synthesis and analytical techniques) · Q17 · [8 marks]

This question also needs Alcohols and haloalkanes.

This question is about reactions of alcohols.

There are 4 structural isomers of $C_4H_{10}O$ that are alcohols:



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.

17(a) Elimination reaction of $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$

[2 marks]

Reagent(s) and/or catalyst

organic product

17(b) Oxidation reaction of $\text{CH}_3\text{CH}_2\text{CHOHCH}_3$

[2 marks]

Reagent(s) and/or catalyst

organic product

17(c) Substitution reaction of $(\text{CH}_3)_2\text{CHCH}_2\text{OH}$

[2 marks]

Reagent(s) and/or catalyst

organic product

17(d) Esterification reaction of $(\text{CH}_3)_3\text{COH}$ **[2 marks]**

Reagent(s) and/or catalyst

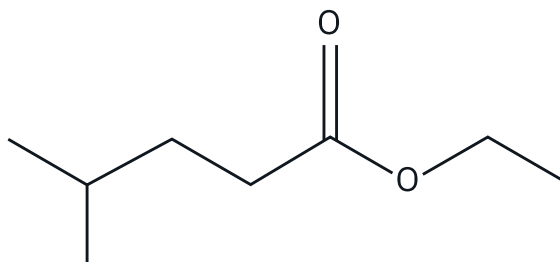
organic product

Q58 · Carbonyls, carboxylic acids and esters · June 2024 · Paper 2 (Synthesis and analytical techniques) · Q20 · [13 marks]

This question is about carboxylic acids and esters.

20(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 marks]**

Ester F has the structure shown below.

**Ester F****20(b)(i)** What is the systematic name for this ester?**[1 mark]**

20(b)(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.

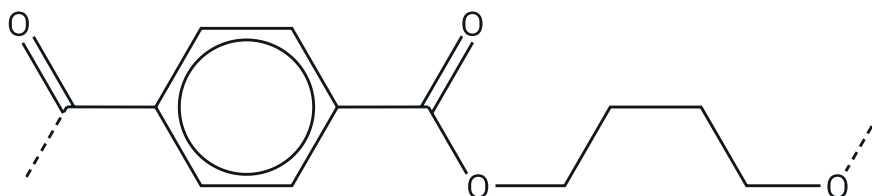
Show organic compounds as structures.

[4 marks]

Step 1

Step 2

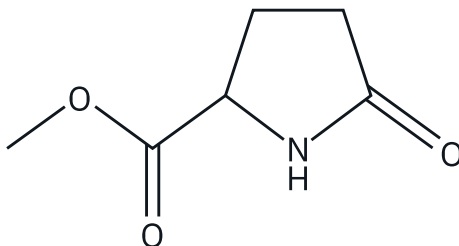
20(c) The repeat unit of a polyester is shown below.



Draw the structures of monomers required to form this polyester.

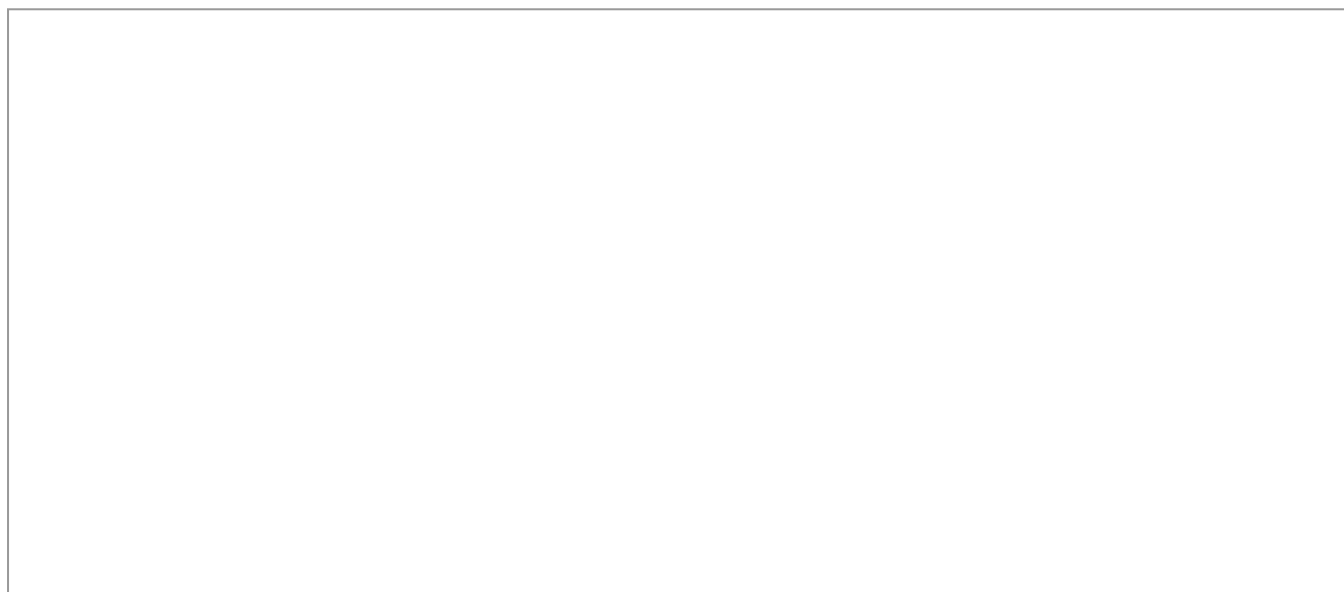
[2 marks]

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



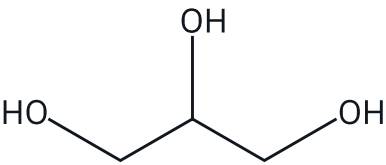
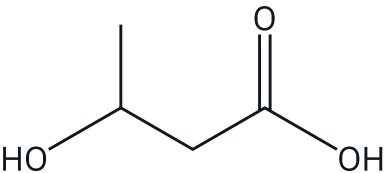
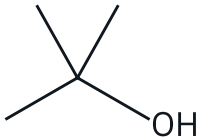
Draw the structures of the organic products formed by the complete **alkaline** hydrolysis of this compound using NaOH(aq).

[4 marks]



[1 mark]

Which molecule(s) would form a ketone group when oxidised?

1	
2	
3	

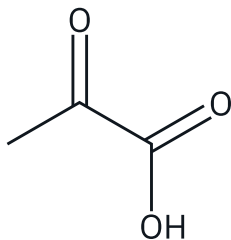
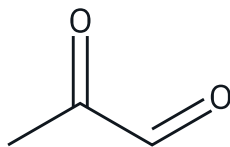
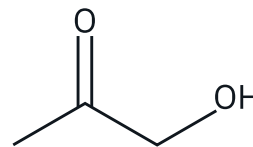
Tick (✓) one box.

- ☐ **A** 1, 2 and 3
- ☐ **B** Only 1 and 2
- ☐ **C** Only 2 and 3
- ☐ **D** Only 1

Q60 · Carbonyls, carboxylic acids and esters · June 2025 · Paper 2 (Synthesis and analytical techniques) · Q21 · [17 marks]

This question is about carbonyl compounds.

The three compounds below each contain a ketone and one other functional group.

**Pyruvic acid****Methylglyoxal****Acetol**

21(a) What is a **functional group**?

[1 mark]

21(b) A chemical test is carried out which gives a positive result for **all three** compounds.

Suggest the reagent and observation of this chemical test.

[2 marks]

Reagent

Observation

21(c) A student is provided with three unlabelled sample tubes, containing either pyruvic acid, methylglyoxal or acetol.

The student carries out three chemical tests on each sample.

Complete the table with the expected observations, including 'no change' where appropriate.

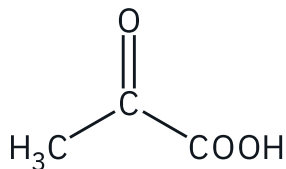
Expected observations			
Chemical test	Pyruvic acid	Methylglyoxal	Acetol
Tollens' reagent			
$\text{Na}_2\text{CO}_3(\text{aq})$			
$\text{Cr}_2\text{O}_7^{2-}(\text{aq})/\text{H}^+(\text{aq})$			

[3 marks]

21(d) Pyruvic acid reacts with NaBH_4 .

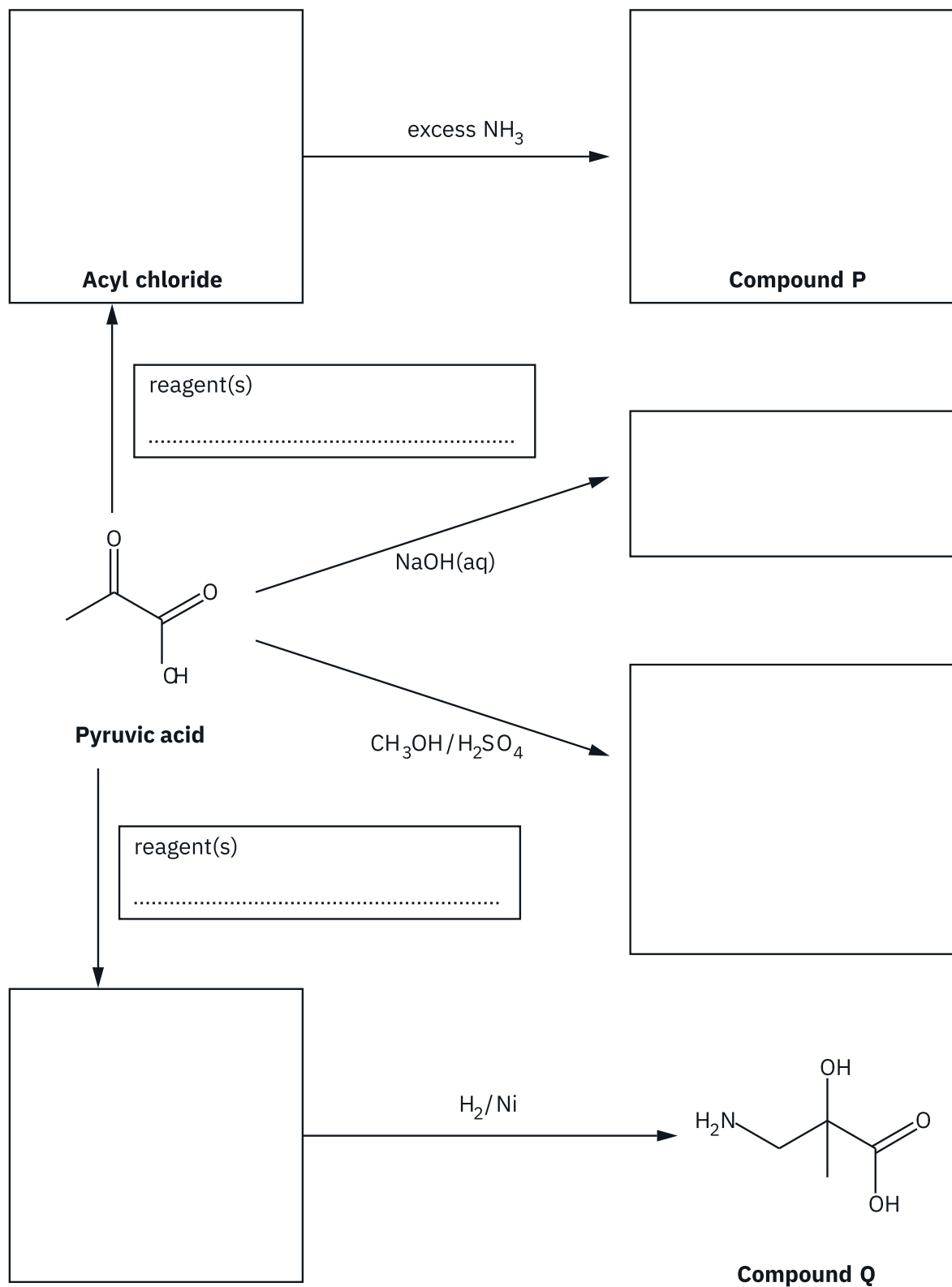
Outline the mechanism for the reaction of pyruvic acid with NaBH_4 .

Include curly arrows and relevant dipoles.



[4 marks]

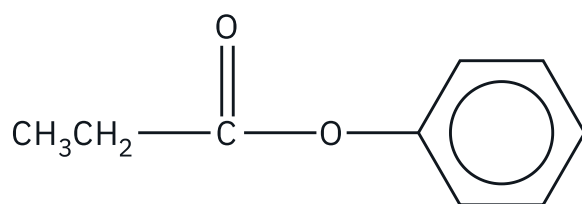
21(e) Complete the flowchart for the reactions of pyruvic acid.



[7 marks]

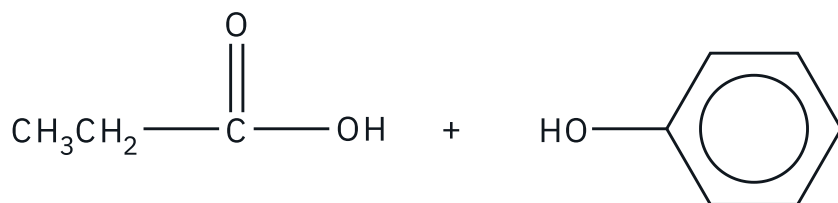
Q61 • Carbonyls, carboxylic acids and esters • June 2025 • Paper 2 (Synthesis and analytical techniques) • Q9 • [1 mark]

Which reagents could a student use to prepare the ester shown?



Tick (✓) one box.

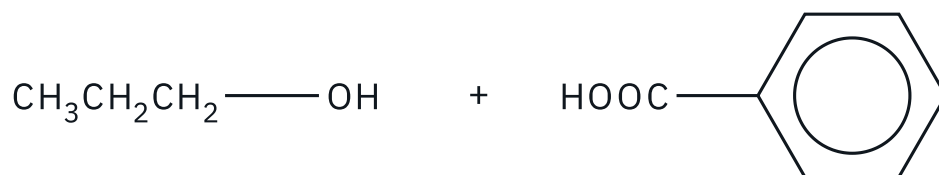
☐ **A**



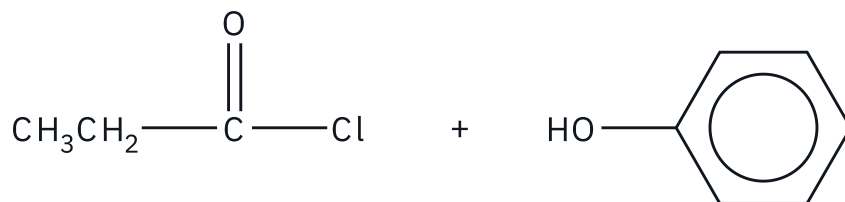
☐ **B**



☐ **C**



☐ **D**



Q62 · Carbonyls, carboxylic acids and esters · November 2020 · Paper 2 (Synthesis and analytical techniques) · Q18 · [11 marks]

This question also needs Alcohols and haloalkanes, Alkenes and addition polymers, Basic concepts of organic chemistry and 3 other topics.

Alcohols can be used to prepare organic compounds with different functional groups.

$\text{HO}(\text{CH}_2)_4\text{OH}$ can be oxidised to form $\text{HOOC}(\text{CH}_2)_2\text{COOH}$.

18(a)(i) State the reagents and conditions and write an equation for this oxidation.

In the equation, use [O] for the oxidising agent.

Reagents and conditions:

Equation:

[3 marks]

18(a)(ii) $\text{HOOC}(\text{CH}_2)_2\text{COOH}$ is soluble in water.

Explain, using a labelled diagram, why $\text{HOOC}(\text{CH}_2)_2\text{COOH}$ is soluble in water.

[2 marks]

$\text{HOOC}(\text{CH}_2)_2\text{COOH}$ and $\text{HO}(\text{CH}_2)_4\text{OH}$ react together to form polymer E.

18(b)(i) Draw one repeat unit of polymer E.

The functional groups should be clearly displayed.

[2 marks]

18(b)(ii) Governments are encouraging the development of biodegradable polymers to reduce dependency on persistent plastic waste derived from fossil fuels.

Polymer E is a biodegradable polymer.

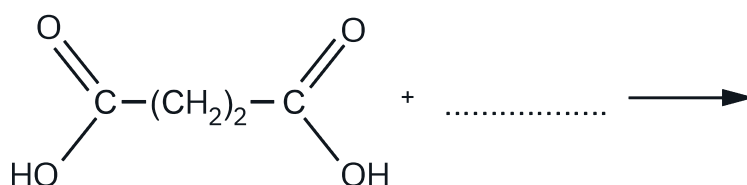
Suggest why polymer E is able to biodegrade.

[1 mark]

18(b)(iii) A large yield of polymer E can be obtained by reacting a diacyl dichloride with $\text{HO}(\text{CH}_2)_4\text{OH}$.

The diacyl dichloride is prepared from $\text{HOOC}(\text{CH}_2)_2\text{COOH}$.

Complete the equation for the formation of a diacyl dichloride from $\text{HOOC}(\text{CH}_2)_2\text{COOH}$.



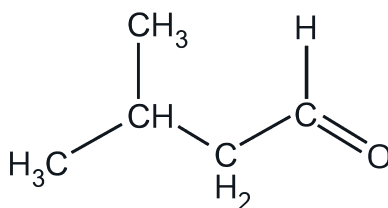
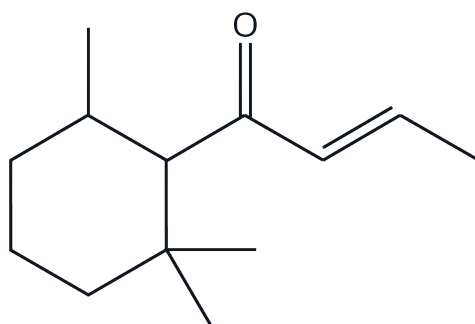
[3 marks]

Draw your answer on the figure above.

Q63 · Carbonyls, carboxylic acids and esters · November 2020 · Paper 2 (Synthesis and analytical techniques) · Q19 · [14 marks]

This question also needs Alkenes and addition polymers, Amount of substance and Basic concepts of organic chemistry.

The carbonyl compounds, F and G, shown below, contribute to the flavour of coffee.

**F****G**

Compound F is a member of a homologous series.

19(a)(i) Explain the term homologous series.

[2 marks]

19(a)(ii) Predict the molecular formula for the member of this homologous series containing 24 carbon atoms.

[1 mark]

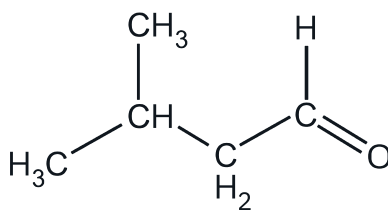
19(b) Describe suitable chemical tests, with observations, that would confirm the presence of the functional groups in F and G.

[4 marks]

Compound F reacts with HCN using NaCN(aq) and H⁺(aq).

19(c)(i) Outline the mechanism for the reaction of F with NaCN(aq) and H⁺(aq) and state the name of the mechanism. The structure of F has been provided.

Include relevant dipoles, lone pairs and the structure of the organic product.



Name of mechanism:

[5 marks]

19(c)(ii) Explain why the mechanism in (c)(i) involves heterolytic fission.

[2 marks]

Q64 • Carbonyls, carboxylic acids and esters • November 2020 • Paper 2 (Synthesis and analytical techniques) • Q3 • [1 mark]

This question also needs Alcohols and haloalkanes and Reaction rates and equilibrium.

Which of these reagent(s) will not react with $\text{HOCH}_2\text{CH}_2\text{CH}_2\text{COOH}$?

Tick (✓) one box.

- ☐ **A** NaCN in ethanol
- ☐ **B** $\text{C}_2\text{H}_5\text{OH}$ in the presence of an acid catalyst
- ☐ **C** $(\text{CH}_3\text{CO})_2\text{O}$
- ☐ **D** concentrated H_2SO_4

Q65 • Carbonyls, carboxylic acids and esters • November 2020 • Paper 2 (Synthesis and analytical techniques) • Q9 • [1 mark]

What is the structural formula of ethyl 3-methylbutanoate?

Tick (✓) one box.

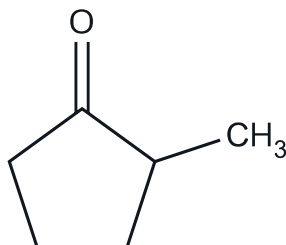
- ☐ **A** $\text{CH}_3\text{CH}_2\text{COOCH}_2\text{CH}_2\text{CH}(\text{CH}_3)_2$
- ☐ **B** $\text{CH}_3\text{CH}_2\text{COOCH}(\text{CH}_3)\text{CH}_2\text{CH}_3$
- ☐ **C** $\text{CH}_3\text{CH}_2\text{CH}(\text{CH}_3)\text{COOCH}_2\text{CH}_3$
- ☐ **D** $(\text{CH}_3)_2\text{CHCH}_2\text{COOCH}_2\text{CH}_3$

Q66 • Carbonyls, carboxylic acids and esters • November 2021 • Paper 2 (Synthesis and analytical techniques) •

Q5 • [1 mark]

This question also needs Alkenes and addition polymers and Amount of substance.

2-Methylcyclopentanone, shown below, is reacted with $\text{NaCN(aq)/H}^+(\text{aq})$ to form an organic product.



2-methylcyclopentanone

Which statement is correct?

Tick (✓) one box.

- ☐ **A** In the mechanism, a CN^- ion accepts an electron pair.
- ☐ **B** The mechanism is electrophilic addition.
- ☐ **C** The organic product has one chiral centre.
- ☐ **D** The organic product has the molecular formula $\text{C}_7\text{H}_{11}\text{NO}$.

Q67 • Carbonyls, carboxylic acids and esters • November 2021 • Paper 2 (Synthesis and analytical techniques) • Q6 • [1 mark]

$\text{CH}_3\text{CH}_2\text{COOCH}_3$ is heated with aqueous sodium hydroxide to produce two organic products.

What are the two organic products?

Tick (✓) one box.

- ☐ **A** $\text{CH}_3\text{CH}_2\text{COOH}$ and CH_3OH
- ☐ **B** $\text{CH}_3\text{CH}_2\text{COONa}$ and CH_3OH
- ☐ **C** $\text{CH}_3\text{CH}_2\text{COOH}$ and CH_3ONa
- ☐ **D** $\text{CH}_3\text{CH}_2\text{COONa}$ and CH_3ONa

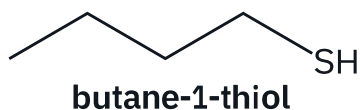
Q68 • Chromatography and functional group tests • June 2017 • Paper 3 (Unified chemistry) • Q5 • [12 marks]

This question also needs Acids, bases and buffers and Basic concepts of organic chemistry.

This question is about organic molecules that have a strong smell.

Thiols are foul-smelling, organic sulfur compounds with the functional group -SH .

Butane-1-thiol, shown below, contributes to the strong smell of skunks.



5(a)(i) Thiols are weak acids.

Write the expression for the acid dissociation constant, K_a , for butane-1-thiol.

[1 mark]

5(a)(ii) Thiols react with carboxylic acids to form thioesters.

Write an equation for the reaction of butane-1-thiol with ethanoic acid.

Use structures for all organic compounds with the functional groups clearly displayed.

[2 marks]

5(a)(iii) When beer is exposed to light, 3-methylbut-2-ene-1-thiol is formed, which gives an unpleasant smell and flavour to the beer.

Draw the skeletal formula for 3-methylbut-2-ene-1-thiol.

[1 mark]

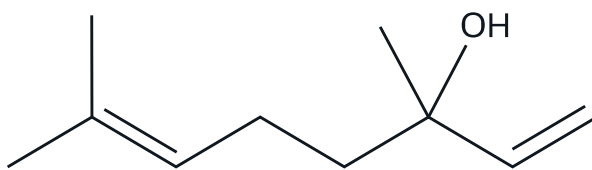
5(a)(iv) Propane-1,3-dithiol reacts with carbonyl compounds in a condensation reaction to form a cyclic organic sulfur product.

Write an equation for the reaction of propane-1,3-dithiol with propanone.

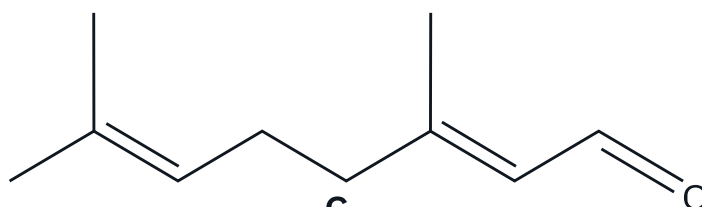
Use structures for organic compounds.

[2 marks]

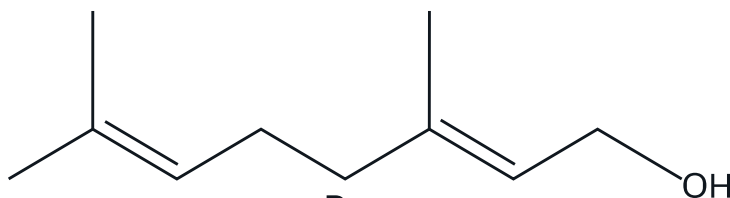
5(b) The structures for six naturally occurring organic compounds with pleasant smells, B–G, are shown below. The common names in brackets relate to their source and smell.



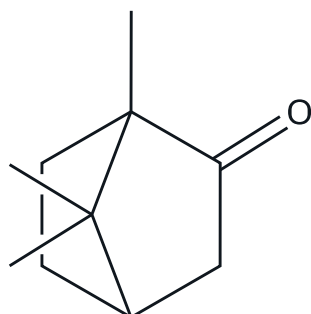
B
(linalool)



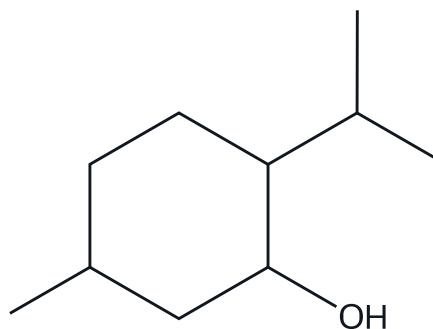
C
(citral)



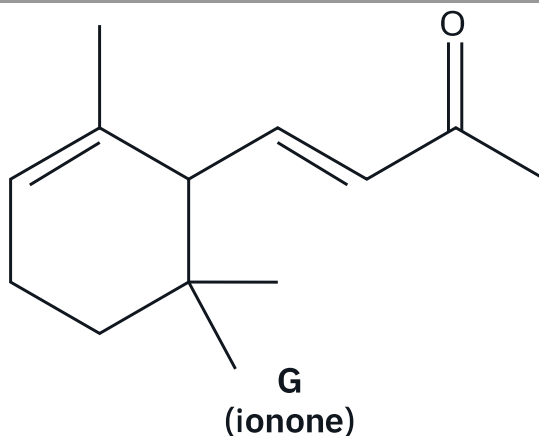
D
(geraniol)



E
(camphor)



F
(menthol)



Explain how chemical tests would allow each compound to be distinguished from the other compounds.

In your answer, include essential details for all test procedures and observations.

Details of apparatus and quantities are not required.

[6 marks]

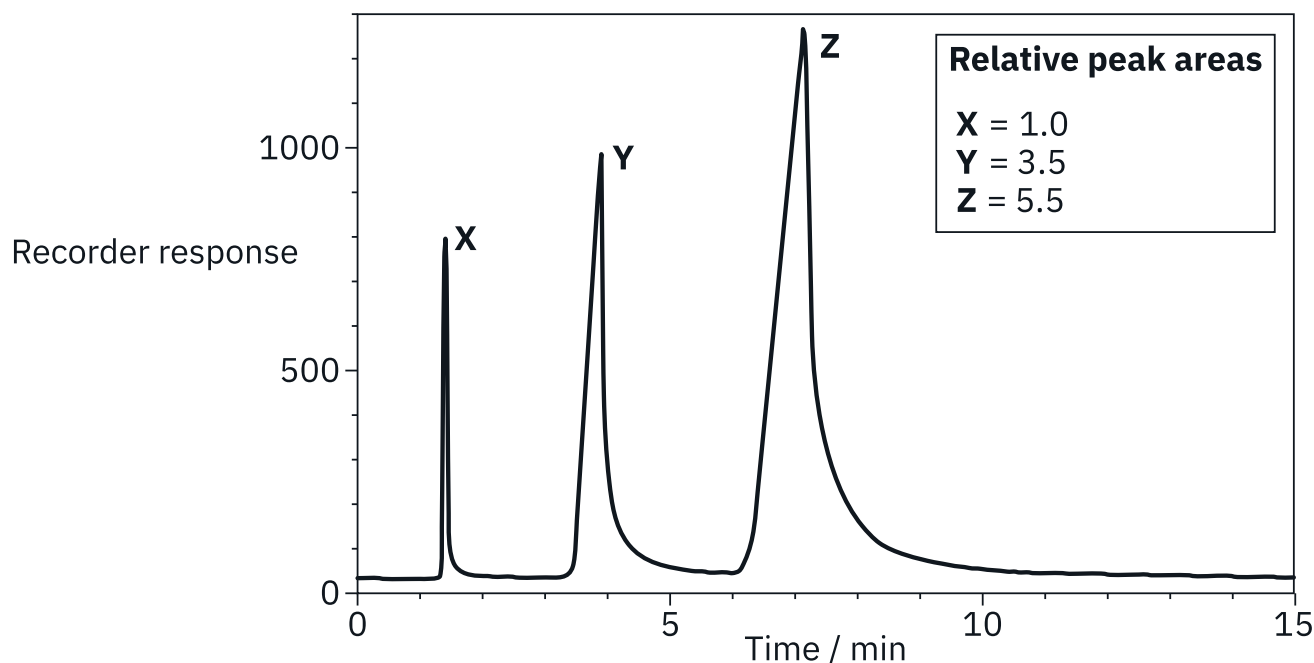
Q69 · Chromatography and functional group tests · June 2024 · Paper 2 (Synthesis and analytical techniques) ·

Q13 · [1 mark]

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.

Tick (✓) one box.

- ☐ **A** 1, 2 and 3
- ☐ **B** Only 1 and 2
- ☐ **C** Only 2 and 3
- ☐ **D** Only 1

Q70 · Chromatography and functional group tests · June 2024 · Paper 3 (Unified chemistry) · Q5 · [13 marks]

This question also needs Alcohols and haloalkanes.

This question is about the analysis of organic compounds.

A student investigates the alkaline hydrolysis of 1-bromopropane as outlined below.

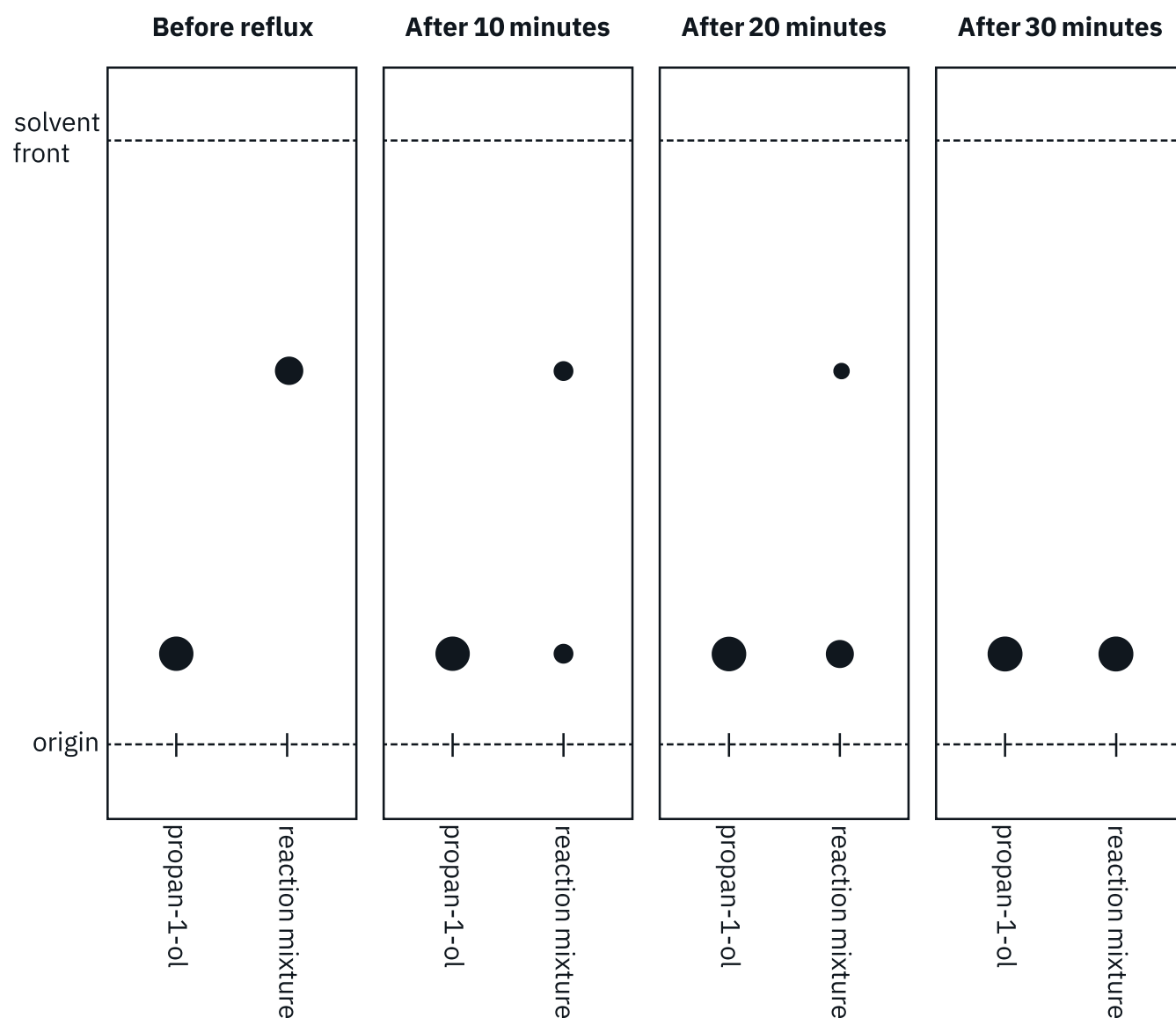
Step 1 The student adds 1-bromopropane to an excess of aqueous potassium hydroxide, KOH(aq), in a pear-shaped flask.

Step 2 A TLC chromatogram is run using propan-1-ol and the reaction mixture.

Step 3 The reaction mixture is refluxed.

A TLC chromatogram of the reaction mixture is run every 10 minutes.

The TLC chromatograms are shown below.



5(a)(i) Determine the R_f value of propan-1-ol.

Show your working.

$R_f =$

[1 mark]

5(a)(ii) Write an equation for the alkaline hydrolysis of 1-bromopropane.

Show structures of organic compounds.

[1 mark]

5(a)(iii) A student investigates the alkaline hydrolysis of 1-chloropropane using the same method as for 1-bromopropane.

Predict, with reasons, how the appearance of the reaction mixture in the chromatogram produced after 20 minutes would be different when 1-chloropropane is used instead of 1-bromopropane.

Suggest why propan-1-ol is run alongside the reaction mixture.

[3 marks]

Compounds F, G, H and I are structural isomers.

A student carries out test-tube tests on the compounds.

The student records the observations after carrying out each test.

These are shown in Table 5.1.

In Table 5.1, 2,4-dinitrophenylhydrazine has been abbreviated to 2,4-DNP.

Table 5.1

Test				
Compound	2,4-DNP	Acidified dichromate(VI) reflux	Bromine water	Tollens' reagent
F	Orange solution	Green solution	Colourless solution	Colourless solution
G	Orange solution	Green solution	Orange solution	Colourless solution
H	Orange precipitate	Orange solution	Orange solution	Colourless solution
I	Orange precipitate	Green solution	Orange solution	Silver mirror

5(b)(i) Write the formula of the species causing the colours after refluxing with acidified dichromate(VI).

[2 marks]

Green solution

Orange solution

5(b)(ii) The student is provided with further information about compounds F–I.

- They all have the molecular formula $C_5H_{10}O$.
- One of the compounds is alicyclic.
- The other compounds are unbranched.

Use this further information and the student's observations in Table 5.1 to answer the following.

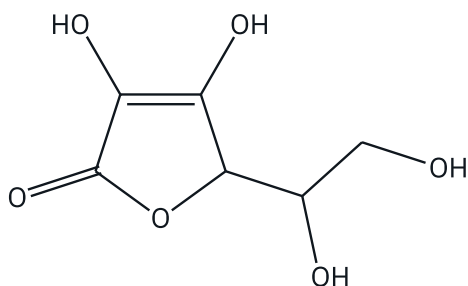
- How do the observations provide evidence for the possible functional groups in compounds F–I?
- Suggest a possible structure for each of the compounds F–I.

Show your reasoning.

[6 marks]

Q71 • Chromatography and functional group tests • June 2025 • Paper 2 (Synthesis and analytical techniques) • Q14 • [1 mark]

The structure of vitamin C is shown.



Which reagent(s) will react with vitamin C?

- 1 Aqueous bromine water
- 2 Acidified potassium dichromate(VI)
- 3 Aqueous silver nitrate in ethanol

Tick (✓) one box.

- ☐ **A** 1, 2 and 3
- ☐ **B** Only 1 and 2
- ☐ **C** Only 2 and 3
- ☐ **D** Only 1

Q72 • Chromatography and functional group tests • June 2025 • Paper 2 (Synthesis and analytical techniques) • Q22 • [6 marks]

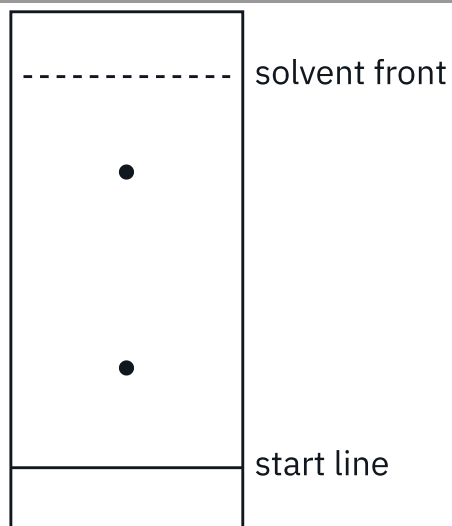
This question is about organic acids.

α -Amino acids have the general formula $\text{RCH}(\text{NH}_2)\text{COOH}$.

Compound S is made of two α -amino acids bonded together.

Compound S is hydrolysed into its component α -amino acids.

The resulting mixture is analysed using TLC to produce a chromatogram:



The R group and the R_f value is shown for some α -amino acids.

R group	R_f value
-H	0.18
-CH ₃	0.25
-CH ₂ CH(CH ₃) ₂	0.64
-CH(CH ₃) ₂	0.77

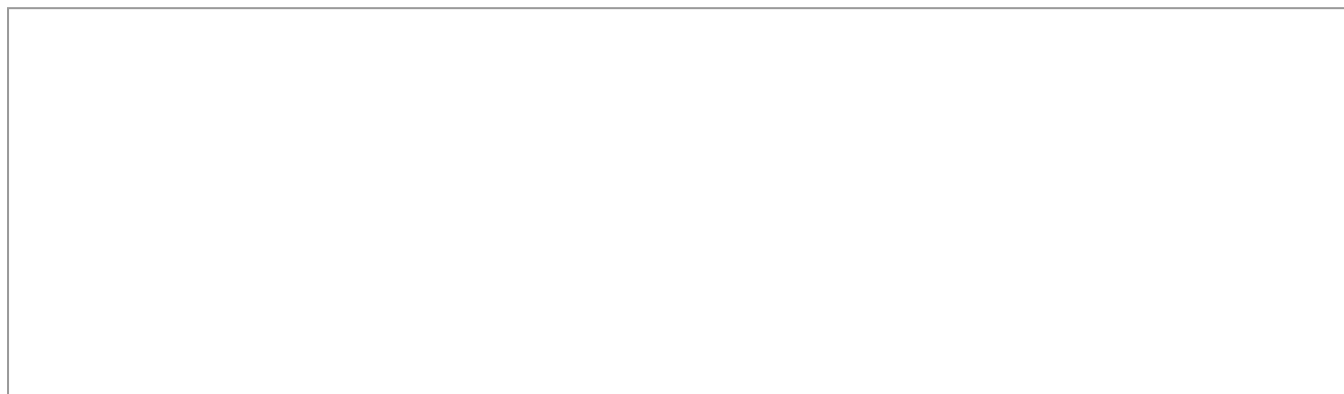
22(a)(i) Determine the R_f values of the **two** α -amino acids in the chromatogram.

[1 mark]

22(a)(ii) Compound S has **two** possible structures.

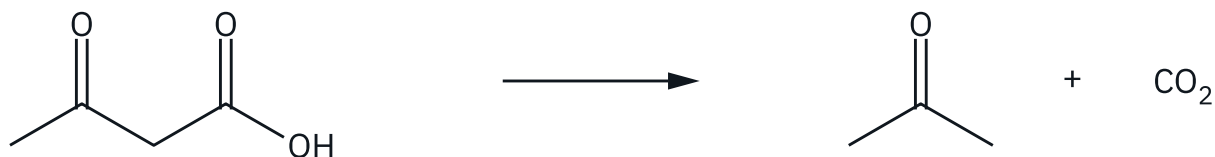
Draw both of these structures.

[2 marks]

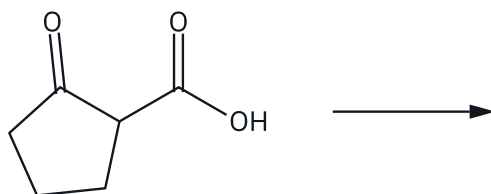
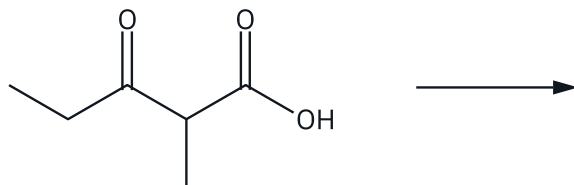


This part is about compounds called β -keto acids.

The equation shows the decomposition of a β -keto acid.



22(b)(i) Draw the structures of the organic products you would expect from the decomposition of the **two** other β -keto acids below.



[2 marks]

22(b)(ii) α -Amino acids have the NH_2 group bonded to the carbon atom adjacent to the carboxylic acid group.

Suggest the difference between an α -keto acid and a β -keto acid.

[1 mark]

Q73 • Chromatography and functional group tests • November 2020 • Paper 2 (Synthesis and analytical techniques) • Q13 • [1 mark]

Which statement(s) is/are correct for gas chromatography?

- 1 The components in a mixture can be identified from their retention time.
- 2 The relative peak areas give the proportions of components in a mixture.
- 3 Calibration curves are used to confirm the concentrations of components in a mixture.

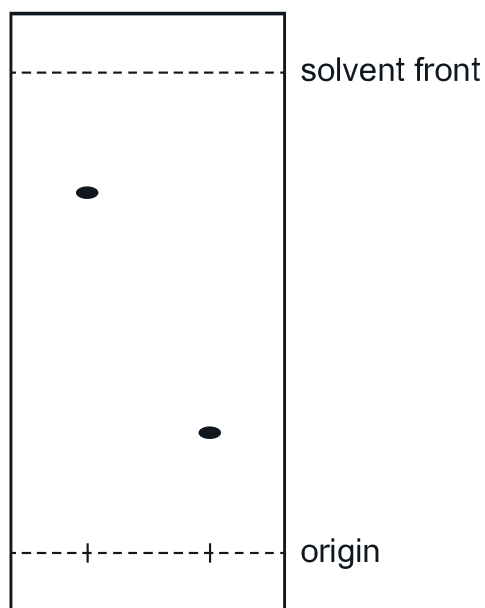
Tick (✓) one box.

- ☐ **A** 1, 2 and 3
- ☐ **B** Only 1 and 2
- ☐ **C** Only 2 and 3
- ☐ **D** Only 1

Q74 • Chromatography and functional group tests • November 2021 • Paper 2 (Synthesis and analytical

techniques) · Q10 · [1 mark]

A TLC chromatogram for two compounds is shown below.



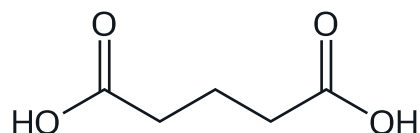
What is the R_f value for the compound that is most strongly adsorbed onto the stationary phase?

Tick (✓) one box.

- ☐ **A** 0.25
- ☐ **B** 0.33
- ☐ **C** 0.69
- ☐ **D** 0.78

Q75 · NMR spectroscopy · June 2017 · Paper 2 (Synthesis and analytical techniques) · Q11 · [1 mark]

The compound below is analysed by ^1H NMR spectroscopy.



How many peaks are observed in the ^1H NMR spectrum?

Tick (✓) one box.

- ☐ **A** 5
- ☐ **B** 4
- ☐ **C** 3
- ☐ **D** 2

Q76 · NMR spectroscopy · June 2017 · Paper 2 (Synthesis and analytical techniques) · Q20 · [9 marks]

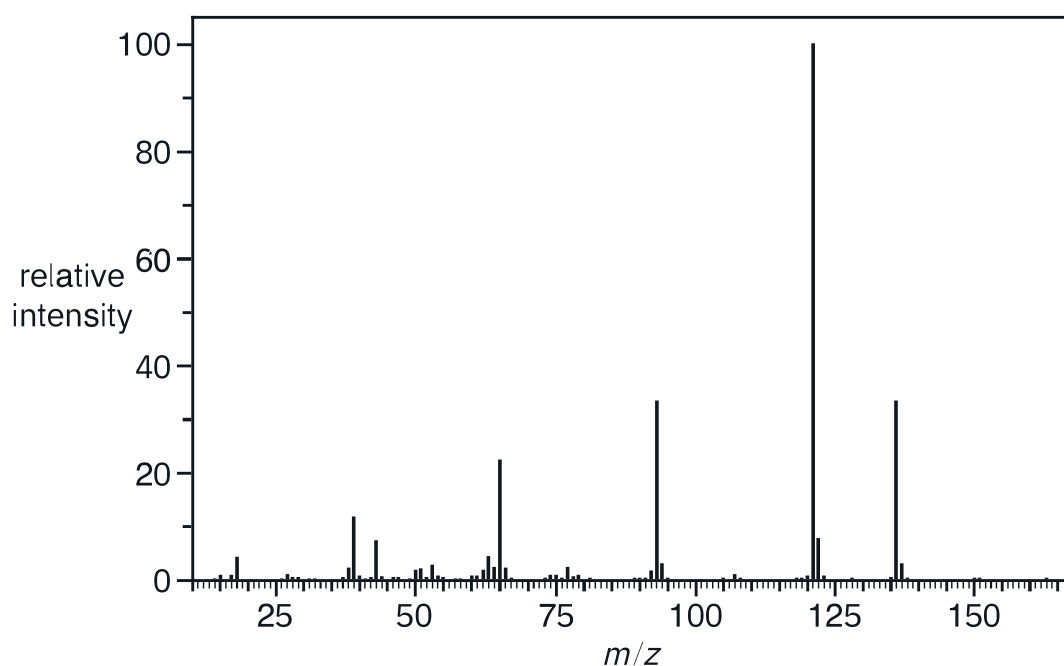
This question also needs Amount of substance, Atomic structure and isotopes and Basic concepts of organic chemistry.

A chemist analyses a naturally occurring aromatic compound.

20(a) The percentage composition and mass spectrum of the compound are shown below.

Percentage composition by mass: C, 70.58%; H, 5.92%; O, 23.50%.

Mass spectrum



Determine the molecular formula of the compound.

Show your working.

molecular formula =

[3 marks]

20(b) Qualitative tests are carried out on the aromatic compound. The results are shown below.

Test	Acidity	Na ₂ CO ₃ (aq)	2,4-DNP	Tollens' reagent
Observation	pH = 5	No observable change	Orange precipitate	No observable change

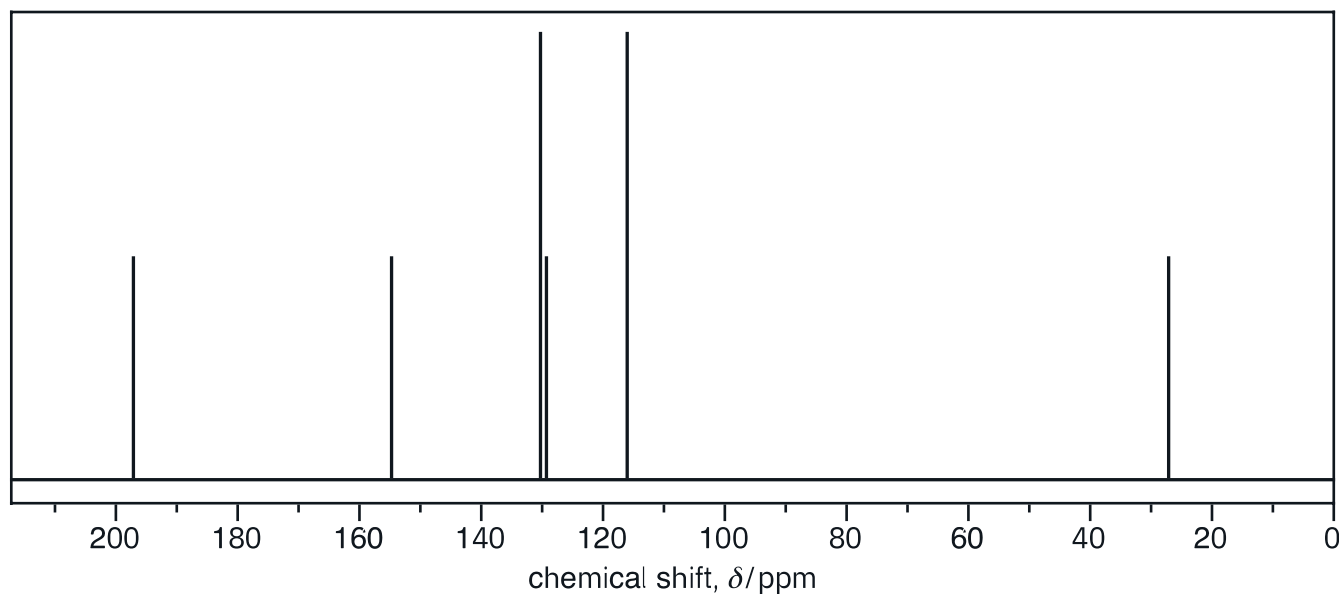
Determine the functional groups in the compound. Explain your reasoning.

[3 marks]

Functional groups

Explanation

20(c) The carbon-13 NMR spectrum of the compound is shown below.



Using the spectrum and the results from (a) and (b), determine the structure of the compound.

Explain your reasoning.

Structure of compound

[3 marks]

Q77 · NMR spectroscopy · June 2018 · Paper 2 (Synthesis and analytical techniques) · Q1 · [1 mark]

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

Tick (✓) one box.

- ☐ **A** $\text{Si}(\text{CH}_3)_4$
- ☐ **B** CDCl_3
- ☐ **C** D_2O
- ☐ **D** CCl_4

Q78 · NMR spectroscopy · June 2018 · Paper 2 (Synthesis and analytical techniques) · Q22 · [18 marks]

This question also needs Alcohols and haloalkanes, Alkanes, Amount of substance and 4 other topics.

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

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

Table 22.1

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

[1 mark]

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

[4 marks]

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

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

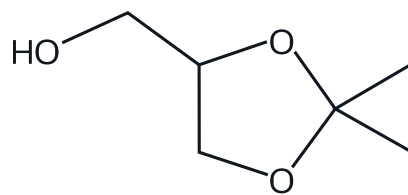
Complete combustion of 1.71 g of compound N produces 2.97 g of CO_2 and 1.62 g of H_2O . The relative molecular mass of compound N is 76.0.

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

compound N

[5 marks]

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



solketal

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

Construct a balanced equation for this synthesis.

Show structures for the organic compounds in your equation.

[2 marks]

22(d) A scientist is researching compounds that might be suitable as fuel additives.

One of the compounds gives the analytical results below.

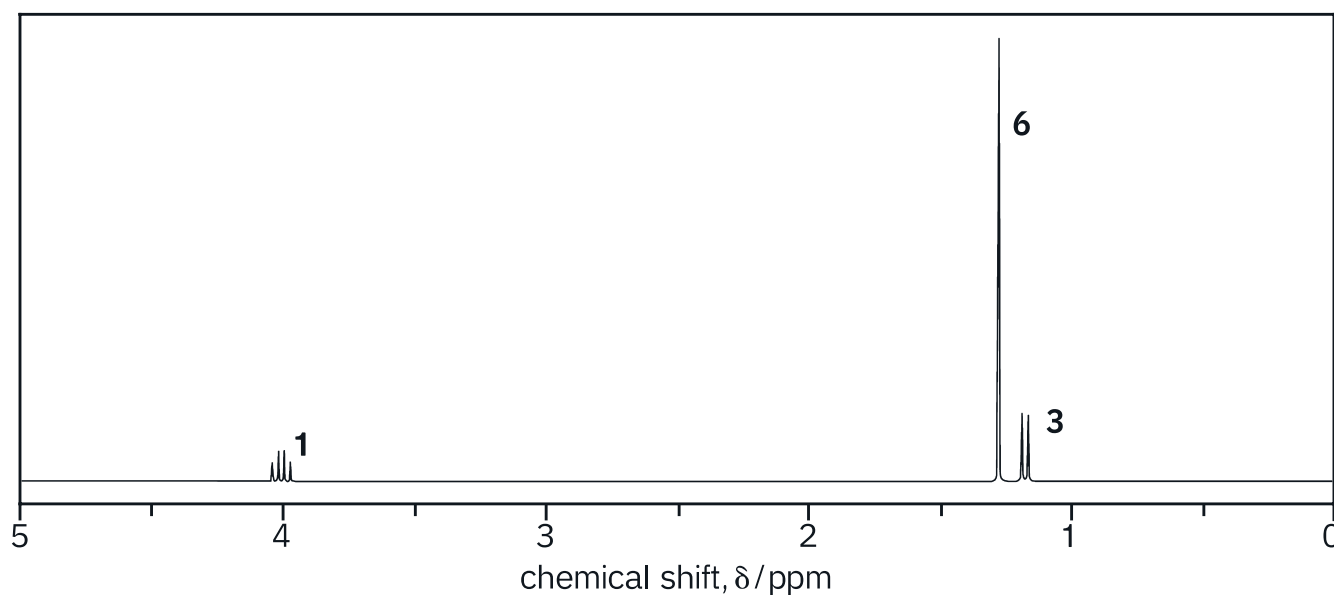
Elemental analysis by mass:

C: 54.54%; H: 9.10%; O: 36.36%

Mass spectrum:

Molecular ion peak at $m/z = 132.0$

^1H NMR spectrum in D_2O



The numbers by the peaks are the relative peak areas.

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

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

Show all your reasoning.

[6 marks]

Q79 · NMR spectroscopy · June 2018 · Paper 2 (Synthesis and analytical techniques) · Q6 · [1 mark]

What is the number of peaks in the ^1H NMR spectrum of $\text{HOOCCH}_2\text{CHOHCH}_2\text{COOH}$?

Tick (✓) one box.

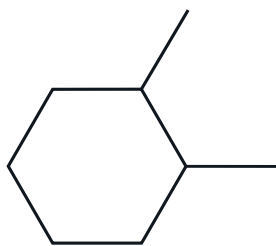
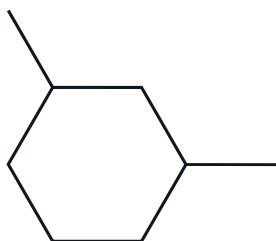
- ☐ **A** 3
- ☐ **B** 4
- ☐ **C** 5
- ☐ **D** 6

Q80 · NMR spectroscopy · June 2019 · Paper 2 (Synthesis and analytical techniques) · Q10 · [1 mark]

Which compound shows 4 peaks in its carbon-13 NMR spectrum?

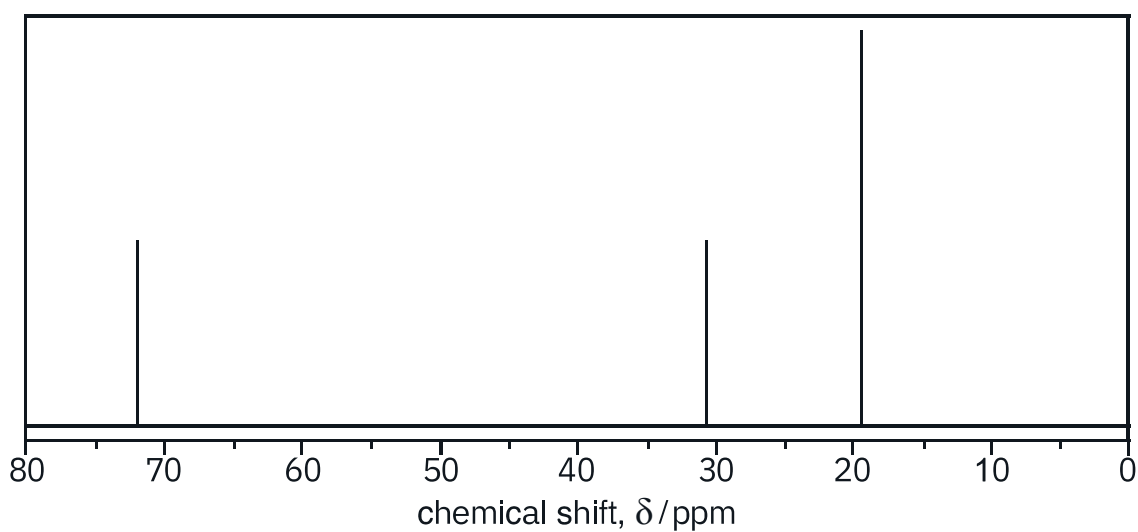
Tick (✓) one box.



☐ **B**☐ **C**☐ **D**

Q81 • NMR spectroscopy • June 2019 • Paper 2 (Synthesis and analytical techniques) • Q12 • [1 mark]

A compound produces the ^{13}C NMR spectrum below.



Which compound could have produced this spectrum?

Tick (✓) one box.

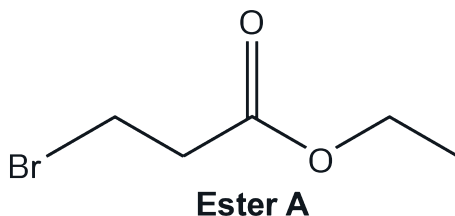
- ☐ **A** Propane
- ☐ **B** 2-Methylbutane
- ☐ **C** 2-Methylpropan-1-ol
- ☐ **D** 2-Methylpropan-2-ol

Q82 · NMR spectroscopy · June 2019 · Paper 2 (Synthesis and analytical techniques) · Q18 · [22 marks]

This question also needs Acids and redox reactions, Alcohols and haloalkanes, Amount of substance and 3 other topics.

This question is about esters.

The structure of ester A is shown below.

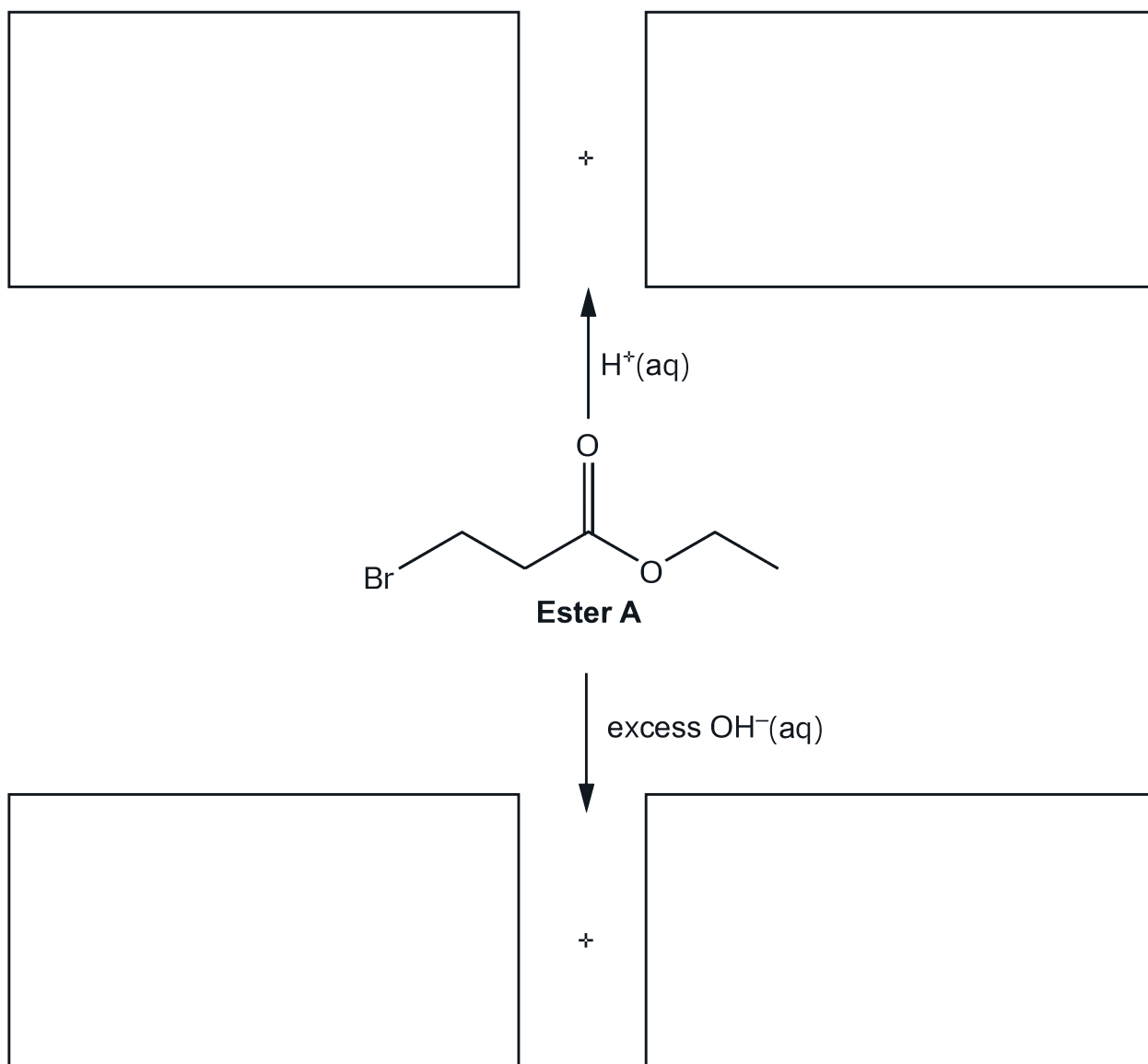


18(a)(i) What is the systematic name of ester A?

[1 mark]

18(a)(ii) In the boxes, draw the organic products for the reactions of the functional groups in ester A shown below.

Each reaction forms two organic products.



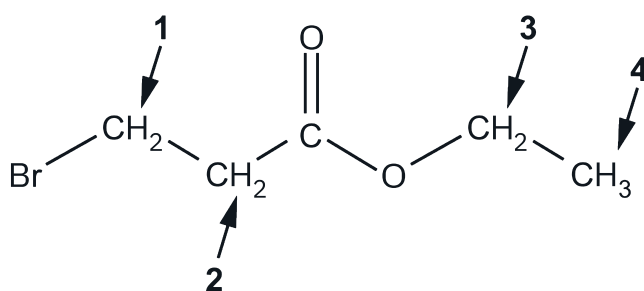
[5 marks]

Draw your answer on the figure above.

18(a)(iii) Name the type of reactions of ester A shown in (ii).

[1 mark]

18(b) The protons in ester A are in four different environments, labelled 1–4 on the structure below.



Complete the table to predict the proton NMR spectrum of ester A.

Proton environment	Chemical shift	Splitting pattern
1		
2		
3		
4		

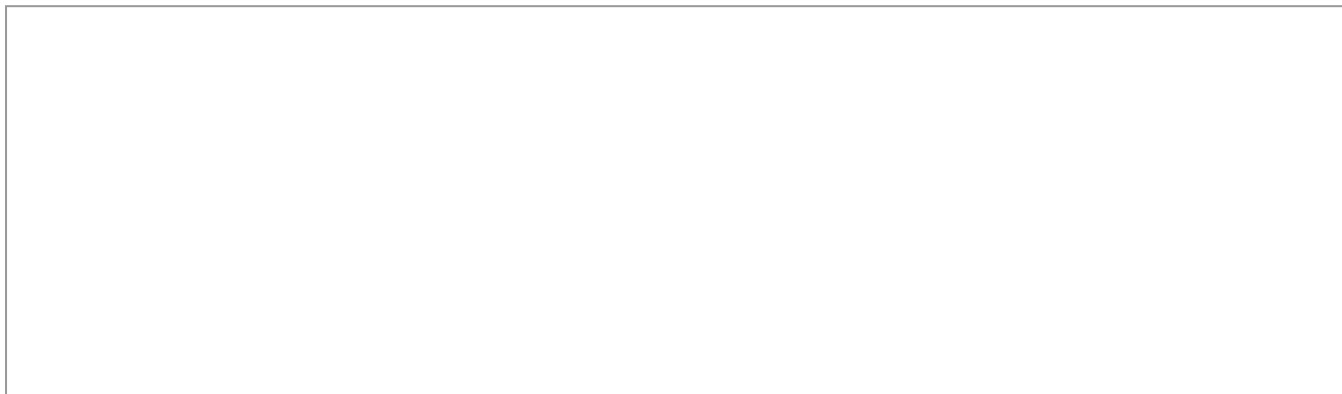
[4 marks]

18(c) Compound B is a structural isomer of ester A.

- Compound B reacts with aqueous sodium carbonate.
- The ^{13}C NMR spectrum of B has 4 peaks.

Draw a possible structure for compound B.

[1 mark]



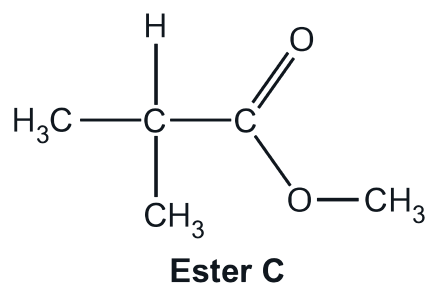
18(d) A polyester is formed from 200 molecules of 4-hydroxybenzoic acid.

What is the relative molecular mass, M_r , of the polyester?

$M_r = \text{g mol}^{-1}$

[2 marks]

A student intends to synthesise ester C.



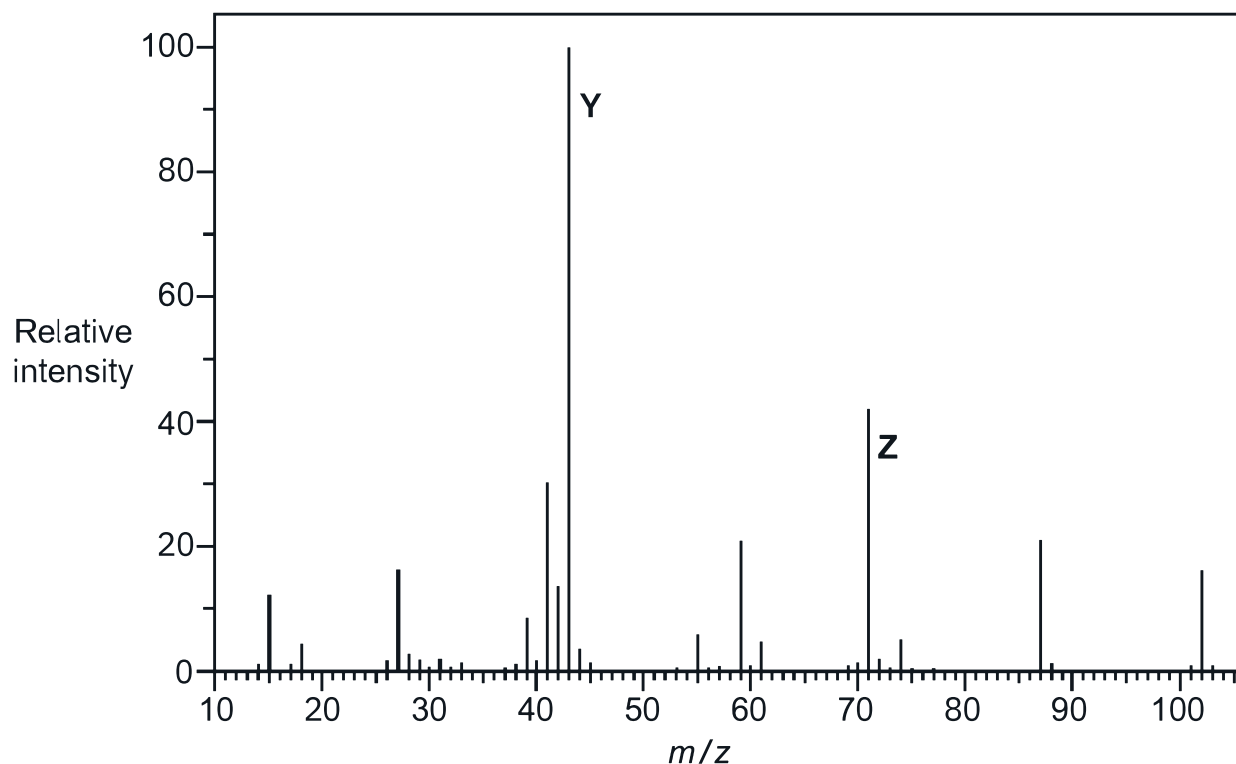
18(e)(i) Plan a two-stage synthesis to prepare 12.75 g of ester C starting from 2-methylpropanal, $(\text{CH}_3)_2\text{CHCHO}$. Assume the overall percentage yield of ester C from 2-methylpropanal is 40%.

In your answer include the mass of 2-methylpropanal required, reagents, conditions and equations where appropriate.

Purification details are not required.

[6 marks]

18(e)(ii) The mass spectrum of ester C is shown below.



Suggest possible structures for the species responsible for peaks Y and Z in the mass spectrum.

Y Z

[2 marks]

Q83 · NMR spectroscopy · June 2022 · Paper 2 (Synthesis and analytical techniques) · Q12 · [1 mark]

Which compound produces two triplets in its ^1H NMR spectrum?

Tick (✓) one box.

- ☐ **A** $\text{CH}_3\text{CH}_2\text{COOCH}_2\text{CH}_3$
- ☐ **B** $\text{CH}_3\text{CH}_2\text{COCH}_2\text{CH}_3$
- ☐ **C** $\text{HOOCCH}_2\text{CH}_2\text{COOH}$
- ☐ **D** $\text{HOOCCH}_2\text{CH}_2\text{CH}_2\text{COOH}$

Q84 · NMR spectroscopy · June 2022 · Paper 2 (Synthesis and analytical techniques) · Q15 · [1 mark]

Which isomer(s) of $\text{C}_5\text{H}_{12}\text{O}$ has/have 4 peaks in its/their ^{13}C NMR spectrum?

1 3-methylbutan-2-ol

2 2-methylbutan-2-ol

3 2-methylbutan-1-ol

Tick (✓) one box.

- ☐ **A** 1, 2 and 3
- ☐ **B** Only 1 and 2
- ☐ **C** Only 2 and 3
- ☐ **D** Only 1

Q85 · NMR spectroscopy · June 2023 · Paper 2 (Synthesis and analytical techniques) · Q1 · [1 mark]

Which compound is used for proton exchange in NMR spectroscopy?

Tick (✓) one box.

- ☐ **A** CCl_4
- ☐ **B** CDCl_3
- ☐ **C** D_2O
- ☐ **D** $\text{Si}(\text{CH}_3)_4$

Q86 · NMR spectroscopy · June 2023 · Paper 2 (Synthesis and analytical techniques) · Q23 · [6 marks]

23 An unknown organic compound is analysed.

The results are shown below.

[6 marks]

Addition of 2,4-DNP

No visible change

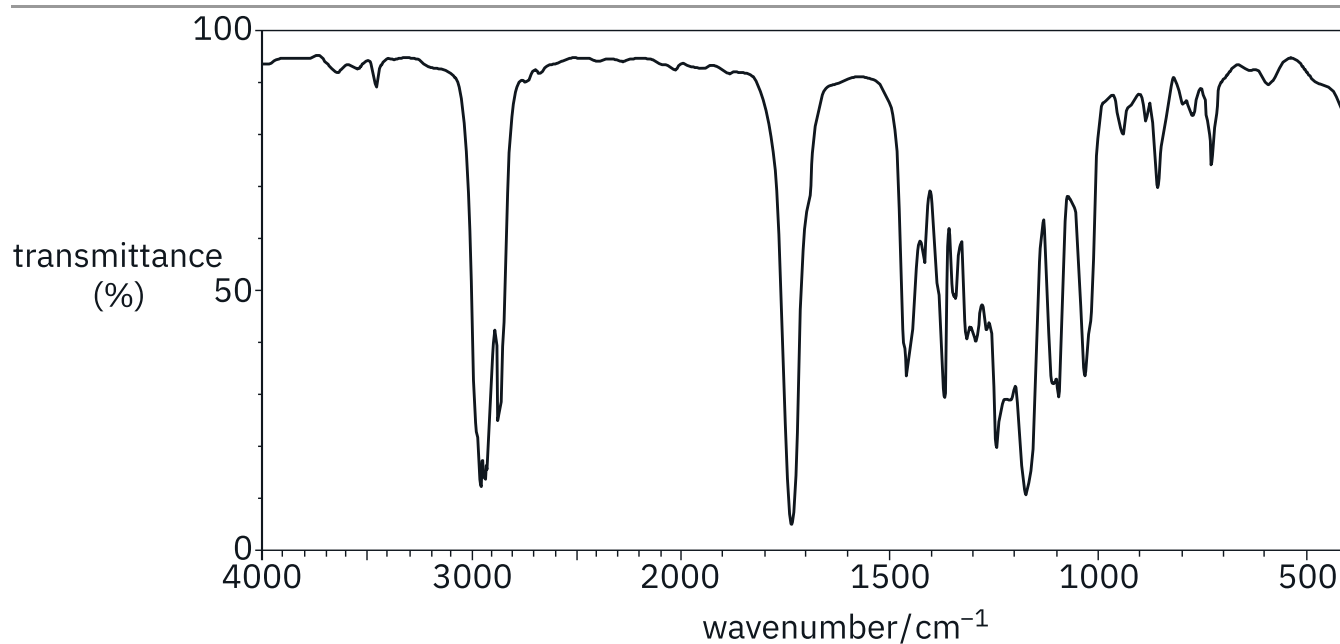
Elemental analysis by mass

C, 66.63%; H, 11.18%; O, 22.19%

Mass spectrum

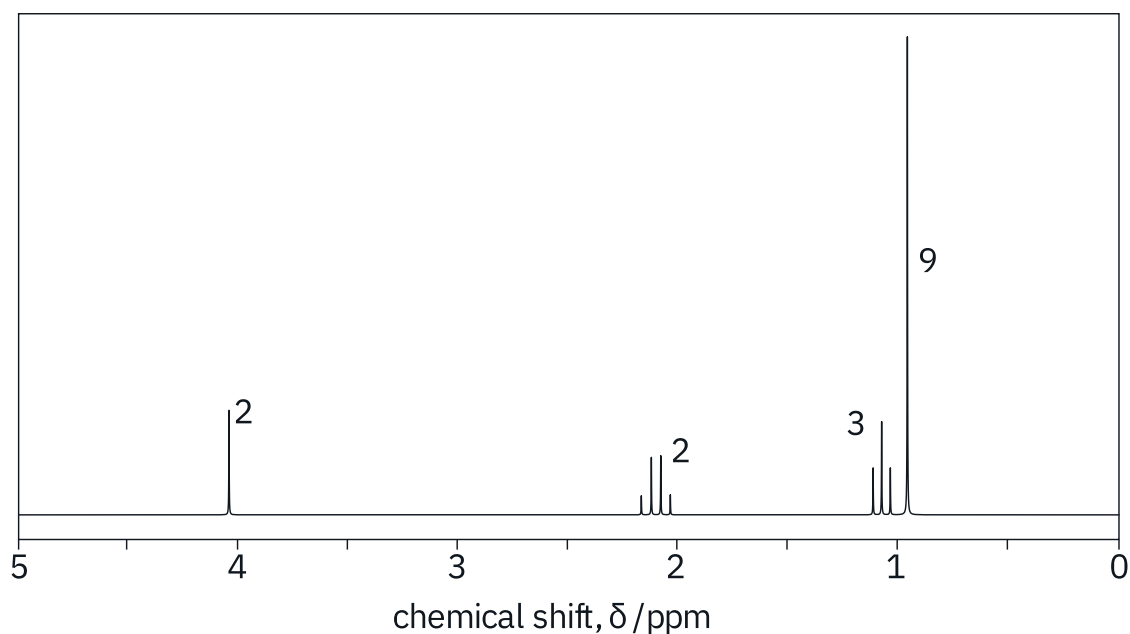
Molecular ion peak at $m/z = 144.0$

IR spectrum



Proton NMR spectrum

The numbers by each peak are the relative peak areas.



Use the information to identify the organic compound.

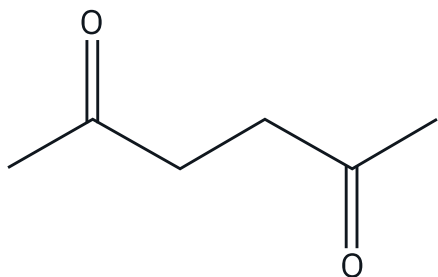
Show **all** your reasoning.

Q87 · NMR spectroscopy · June 2023 · Paper 2 (Synthesis and analytical techniques) · Q9 · [1 mark]

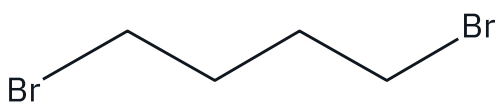
Which compound has the greatest number of peaks in its proton NMR spectrum?

Tick (✓) one box.

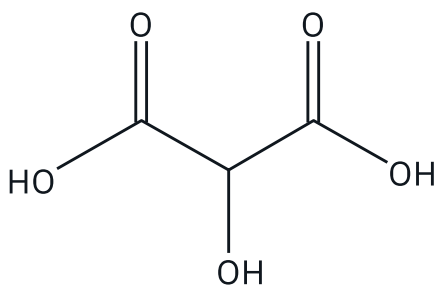
☐ **A**



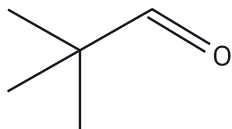
☐ **B**



☐ **C**



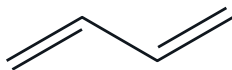
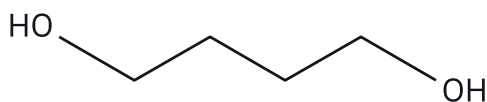
☐ **D**



Q88 · NMR spectroscopy · June 2024 · Paper 2 (Synthesis and analytical techniques) · Q14 · [1 mark]

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**

Tick (✓) one box.

- ☐ **A** 1, 2 and 3
- ☐ **B** Only 1 and 2
- ☐ **C** Only 2 and 3
- ☐ **D** Only 1

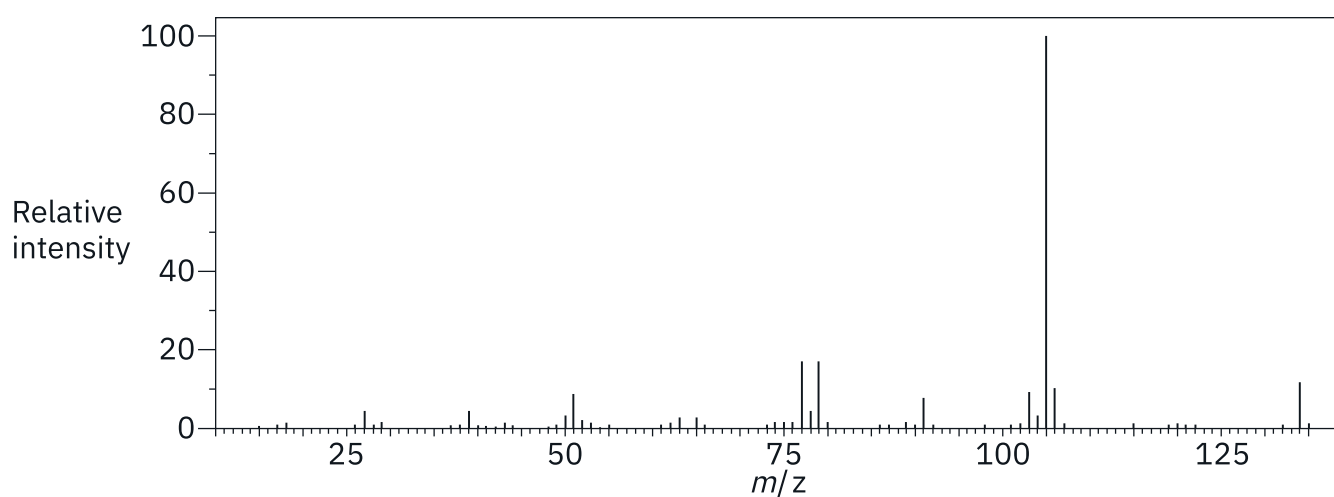
Q89 · NMR spectroscopy · June 2024 · Paper 2 (Synthesis and analytical techniques) · Q24 · [6 marks]

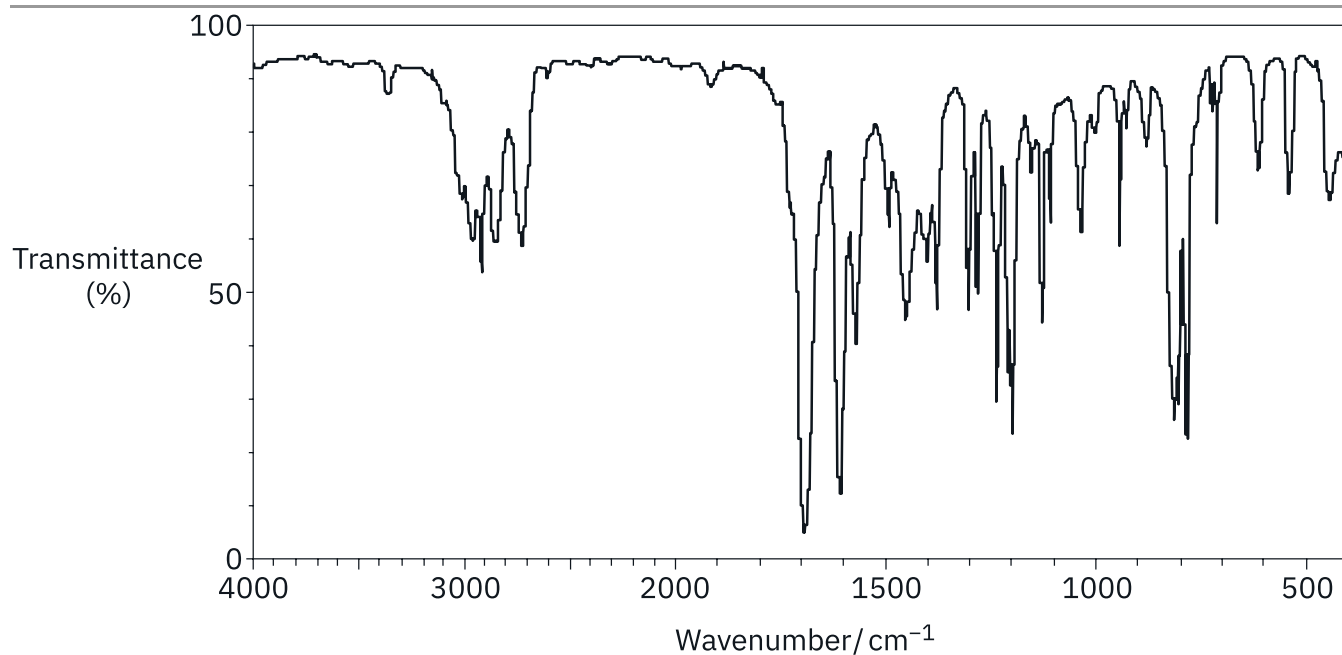
24 Analysis of an unknown organic compound J produces the following results.

[6 marks]

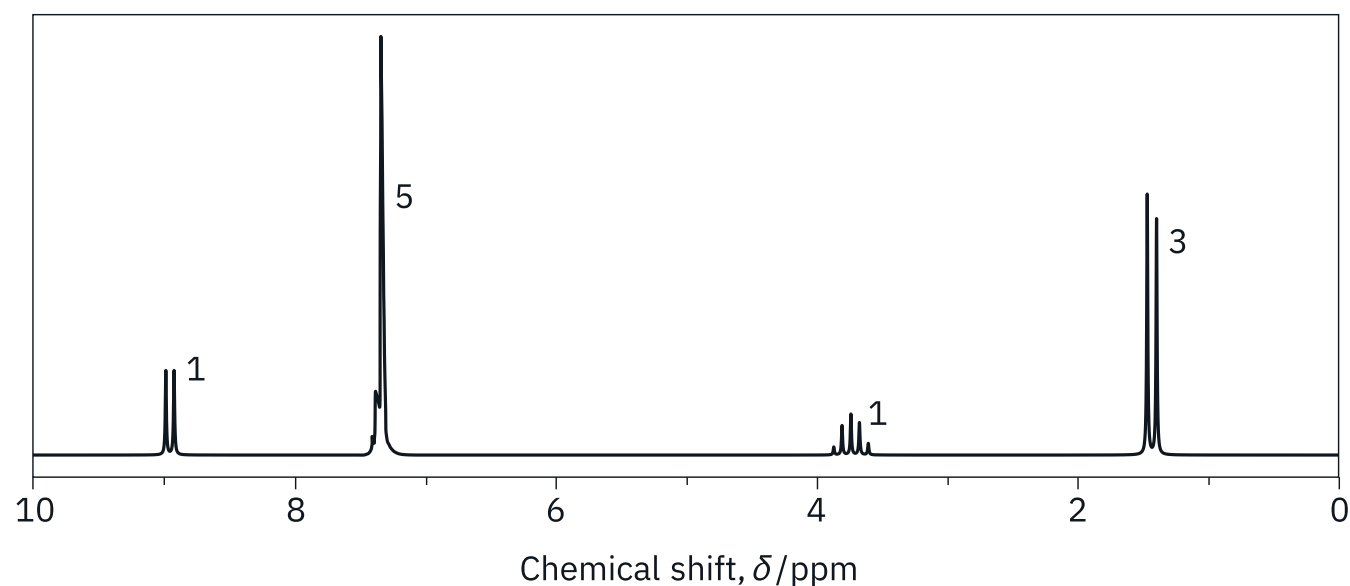
Elemental analysis by mass of compound J

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

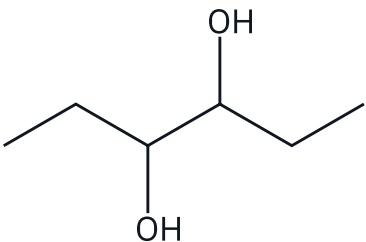
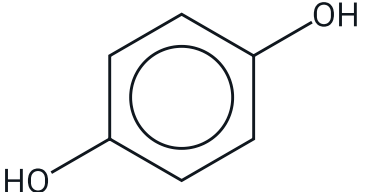
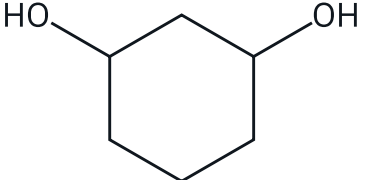


The numbers by the peaks are the relative peak areas.

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

Q90 • NMR spectroscopy • June 2025 • Paper 2 (Synthesis and analytical techniques) • Q15 • [1 mark]

Which compound(s) has/have **three** peaks in their ^{13}C NMR spectrum?

1	
2	
3	

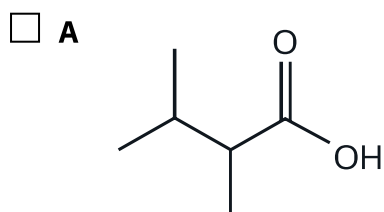
Tick (✓) one box.

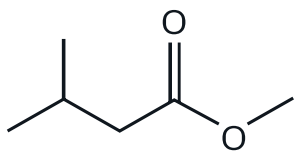
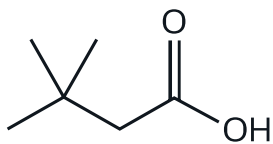
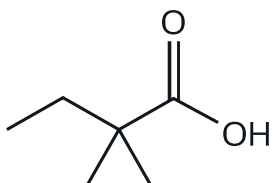
- ☐ **A** 1, 2 and 3
- ☐ **B** Only 1 and 2
- ☐ **C** Only 2 and 3
- ☐ **D** Only 1

Q91 • NMR spectroscopy • November 2020 • Paper 2 (Synthesis and analytical techniques) • Q8 • [1 mark]

Which isomer of $\text{C}_6\text{H}_{12}\text{O}_2$ produces the smallest number of peaks in its ^{13}C NMR spectrum?

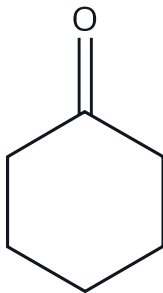
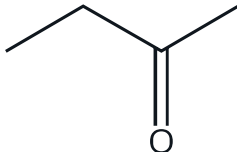
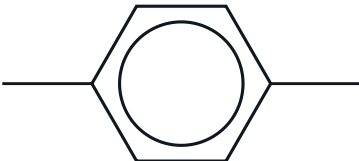
Tick (✓) one box.



☐ **B**☐ **C**☐ **D**

Q92 · NMR spectroscopy · November 2021 · Paper 2 (Synthesis and analytical techniques) · Q13 · [1 mark]

Which compound(s) has/have four peaks in a ^{13}C NMR spectrum?

1	
2	
3	

Tick (✓) one box.

- ☐ **A** 1, 2 and 3
- ☐ **B** Only 1 and 2
- ☐ **C** Only 2 and 3
- ☐ **D** Only 1

Q93 · NMR spectroscopy · November 2021 · Paper 2 (Synthesis and analytical techniques) · Q21 · [6 marks]

This question also needs Amount of substance and Basic concepts of organic chemistry.

21 Compounds D, E and F are isomers with the molecular formula $C_5H_{10}O$.

One of the compounds is alicyclic.

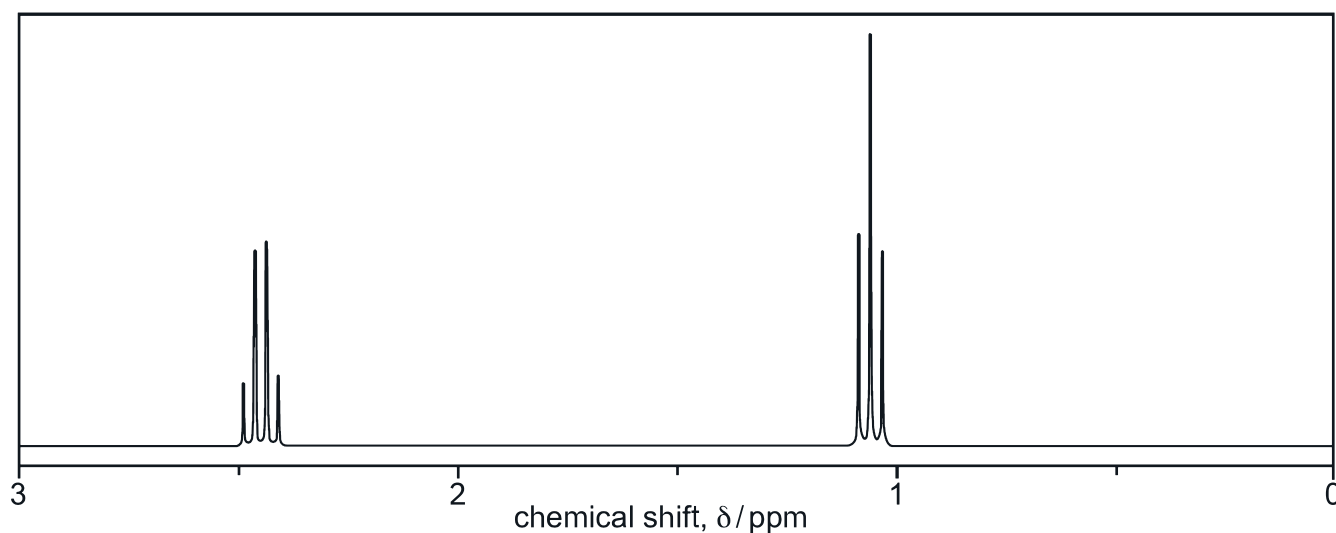
A student carries out test-tube tests on the compounds.

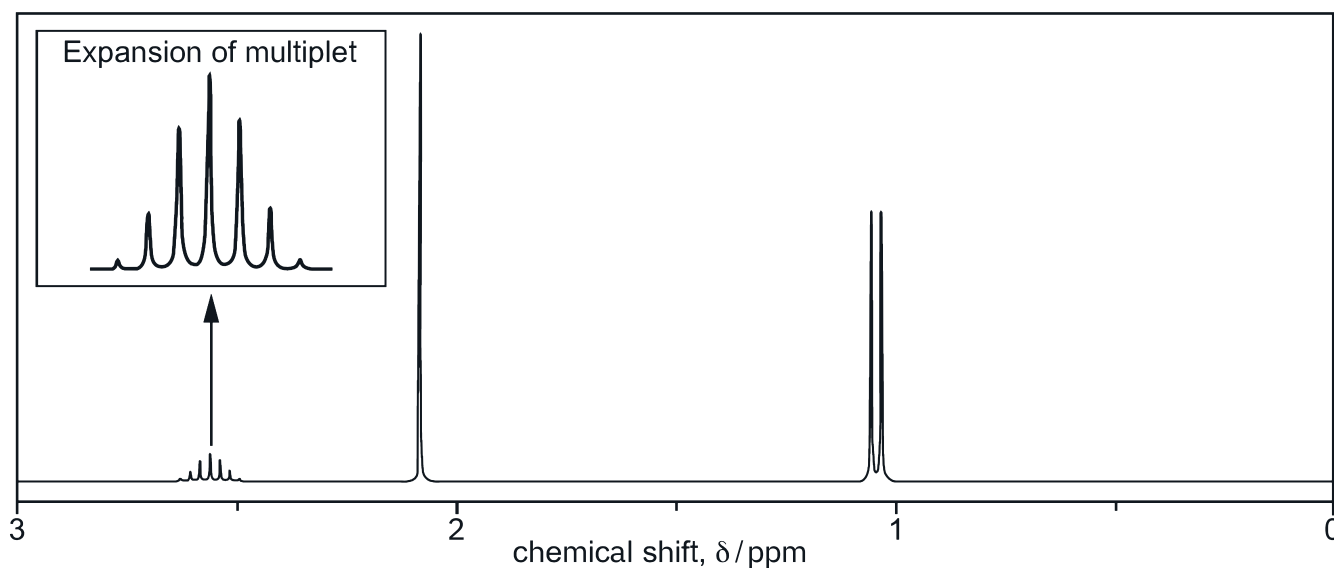
The observations are shown below.

Compound	2,4-DNP	$H^+/Cr_2O_7^{2-}$, reflux	Bromine water
D	No change	Green solution	No colour change
E	Orange precipitate	No colour change	No colour change
F	Orange precipitate	No colour change	No colour change

^{13}C NMR spectrum of D	Compound D has 3 peaks at δ / ppm: 24, 36, 73.
^1H NMR spectra of E and F	The integration data has been omitted.

Compound E



Compound F

Analyse the observations and results to identify the structures of D, E and F.

Explain your reasoning.

[6 marks]

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Mark scheme:

whiteboardchemistry.com/revision/exam-questions/ocr-a-level-chemistry/pdf/module-6-organic-chemistry-and-analysis-mark-scheme.pdf