OXFORD

INTERNATIONAL
AQA EXAMINATIONS

Please write clearly in block capitals.

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

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Candidate signature _____
I declare this is my own work.

INTERNATIONAL A-LEVEL
CHEMISTRY (9620)

Unit 4: Organic 2 and Physical 2

Thursday 20 January 2022 07:00 GMT Time allowed: 1 hour 30 minutes

Materials
For this paper you must have:
- the Periodic Table/Data Sheet, provided as an insert
- a ruler with millimetre measurements
- a scientific calculator, which you are expected to use where appropriate.

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 80.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
9	
TOTAL	

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Answer **all** questions in the spaces provided.

0 1 This question is about reaction kinetics.

Substances **A** and **B** react together in acidic conditions.

The overall equation can be represented by

$$2\mathbf{A} + \mathbf{B} \rightarrow \mathbf{C} + \mathbf{D}$$

The rate equation for the reaction is

$$Rate = k[\mathbf{A}]^2[H^+]$$

0 1 . 1 State the meaning of the term order of reaction with respect to a substance.

[1 mark]

A series of experiments is carried out at a given temperature.

Table 1 shows an incomplete set of results.

Table 1

Experiment	Initial [A] / mol dm^{-3}	Initial [H$^+$] / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	0.0500	0.100	3.42×10^{-7}
2	0.100	0.0500	
3	0.0250		1.14×10^{-7}

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0 1 . 2 Use data from **Experiment 1** in **Table 1** to calculate a value for the rate constant, *k*, for this reaction at this temperature.

Give its units.

[3 marks]

Rate constant _____

Units _____

0 1 . 3 Complete **Table 1**.

[2 marks]

Space for working

0 1 . 4 Suggest the role of H^+ ions in this reaction.

Use the overall equation and the rate equation to explain your answer.

[2 marks]

Role of H^+ _____

Explanation _____

_____

0 1 . 5 Give **one** piece of evidence that the overall reaction between **A** and **B** must have more than one step.

[1 mark]

_____

_____

9

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0 2 This question is about the equilibrium

$$2\,NOCl(g) \rightleftharpoons 2\,NO(g) + Cl_2(g) \qquad \Delta H = +76\,kJ\,mol^{-1}$$

0 2 . 1 In an experiment, 0.340 mol of NOCl is heated at 400 K and allowed to reach equilibrium.
At this temperature, 0.120 mol of NOCl remains at equilibrium.

Deduce the amount, in moles, of NO and Cl_2 in the equilibrium mixture.

[2 marks]

Amount of NO _____ mol

Amount of Cl_2 _____ mol

0 2 . 2 In a different experiment, an equilibrium mixture contains 0.240 mol of NOCl, 0.170 mol of NO and 0.0800 mol of Cl_2
The total pressure of the mixture is 52.0 kPa

Calculate the partial pressure, in kPa, of NOCl in the mixture.
Give your answer to 3 significant figures.

[3 marks]

Partial pressure _____ kPa

Do not write outside the box

0 2 . 3 Write an expression for the equilibrium constant, K_p, for this reaction.

[1 mark]

K_p

0 2 . 4 The temperature of the equilibrium mixture in Question **02.2** is increased at a constant pressure.

Deduce the effect of this increase on the partial pressure of NO and on the equilibrium constant, K_p

Tick (✓) **one** box.

[1 mark]

Partial pressure of NO	**Equilibrium constant K_p**	**Tick (✓) one box**
decreases	increases	
decreases	stays the same	
increases	stays the same	
increases	increases	

7

Turn over for the next question

Do not write outside the box

0 3 This question is about isomers of C_4H_8O

$CH_3CH(CH_3)CHO$	$CH_3COCH_2CH_3$
D	**E**

0 3 . 1 Use IUPAC rules to name **D**.

[1 mark]

0 3 . 2 Isomer **E** reacts with KCN followed by dilute acid to form 2-hydroxy-2-methylbutanenitrile.

Outline the mechanism for this reaction.

[4 marks]

0 3 . 3 State **one** hazard of using KCN

[1 mark]

0 3 . 4 2-hydroxy-2-methylbutanenitrile contains an asymmetric carbon atom.

Describe how plane polarised light can show that a racemic mixture is formed in the reaction in Question **03.2**.

[1 mark]

7

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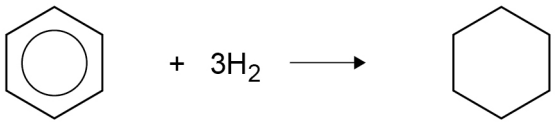
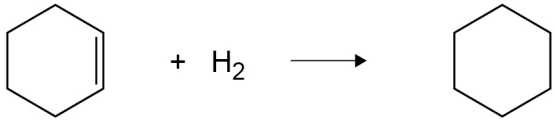
0 4 This question is about benzene and its derivatives.

0 4 . 1 Benzene can be converted into cyclohexane by reaction with hydrogen in the presence of a catalyst.



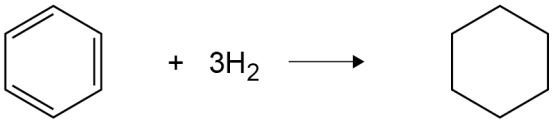
$\Delta H = -208 \text{kJ mol}^{-1}$

Cyclohexene can be converted into cyclohexane by reaction with hydrogen in the presence of a catalyst.



$\Delta H = -120 \text{kJ mol}^{-1}$

The conversion of the theoretical compound cyclohexa-1,3,5-triene into cyclohexane is shown



ΔH to be calculated

Calculate the enthalpy change for the conversion of cyclohexa-1,3,5-triene into cyclohexane.

Calculate the difference between this value and the enthalpy change for the conversion of benzene into cyclohexane.

Explain why the value is different from the value for benzene.

(If you could not calculate the enthalpy change for the conversion of cyclohexa-1,3,5-triene into cyclohexane, you should use the value –300 kJ mol^{-1} This is **not** the correct answer.)

[4 marks]

Enthalpy change _____ kJ mol^{-1}

Difference _____ kJ mol^{-1}

Explanation _____

_____

_____

_____

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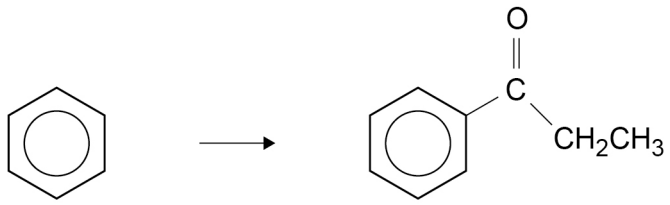
0 4 . 2 Identify a reagent and a catalyst needed to convert benzene into compound **F**.

[2 marks]



F

Reagent _____

Catalyst _____

0 4 . 3 One mole of benzene produces one mole of **F**.
The percentage yield for the conversion of benzene to **F** is 65.0%

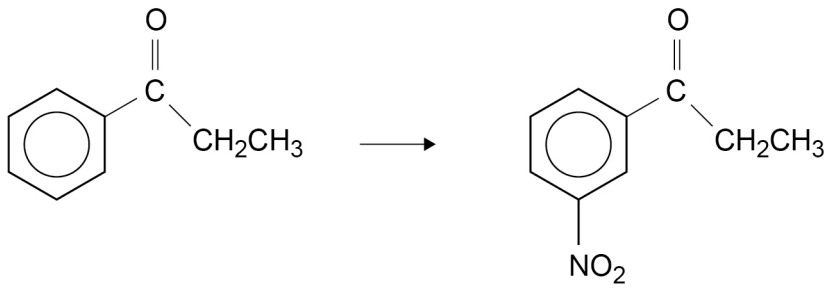
Calculate the mass of benzene needed to form 1.21 g of **F**.

[3 marks]

Mass_____g

Do not write outside the box

0 4 . 4 Concentrated sulfuric acid and concentrated nitric acid react together to form an electrophile. This electrophile reacts with **F** to form **G**.



F **G**

The reaction of the electrophile with **F** is similar to the reaction of this electrophile with methylbenzene.

Give the formula of the electrophile which reacts with the benzene ring in **F**.

Outline the mechanism of this reaction to form **G**.

[4 marks]

Formula of electrophile _____

Mechanism

13

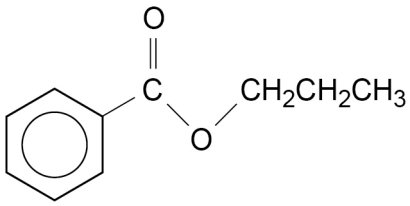
Turn over for the next question

Do not write outside the box

0 5 This question is about esters and carboxylic acids.

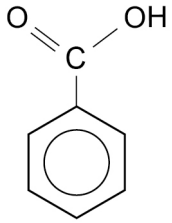
The structures and melting points of propyl benzoate (propyl benzenecarboxylate) and benzoic acid (benzenecarboxylic acid) are shown.

propyl benzoate



melting point –52 °C

benzoic acid



melting point 122 °C

0 5 . 1 Explain why benzoic acid has a higher melting point than propyl benzoate.

[3 marks]

Do not write outside the box

Propyl benzoate can be used to prepare pure benzoic acid.
The final stage in the preparation involves recrystallisation of impure benzoic acid in a series of steps.

Step 1 Dissolve the impure benzoic acid in the minimum volume of hot water.

Step 2 Filter the mixture while hot.

Step 3 Cool the filtrate in an ice-bath to form crystals.

Step 4 Filter off the crystals under reduced pressure.

Step 5 Wash the crystals with a small volume of cold water.

Step 6 Dry the crystals.

0 5 . 2 Explain why a **minimum** volume of hot water is used in **Step 1**.

[1 mark]

0 5 . 3 Give **one** reason why the mixture needs to be filtered while hot in **Step 2**.

[1 mark]

0 5 . 4 Give **one** reason why the crystals of benzoic acid are washed with cold water in **Step 5**.

[1 mark]

0 5 . 5 Melting point apparatus can be used to confirm the purity of the benzoic acid.

State **one** observation about the melting point measured if the crystals are not completely dry.

[1 mark]

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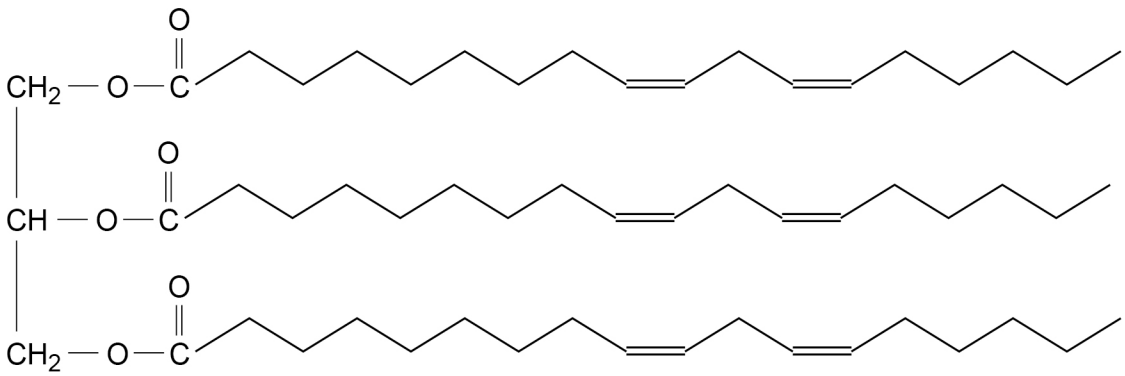
Vegetable oils and fats contain esters that can be used to make soap.
The structure of an ester found in a vegetable oil is shown.



0 5 . 6 Identify a reagent that could be used in a test-tube reaction to show that the ester is unsaturated.

State what you would observe.

[2 marks]

Reagent _____

Observation _____

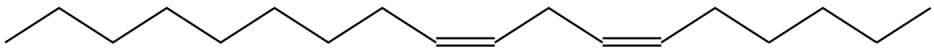
0 5 . 7 In the production of soap, sodium hydroxide reacts with the ester to give two products.

Complete the structure of the soap formed.

Give the structure of the other product.

[2 marks]

Soap



Other product

11

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Turn over for the next question

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ANSWER IN THE SPACES PROVIDED

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0 6 Coconut oil contains a mixture of carboxylic acids.
Gas chromatography can be used to identify the different carboxylic acids in coconut oil.

Figure 1 shows the chromatogram.

Figure 1

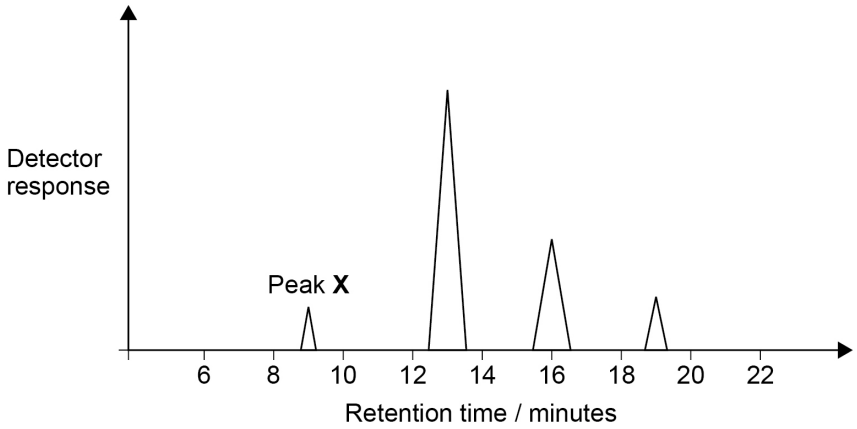
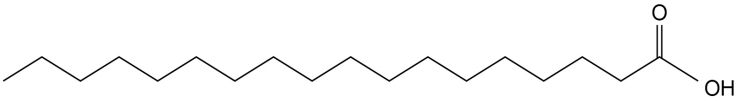
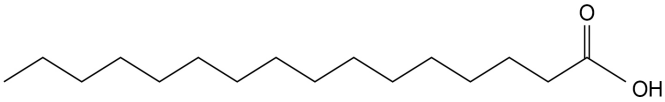
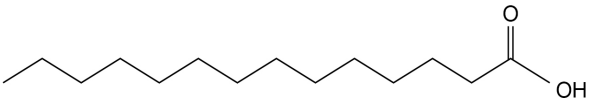
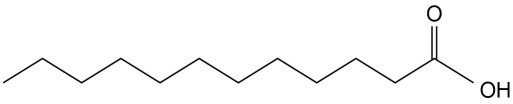
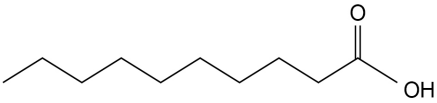
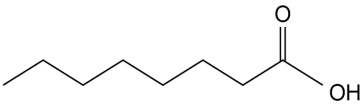


Table 2 shows the retention times of some carboxylic acids.

Table 2

Fatty acid	Structure	Molecular formula	Retention time/minutes
H		$C_{18}H_{36}O_2$	21
J		$C_{16}H_{32}O_2$	19
K		$C_{14}H_{28}O_2$	16
L		$C_{12}H_{24}O_2$	13
M		$C_{10}H_{20}O_2$	11
N		$C_8H_{16}O_2$	9

Do not write outside the box

0 6 . 1 State the meaning of the term retention time.

[1 mark]

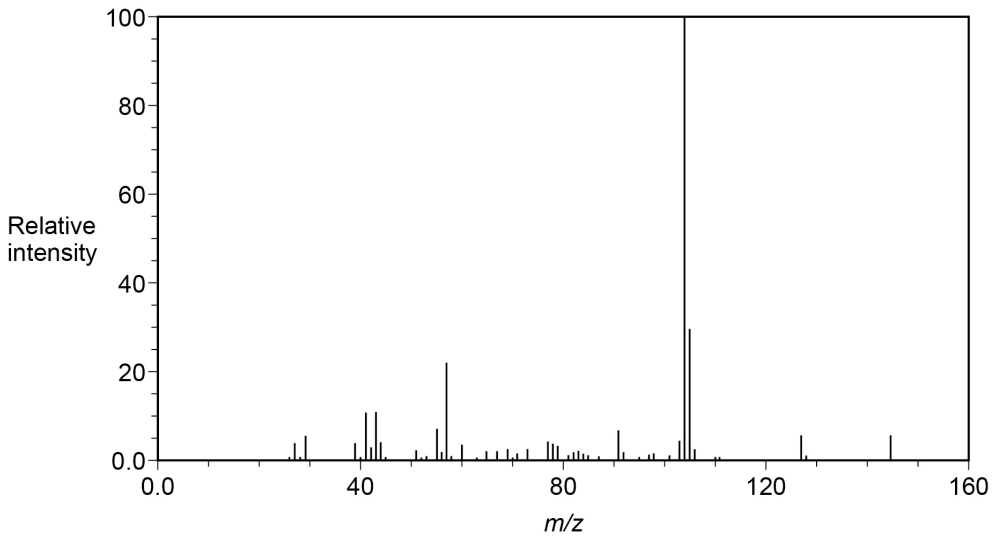
0 6 . 2 'In this experiment, the moving phase is more polar than the stationary phase.'

Justify this statement.

[2 marks]

Mass spectrometry can be used to analyse the carboxylic acids separated in gas chromatography. The mass spectrum of the carboxylic acid that caused the peak **X** in **Figure 1** is shown in **Figure 2**.

Figure 2



0 6 . 3 Explain how the peak at *m/z* = 144.0 can be used to confirm the identity of the carboxylic acid.

[1 mark]

4

Turn over ►

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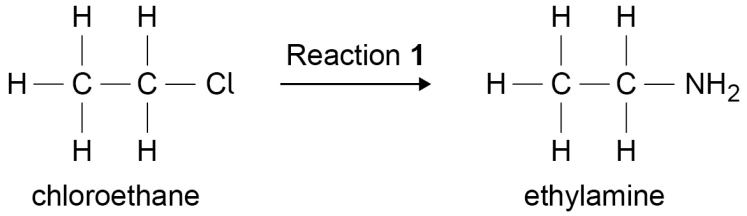
0 7 This question is about amines and amides.

Ethylamine can be formed from chloroethane by **Synthesis 1** or from chloromethane by **Synthesis 2**.

Synthesis 1



Synthesis 2

0 7 . 1 Complete the equation for Reaction **1**.

[1 mark]

CH_3CH_2Cl + _____ → $CH_3CH_2NH_2$ + _____

0 7 . 2 In Reaction **3**, **P** is converted into ethylamine.

Draw the displayed formula of **P**.

Give the reagent and **one** condition needed for Reaction **3**.

[2 marks]

Displayed formula

Reagent and **one** condition _____

Do not write outside the box

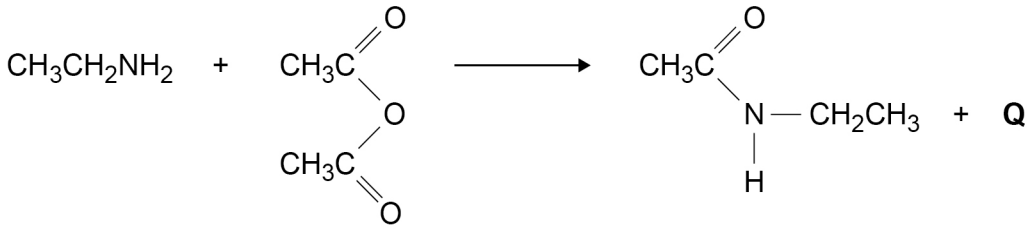
0 7 . 3 State why **Synthesis 2** might produce a higher yield of ethylamine than **Synthesis 1**.

[1 mark]

_____

_____

0 7 . 4 Ethylamine reacts with ethanoic anhydride to form an amide and another product, **Q**.



Name the mechanism for the reaction of ethylamine with ethanoic anhydride.

Use IUPAC rules to name the amide formed.

Identify **Q**.

[3 marks]

Name of mechanism _____

Name of amide _____

Identity of **Q**

_____

Question 7 continues on the next page

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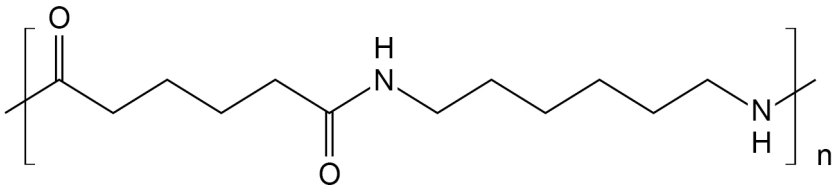
Nylon-6,6 is a polymer formed by the reaction of a diamine with hexanedioic acid. The repeating unit of nylon-6,6 is shown.



0 7 . 5 Give the structure of the diamine monomer that reacts with hexanedioic acid to make nylon-6,6

[1 mark]

0 7 . 6 Name the type of polymerisation that produces nylon-6,6

[1 mark]

_____

0 7 . 7 Under different conditions, the diamine and hexanedioic acid react to form a salt.

State why the diamine is able to form a salt with hexanedioic acid.

[1 mark]

_____

_____

10

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Turn over for the next question

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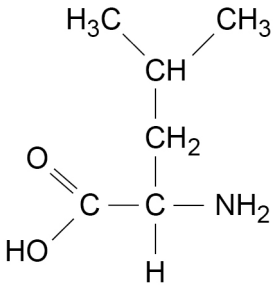
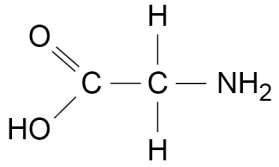
0 8 This question is about naturally occurring compounds.

Leucine and glycine are two naturally occurring amino acids.



leucine



glycine

0 8 . 1 Use IUPAC rules to name leucine.

[1 mark]

_____

0 8 . 2 Glycine has a melting point of 233 °C

Draw the structure of the species that exists in a crystal of glycine.

Name this type of species.

[2 marks]

Structure

Type of species _____

Do not write outside the box

0 8 . 3 Draw the two dipeptides formed when one molecule of glycine reacts with one molecule of leucine.

[2 marks]

Dipeptide 1

Dipeptide 2

Do not write outside the box

Polypeptide chains fold into 3-dimensional structures because of interactions between functional groups on different parts of the chain.

0 8 . 4 State the meaning of the term primary structure of a protein.

[1 mark]

_____

0 8 . 5 β-pleated sheets are an example of secondary structures formed in proteins.

Name a different type of secondary structure.

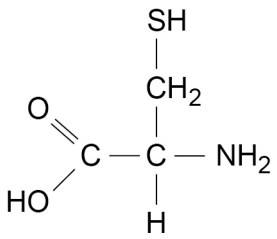
Identify the force between amino acids that holds the secondary structure in place.

[2 marks]

Secondary structure _____

Force _____

0 8 . 6 The amino acid cysteine contains the thiol group –SH



cysteine

Proteins are held in a tertiary structure by a bond that forms between thiol groups.

Identify this bond.

[1 mark]

_____

Do not write outside the box

0 8 . 7 Cisplatin is used as an anticancer drug.

Explain how cisplatin affects cancer cells.

In your answer consider how cisplatin reacts with DNA in cancer cells.

[2 marks]

_____

_____

_____

_____

11

Turn over for the next question

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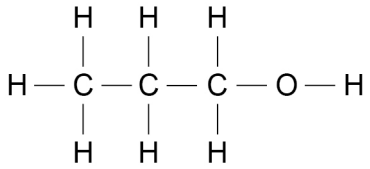
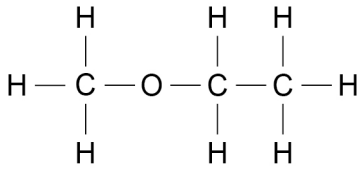
0 9 Compound **R** has the molecular formula C_3H_8O

Two isomers of C_3H_8O are shown.





0 9 . 1 The ^{13}C NMR spectrum of each of these isomers has the same number of peaks.

Give the number of peaks.

[1 mark]

_____

0 9 . 2 Draw the third isomer of C_3H_8O

[1 mark]

0 9 . 3 ^{1}H NMR spectroscopy is used to show which of these three isomers is **R**.
A sample of **R** is used in a solution that contains the inert standard tetramethylsilane (TMS).

Give **two** other reasons why TMS is a suitable standard.

[2 marks]

Reason 1 _____

_____

Reason 2 _____

_____

Do not write outside the box

Table 3 gives data from the ^{1}H NMR spectrum of **R**.

Table 3

δ / ppm	1.1	3.2	3.5
Splitting pattern	triplet	singlet	quartet
Integration value	0.75	0.75	0.5

Use **Table 3** and **Table B** on the Chemistry Data Sheet to answer the following questions.

0 9 . 4 Draw the part of the structure responsible for the peak at δ = 1.1 ppm

[1 mark]

0 9 . 5 Draw the part of the structure responsible for the peak at δ = 3.2 ppm

[1 mark]

0 9 . 6 Draw the part of the structure responsible for the peak at δ = 3.5 ppm

[1 mark]

0 9 . 7 Draw the structure of **R**.

[1 mark]

8

END OF QUESTIONS

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ANSWER IN THE SPACES PROVIDED

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Question number	**Additional page, if required.** **Write the question numbers in the left-hand margin.**

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Question number	**Additional page, if required.** **Write the question numbers in the left-hand margin.**

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