Oxford Cambridge and RSA

Monday 20 June 2022 – Morning

A Level Chemistry A

H432/02 Synthesis and analytical techniques

Time allowed: 2 hours 15 minutes

You must have:
- the Data Sheet for Chemistry A

You can use:
- a scientific or graphical calculator
- an HB pencil

Please write clearly in black ink. **Do not write in the barcodes.**

Centre number | | | | | | Candidate number | | | | |

First name(s) _____

Last name _____

INSTRUCTIONS
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

INFORMATION
- The total mark for this paper is **100**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended response will be assessed in questions marked with an asterisk (*****).
- This document has **32** pages.

ADVICE
- Read each question carefully before you start your answer.

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Answer **all** the questions.

SECTION A

You should spend a maximum of 20 minutes on this section.

Write your answer to each question in the box provided.

1 Which statement is correct for the different rates of hydrolysis of RC*l* and RBr?

A RBr is hydrolysed faster because C*l* is more electronegative than Br.

B RBr is hydrolysed faster because the C–C*l* bond enthalpy is greater than C–Br.

C RC*l* is hydrolysed faster because C*l* is more electronegative than Br.

D RC*l* is hydrolysed faster because the C–Br bond enthalpy is greater than C–C*l*.

Your answer ☐

[1]

2 Which statement about absorption of radiation is correct?

A Infrared radiation can result in the breakdown of the ozone layer.

B Ultraviolet radiation can cause some polymers to photodegrade to benefit the environment.

C Ultraviolet radiation is linked to global warming.

D Ultraviolet radiation is used in modern breathalysers to measure ethanol in the breath.

Your answer ☐

[1]

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

A 7

B 10

C 12

D 15

Your answer ☐

[1]

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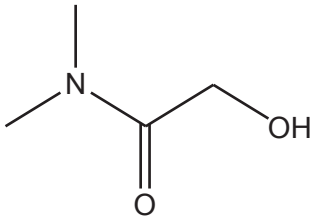
4 The skeletal formula of an organic compound is shown below.



Which functional groups are present?

A amide and alcohol

B amide and carboxylic acid

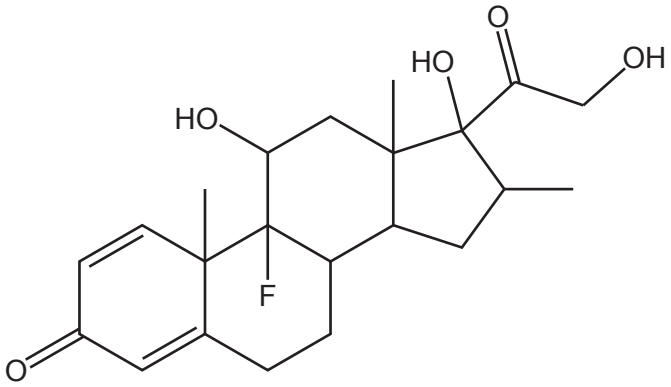
C amine and carboxylic acid

D amine, ketone and alcohol

Your answer ☐

[1]

5 The structure of a drug is shown below:



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

A 5

B 6

C 7

D 8

Your answer ☐

[1]

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6 Which process has the highest atom economy for preparing ethene, C_2H_4?

In each process, assume that ethene is the only product that is used.

A $C_{10}H_{22} \rightarrow 3C_2H_4 + C_4H_{10}$

B $C_6H_{14} \rightarrow 2C_2H_4 + C_2H_6$

C $C_2H_5Cl \rightarrow C_2H_4 + HCl$

D $C_2H_5OH \rightarrow C_2H_4 + H_2O$

Your answer ☐

[1]

7 Complete combustion of 0.050 mol of an alkane produces 5.40 g of H_2O.

What is the molecular formula of the alkane?

A C_2H_6

B C_3H_8

C C_4H_{10}

D C_5H_{12}

Your answer ☐

[1]

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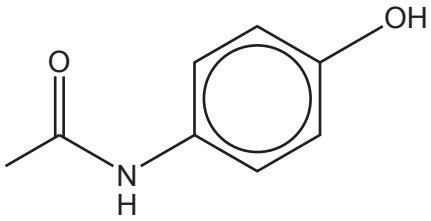
8 The structure of the painkiller, paracetamol, is shown below.



paracetamol

A tablet contains 3.31×10^{-3} mol of paracetamol.

What is the mass of paracetamol in the tablet?

A 493 mg

B 497 mg

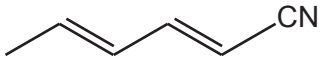
C 500 mg

D 506 mg

Your answer ☐

[1]

9 The compound below reacts with hydrogen gas to form a saturated compound.



What is the volume of hydrogen, measured at room temperature and pressure, that reacts with 0.0500 mol of the compound?

A 2.40 dm^3

B 3.60 dm^3

C 4.80 dm^3

D 6.00 dm^3

Your answer ☐

[1]

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10 Butyl propanoate is hydrolysed by aqueous sodium hydroxide.

Which compound is one of the products of this hydrolysis?

A C_3H_7ONa

B $C_3H_5O_2Na$

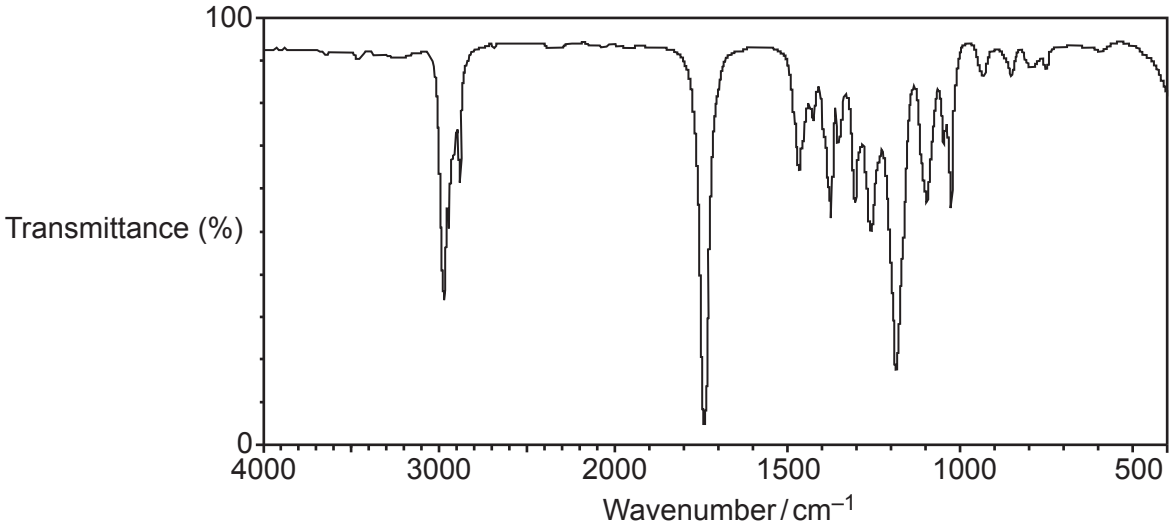
C C_4H_9ONa

D $C_4H_7O_2Na$

Your answer ☐

[1]

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



Which compound could have produced this spectrum?

A $H_2C{=}CHCH_2CH_2OH$

B $CH_3COOCH_2CH_3$

C $H_2NCH_2COOCH_3$

D $(CH_3)_2CHCONH_2$

Your answer ☐

[1]

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

A $CH_3CH_2COOCH_2CH_3$

B $CH_3CH_2COCH_2CH_3$

C $HOOCCH_2CH_2COOH$

D $HOOCCH_2CH_2CH_2COOH$

Your answer ☐

[1]

13 Which equation(s) could be part of the propagation step in the radical substitution of C_5H_{12} to form $C_5H_{11}Cl$?

1 $C_5H_{11}\bullet + Cl_2 \longrightarrow C_5H_{11}Cl + Cl\bullet$

2 $C_5H_{12} + Cl\bullet \longrightarrow C_5H_{11}Cl + H\bullet$

3 $C_5H_{11}\bullet + Cl\bullet \longrightarrow C_5H_{11}Cl$

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer ☐

[1]

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14 Which species could react as a nucleophile?

1 NH_3

2 OH^-

3 CH_3NH_2

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer ☐

[1]

15 Which isomer(s) of $C_5H_{12}O$ 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

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer ☐

[1]

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PLEASE DO NOT WRITE ON THIS PAGE

Turn over for the next question

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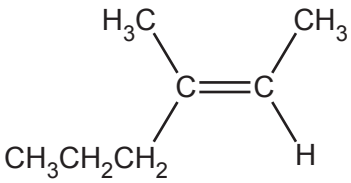
SECTION B

16 This question is about unsaturated hydrocarbons.

(a) The unsaturated hydrocarbon **A**, shown below, is reacted with bromine.



Hydrocarbon A

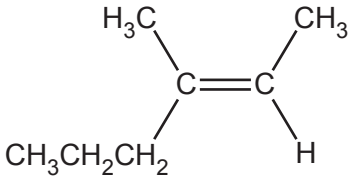
(i) What is the systematic name of hydrocarbon **A**?

..... **[1]**

(ii) Outline the mechanism for the reaction of hydrocarbon **A** with bromine.

The structure of hydrocarbon **A** has been provided.

Include curly arrows and relevant dipoles.



[3]

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(b) Compounds **B** and **C** are **branched** hydrocarbons that are structural isomers of C_6H_{12}.

Compounds **B** and **C** both have stereoisomers.

- Compound **B** has *cis* and *trans* isomers but does **not** have optical isomers.
- Compound **C** has optical isomers but does **not** have *cis* and *trans* isomers.

(i) What is meant by the term **structural isomers**?

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..... **[1]**

(ii) What is meant by the term **stereoisomers**?

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..... **[1]**

(iii) Draw structures for the *cis* and *trans* isomers of the branched hydrocarbon **B**.

***cis* isomer**	***trans* isomer**

[2]

(iv) Draw 3D structures for the optical isomers of compound **C**.

Optical isomers	

[2]

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(v) Compounds **D** and **E** are two more structural isomers of C_6H_{12}.

Compounds **D** and **E** do **not** show stereoisomerism.

Table 16.1 shows NMR and infrared (IR) spectral data for **D** and **E**.

	Number of peaks in ^{1}H NMR spectrum	**Number of peaks in ^{13}C NMR spectrum**	**IR peak at 1620–1680 cm^{-1}**
D	1	1	No
E	1	2	Yes

Table 16.1

Draw the structures of **D** and **E** and explain how the spectral data in **Table 16.1** provides evidence for the structures.

D	**E**

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..... **[4]**

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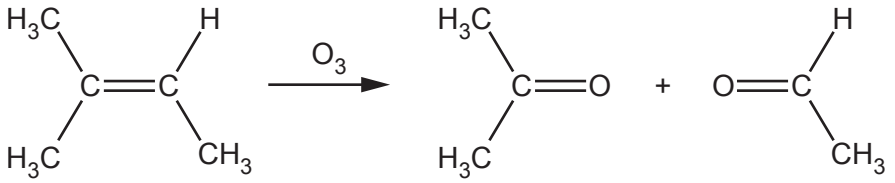
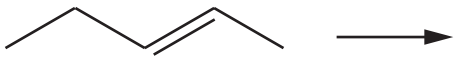
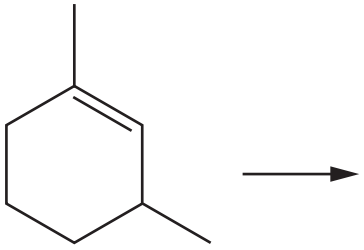
(c) 'Ozonolysis' is used in organic synthesis. Ozone breaks C=C bonds to form carbonyl compounds.

For example, the complete ozonolysis of methylbut-2-ene is shown below.



(i) Draw the structures of the products you would expect from the ozonolysis of the **two** compounds below.



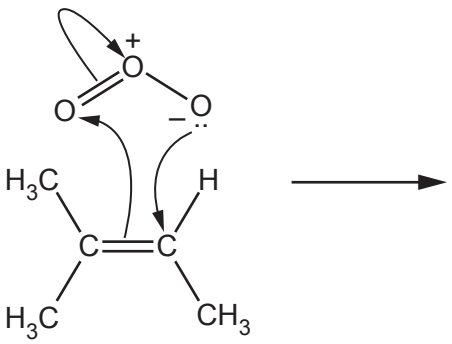


[2]

(ii) The mechanism for ozonolysis takes place in several steps.

The curly arrows in the first step in the ozonolysis of methylbut-2-ene are shown below.

In the box, draw the structure(s) for the product(s) of this step.



[1]

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17 This question is about an analysis of an unknown organic **Compound X**.

Some properties of **Compound X** are shown in the table.

Molecular formula	Functional groups	Chirality
$C_xH_yF_6O$	C–F C–O–C	1 chiral carbon

At a pressure of 1.07×10^5 Pa at 30 °C, 1.327 g of **Compound X** is a gas with a volume of 186 cm^3.

Determine the molar mass of **Compound X** and its molecular formula.

Draw a possible structure for a molecule of **Compound X**.

molar mass ..... g mol^{-1}

molecular formula .....

Structure of Compound X

[6]

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18 This question is about carbonyl compounds.

(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.

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..... **[3]**

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

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

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..... **[1]**

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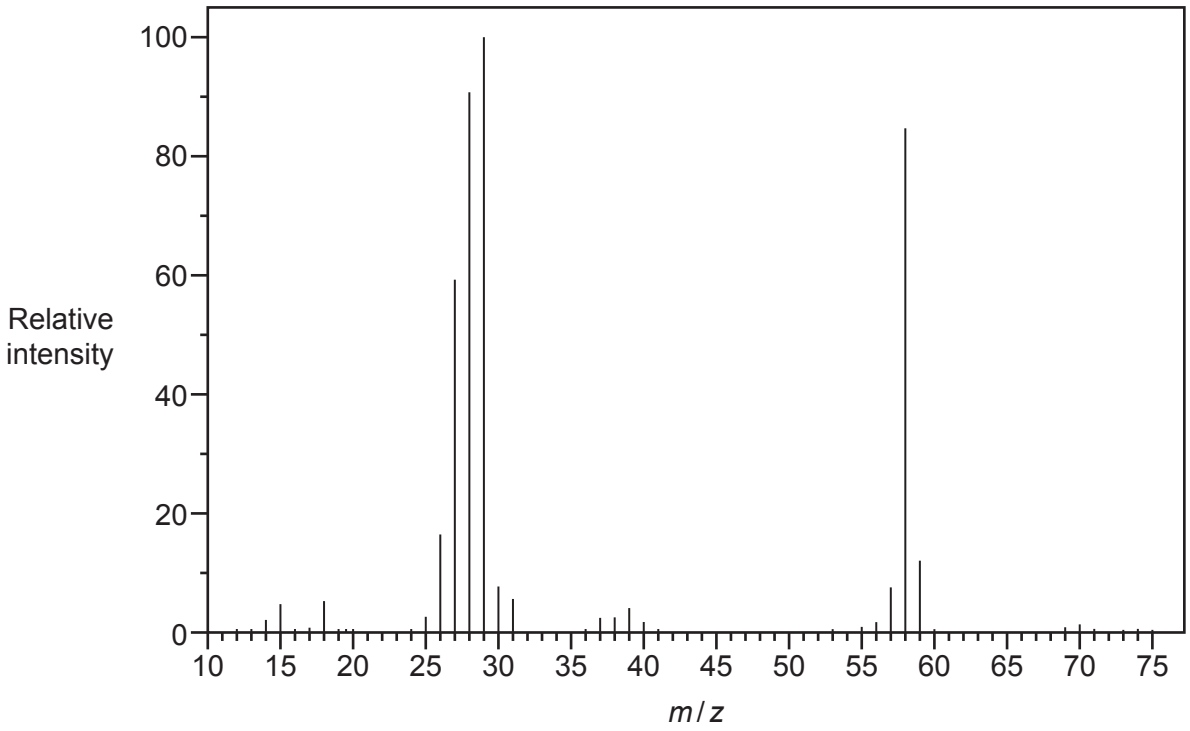
(b) A student is provided with two unknown carbonyl compounds, **F** and **G**.

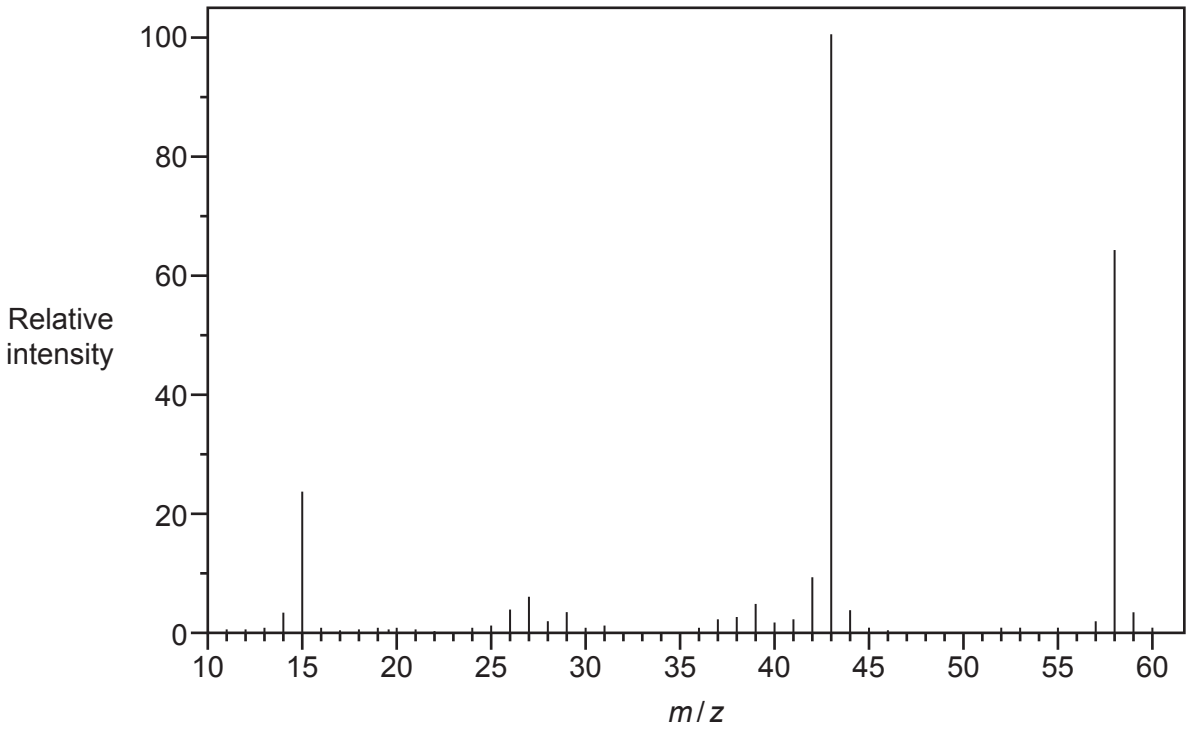
The compounds are analysed and found to have identical percentage compositions by mass:
C: 62.07%; H: 10.34%; O: 27.59%

The mass spectra of the two compounds are shown below.

Mass spectrum of F



Mass spectrum of G



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

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

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F	G

[4]

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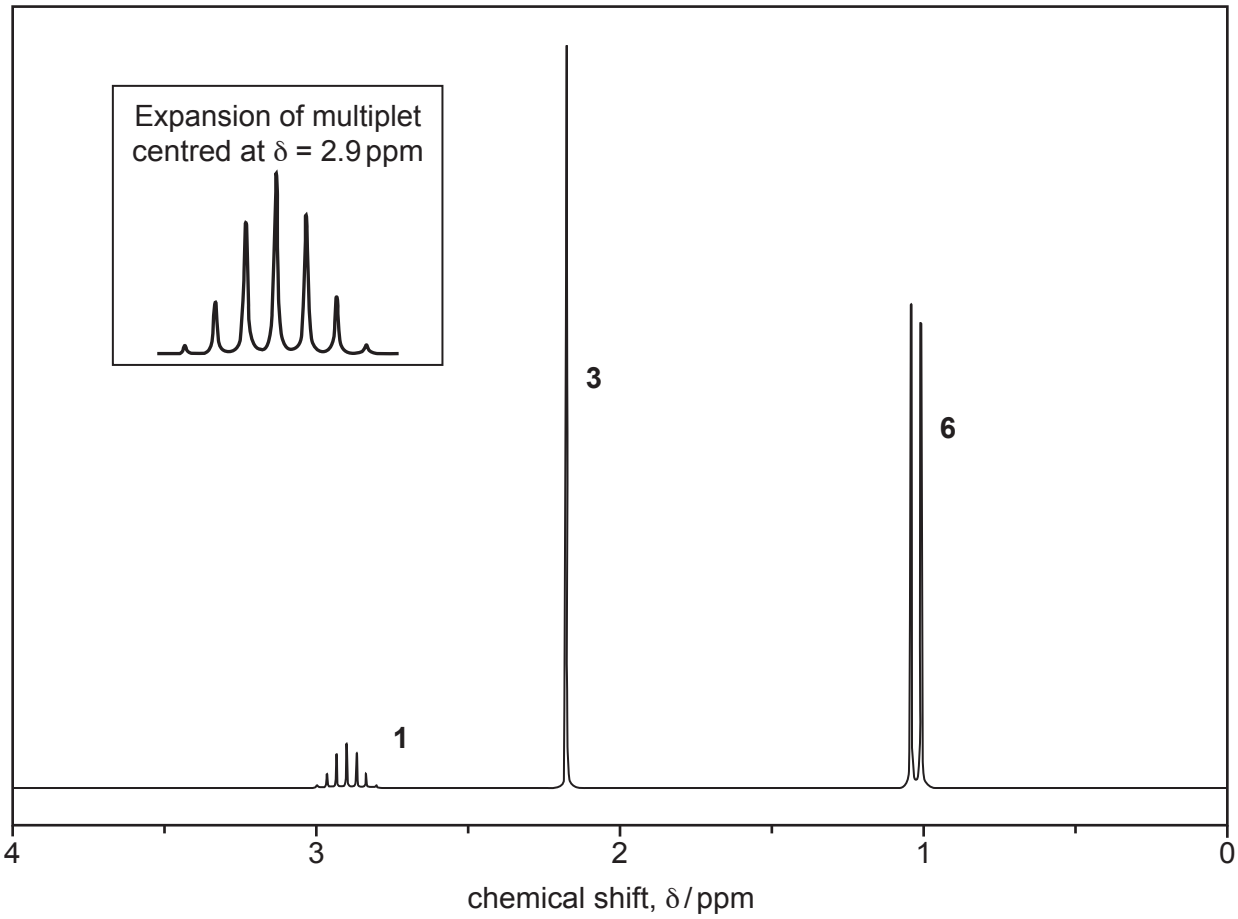
(c) The organic compound **H** contains carbon, hydrogen and oxygen only and has an M_r of 114.0.

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

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



The numbers by the peaks are the relative peak areas.

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

Show all your reasoning.

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Compound H

[4]

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

(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]

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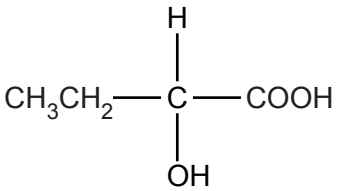
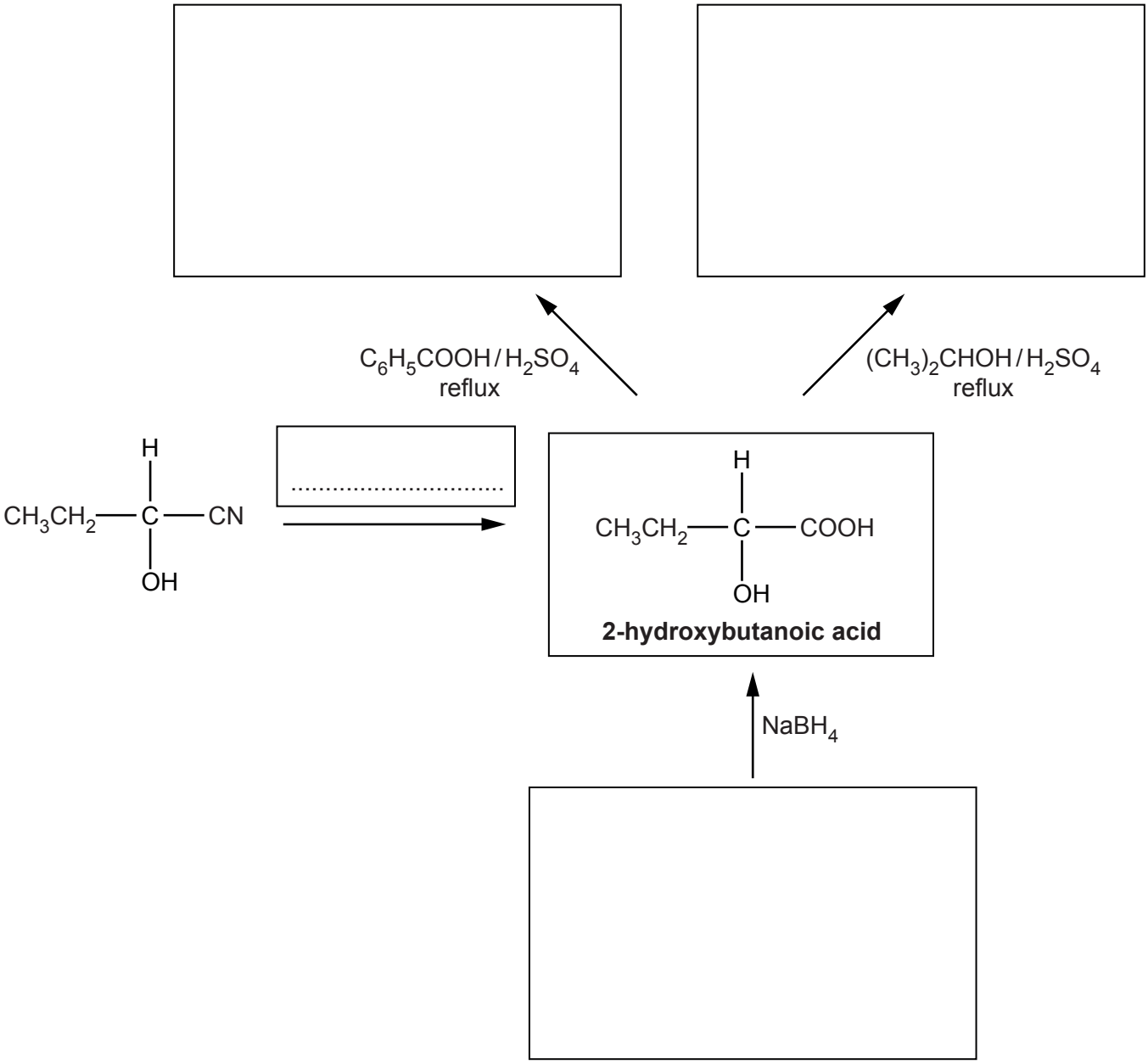
(b) The structure of 2-hydroxybutanoic acid is shown below.



2-hydroxybutanoic acid

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



[4]

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(c) This part is about polymers derived from carboxylic acid monomers.

(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.

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

[2]

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

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

[2]

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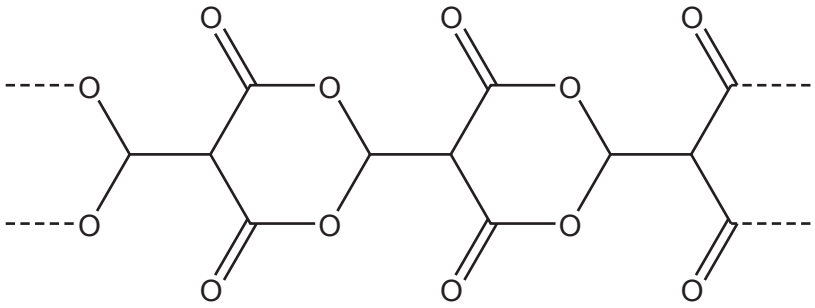
(iii) Three repeat units of a condensation polymer are shown below.



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

[1]

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

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

[1]

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

M_r = ... **[2]**

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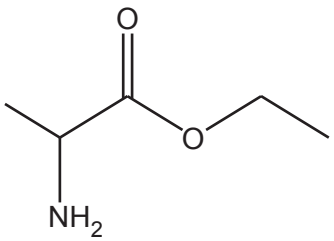
(e)* A student intends to synthesise compound **I**.



Compound I

Plan a synthesis to prepare 9.36 g of compound **I** starting from 2-chloropropanoic acid, $CH_3CHClCOOH$. 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]**

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Additional answer space if required.

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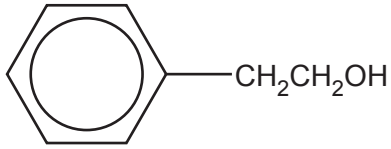
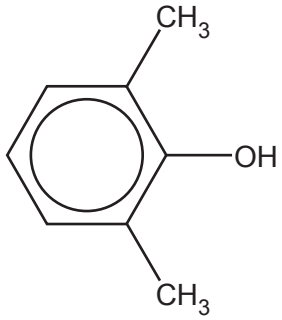
20 This question is about the chemistry of aromatic compounds.

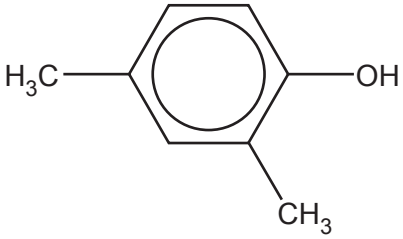
(a) Compounds **J**, **K** and **L**, shown below, are structural isomers.



Compound J



Compound K



Compound L

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

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..... **[1]**

(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.

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..... **[3]**

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(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]

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

Explain why.

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..... **[3]**

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(c) Compound **J**, $C_6H_5CH_2CH_2OH$, is reacted with acidified potassium dichromate(VI) under reflux to form organic product **M**.

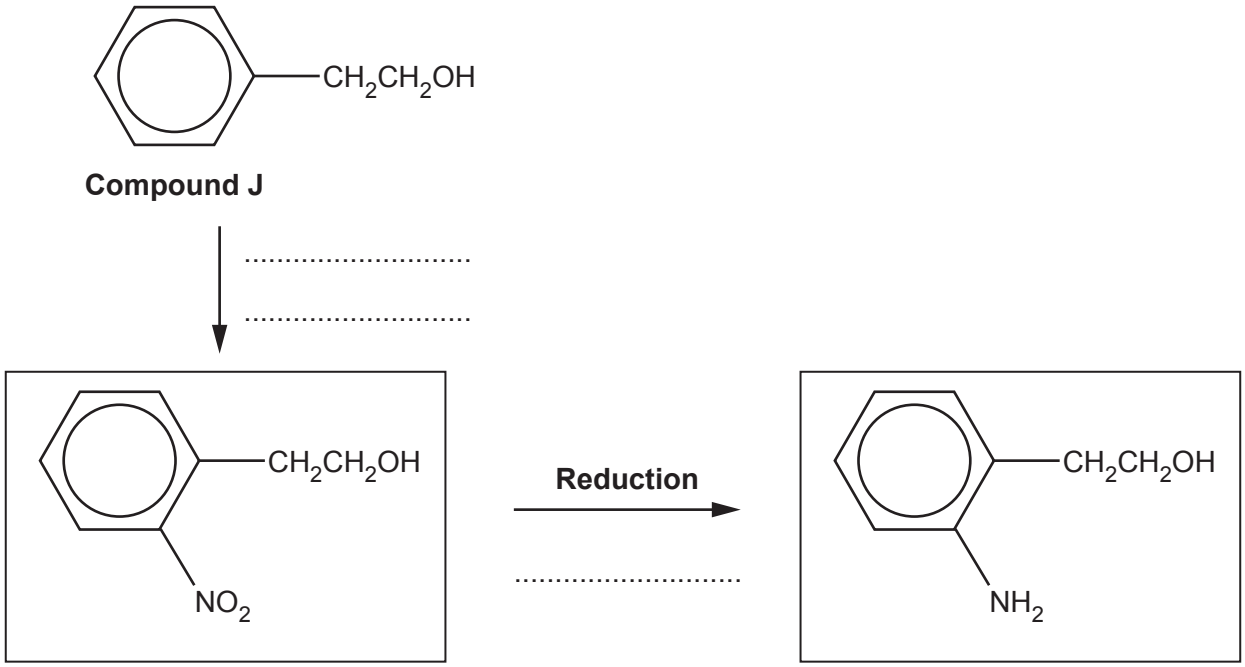
Write an equation for this reaction.

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

[2]

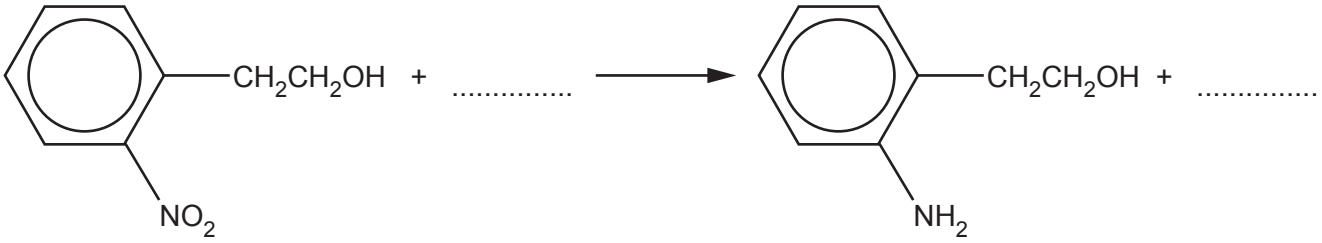
(d) A two-stage synthesis of an amine from compound **J** is shown below.

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



[2]

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



[1]

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(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.

2-phenylethanol **1-phenylethanol**

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

Show structures for organic compounds.

Stage 1

reagents and conditions .....

equation:

Stage 2

reagents and conditions .....

equation:

[4]

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

Benzoic anhydride is the acid anhydride of benzoic acid, C_6H_5COOH.

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]

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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]**

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END OF QUESTION PAPER

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ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).

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