AQA

A-level
CHEMISTRY
(7405/2)

Paper 2: Organic and Physical Chemistry

| Specimen 2015 | Session | Time allowed: 2 hours |

Materials

For this paper you must have:
* the Data Booklet, provided as an insert
* a ruler
* a calculator.

Instructions
* Answer **all** questions.
* Show **all** your working.

Information
* The maximum mark for this paper is 105.

Please write clearly, in block capitals, to allow character computer recognition.

Centre number ☐☐☐☐☐   Candidate number ☐☐☐☐

Surname ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

Forename(s) ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

Candidate signature _____

Answer **all** questions.

1 This question involves the use of kinetic data to deduce the order of a reaction and calculate a value for a rate constant.

The data in **Table 1** were obtained in a series of experiments on the rate of the reaction between compounds **A** and **B** at a constant temperature.

Table 1

Experiment	Initial concentration of A / mol dm^{-3}	Initial concentration of B / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	0.12	0.26	2.10×10^{-4}
2	0.36	0.26	1.89×10^{-3}
3	0.72	0.13	3.78×10^{-3}

0 1 . 1 Show how these data can be used to deduce the rate expression for the reaction between **A** and **B**.

[3 marks]

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PMT

The data in **Table 2** were obtained in two experiments on the rate of the reaction between compounds **C** and **D** at a constant temperature.

Table 2

Experiment	Initial concentration of C / mol dm^{-3}	Initial concentration of D / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
4	1.9×10^{-2}	3.5×10^{-2}	7.2×10^{-4}
5	3.6×10^{-2}	5.4×10^{-2}	To be calculated

The rate equation for this reaction is

$$rate = k[\mathbf{C}]^2[\mathbf{D}]$$

0 1 . 2 Use the data from experiment **4** to calculate a value for the rate constant, k, at this temperature. Deduce the units of k.

[3 marks]

$k =$ _____ Units = _____

0 1 . 3 Calculate a value for the initial rate in experiment **5**.

[1 mark]

Initial rate = _____ mol dm^{-3} s^{-1}

Question 1 continues on the next page

Turn over ▶

0 1 . 4 The rate equation for a reaction is

$$rate = k[\mathbf{E}]$$

Explain qualitatively why raising the temperature by 10 °C has a much greater effect on the rate of the reaction than doubling the concentration of **E**.

[3 marks]

0 1 . 5 A slow reaction has a rate constant $k = 6.51 \times 10^{-3}$ mol^{-1} dm^3 at 300 K.

Use the equation $\ln k = \ln A - E_a/RT$ to calculate a value, in kJ mol^{-1}, for the activation energy of this reaction.

The constant $A = 2.57 \times 10^{10}$ mol^{-1} dm^3.
The gas constant $R = 8.31$ J K^{-1} mol^{-1}.

[2 marks]

Activation energy = _____

Turn over for the next question

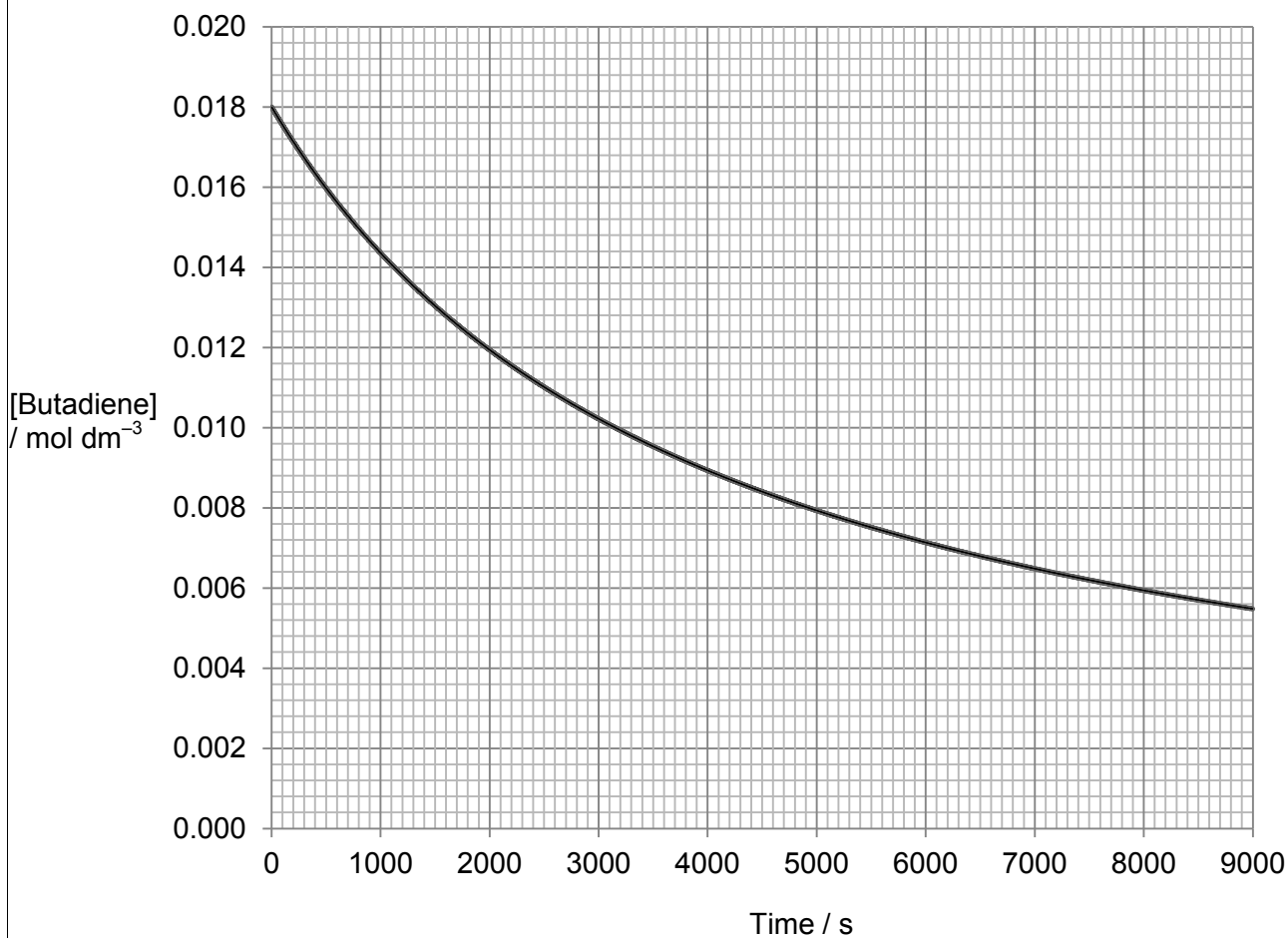**DO NOT WRITE ON THIS PAGE**
ANSWER IN THE SPACES PROVIDED

2   Butadiene dimerises according to the equation

$$2C_4H_6 \longrightarrow C_8H_{12}$$
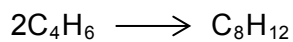
The kinetics of the dimerisation are studied and the graph of the concentration of a sample of butadiene is plotted against time. The graph is shown in **Figure 1**.

Figure 1

0 2 . **1** Draw a tangent to the curve when the concentration of butadiene is 0.0120 mol dm^{-3}.

[1 mark]

0 2 . 2 The initial rate of reaction in this experiment has the value 4.57×10^{-6} mol dm^{-3} s^{-1}.

Use this value, together with a rate obtained from your tangent, to justify that the order of the reaction is 2 with respect to butadiene.

[5 marks]
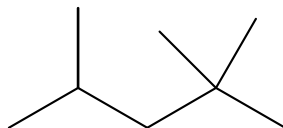
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Turn over for the next question

3   Isooctane (C_8H_{18}) is the common name for the branched-chain hydrocarbon that burns smoothly in car engines.   The skeletal formula of isooctane is shown in **Figure 2**.

Figure 2

| 0 | 3 | . | 1 | Give the IUPAC name for isooctane.

[1 mark]

_____

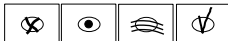| 0 | 3 | . | 2 | Deduce the number of peaks in the ^{13}C NMR spectrum of isooctane.

[1 mark]

Only **one** answer is allowed.

Completely fill in the circle alongside the appropriate answer.

CORRECT METHOD ⬤   WRONG METHODS ⊗ ⊙ ⊜ ∅

If you want to change your answer you must cross out your original answer as shown. ⊠

If you wish to return to an answer previously crossed out, ring the answer you now wish to select as shown. ⊗

5   ⬭

6   ⬭

7   ⬭

8   ⬭

0 3 . 3 Isooctane can be formed, together with propene and ethene, in a reaction in which one molecule of an alkane that contains 20 carbon atoms is cracked.

Using molecular formulas, write an equation for this reaction.

[1 mark]

0 3 . 4 How do the products of the reaction in Question **3.3** show that the reaction is an example of thermal cracking?

[1 mark]

0 3 . 5 Deduce the number of monochloro isomers formed by isooctane.
Draw the structure of the monochloro isomer that exists as a pair of optical isomers.

[2 marks]

Number of monochloro isomers _____

Structure

0 3 . 6 An isomer of isooctane reacts with chlorine to form only one monochloro compound.

Draw the **skeletal formula** of this monochloro compound.

[1 mark]

Question 3 continues on the next page

| 0 | 3 | . | 7 | A sample of a monochlorooctane is obtained from a comet. The chlorine in the monochlorooctane contains the isotopes ^{35}Cl and ^{37}Cl in the ratio 1.5 : 1.0 Calculate the M_r of this monochlorooctane. |

[2 marks]

M_r = _____

| 0 | 3 | . | 8 | Isooctane reacts with an excess of chlorine to form a mixture of chlorinated compounds. One of these compounds contains 24.6% carbon and 2.56% hydrogen by mass. Calculate the molecular formula of this compound. |

[3 marks]

Molecular formula = _____

Turn over for the next question

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ANSWER IN THE SPACES PROVIDED**

4   Alcohol **A** $(CH_3)_2CHCH(OH)CH_3$ undergoes reactions separately with acidified potassium dichromate(VI) and with concentrated sulfuric acid.

0 4 . 1 | Deduce the IUPAC name for alcohol **A**.

[1 mark]

_____

0 4 . 2 | Draw the structure of the organic product, **B**, formed when **A** is oxidised in the reaction with acidified potassium dichromate(VI).

[1 mark]

0 4 . 3 | Two isomeric alkenes, **C** and **D**, are formed when **A** is dehydrated in the reaction with concentrated sulfuric acid.

Name the mechanism for this dehydration reaction.

[1 mark]

_____

0 4 . 4 | Draw the structure of each isomer.

[2 marks]

Isomer **C**   Isomer **D**

0 4 . 5 Name the type of structural isomerism shown by **C** and **D**.

[1 mark]

_____

0 4 . 6 List alcohol **A**, product **B** and isomer **C** in order of increasing boiling point.

[1 mark]

_____

0 4 . 7 Draw the structure of the isomer of **A** that is **not** oxidised by acidified potassium dichromate(VI).
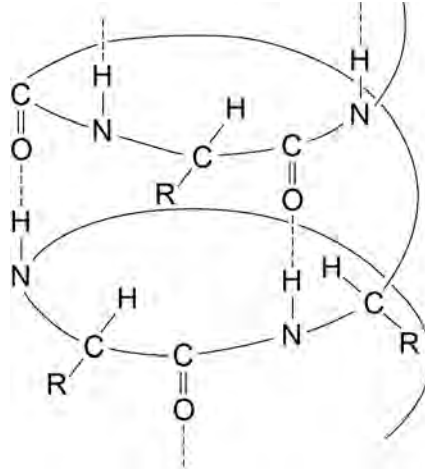
[1 mark]

0 4 . 8 Draw the structure of the isomer of **A** that **cannot** be dehydrated to form an alkene by reaction with concentrated sulfuric acid.

[1 mark]

Turn over for the next question

5   **Figure 3** shows a simplified representation of the arrangement of some amino acids in a portion of a protein structure in the form of an α-helix.

Figure 3

| 0 | 5 | . | 1 | Name the type of protein structure in **Figure 3**.

[1 mark]

_____

| 0 | 5 | . | 2 | Explain the origin of the interaction represented by the dotted lines in **Figure 3**.

[4 marks]

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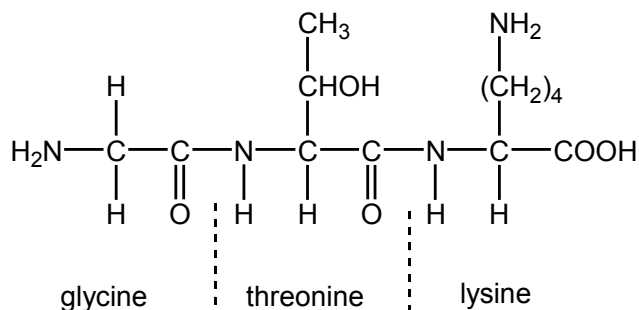**6**   The tripeptide shown in **Figure 4** is formed from the amino acids glycine, threonine and lysine.

Figure 4

glycine   threonine   lysine

0 6 . 1 Draw a separate circle around **each** of the asymmetric carbon atoms in the tripeptide in **Figure 4**.

[1 mark]

0 6 . 2 Draw the zwitterion of glycine.

[1 mark]

0 6 . 3 Draw the structure of the species formed when glycine reacts with an excess of bromomethane.

[1 mark]

0 6 . 4 Deduce the IUPAC name of threonine.

[1 mark]

0 6 . 5 Draw the structure of the species formed by lysine at low pH.

[1 mark]

7 Repeating units of two polymers, **P** and **Q**, are shown in **Figure 5**.

Figure 5

P   Q
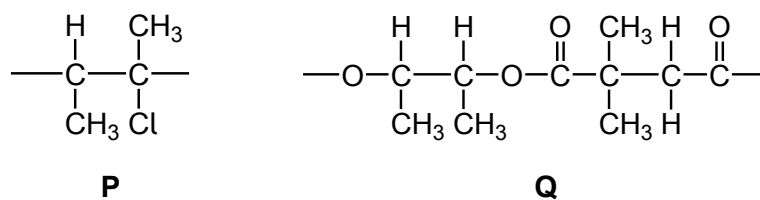
0 7 . 1 Draw the structure of the monomer used to form polymer **P**.
Name the type of polymerisation involved.

[2 marks]

Monomer

Type of polymerisation _____

0 7 . 2 Draw the structures of **two** compounds that react together to form polymer **Q**.

[2 marks]

Structure of compound 1

Structure of compound 2

0 7 . 3 Suggest an environmental advantage of polymer **Q** over polymer **P**.
Justify your answer.

[3 marks]
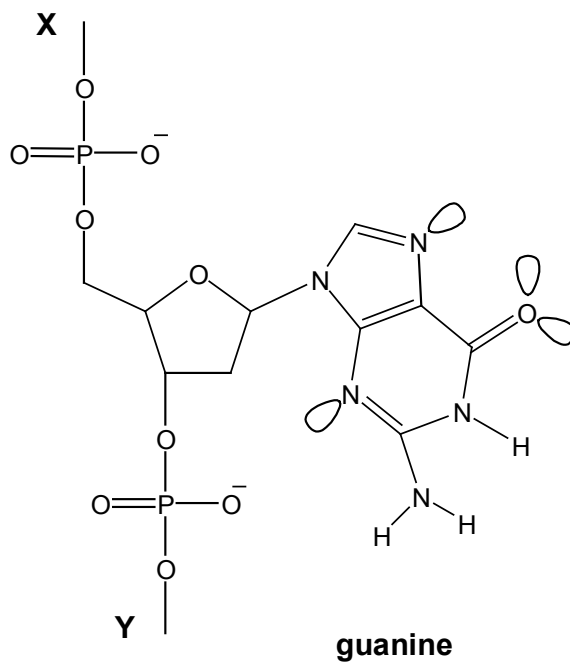
Advantage _____

Justification _____

_____

_____

_____

_____

Turn over for the next question

8 The anticancer drug cisplatin operates by reacting with the guanine in DNA.

Figure 6 shows a small part of a single strand of DNA. Some lone pairs are shown.

Figure 6

guanine

| 0 | 8 | . | 1 | The DNA chain continues with bonds at **X** and **Y**.

State the name of the sugar molecule that is attached to the bond at **X**.
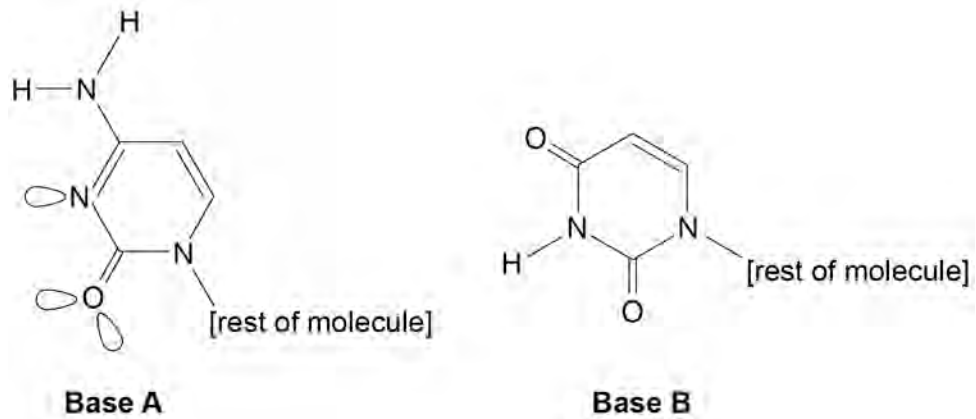
[1 mark]

| 0 | 8 | . | 2 | Messenger RNA is synthesised in cells in order to transfer information from DNA. The bases in one strand of DNA pair up with the bases used to synthesise RNA.

Figure 7 shows two bases used in RNA.

Figure 7

Base A   Base B

Suggest which of the bases **A** and **B** forms a pair with guanine in **Figure 6** when messenger RNA is synthesised.
Explain how the base that you have chosen forms a base pair with guanine.

[4 marks]

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Question 8 continues on the next page

0 8 . 3 Cisplatin works because one of the atoms on guanine can form a co-ordinate bond with platinum, replacing one of the ammonia or chloride ligands. Another atom on another guanine can also form a co-ordinate bond with the same platinum by replacing another ligand.

On **Figure 6,** draw a ring round an atom in guanine that is likely to bond to platinum.

[1 mark]

0 8 . 4 An adverse effect of cisplatin is that it also prevents normal healthy cells from replicating.

Suggest **one** way in which cisplatin can be administered so that this side effect is minimised.

[1 mark]

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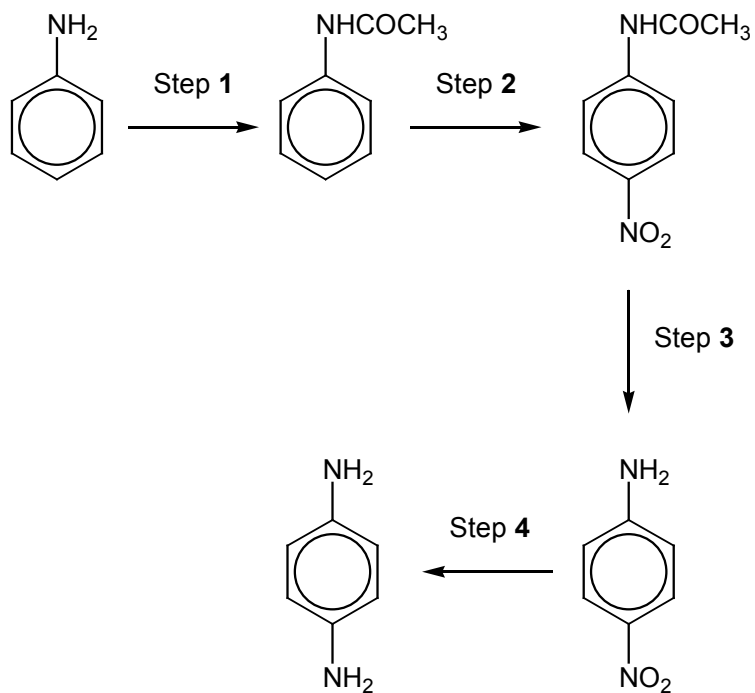
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ANSWER IN THE SPACES PROVIDED

PMT

9 1,4-diaminobenzene is an important intermediate in the production of polymers such as Kevlar and also of polyurethanes, used in making foam seating.

A possible synthesis of 1,4-diaminobenzene from phenylamine is shown in **Figure 8**.

Figure 8

0 9 . 1 A suitable reagent for step **1** is CH$_3$COCl

Name and draw a mechanism for the reaction in step **1**.

[5 marks]

Name of mechanism _____

Mechanism

| 0 | 9 | . | 2 | The product of step **1** was purified by recrystallisation as follows.

The crude product was dissolved in **the minimum quantity of hot water** and the hot solution was filtered through a hot filter funnel into a conical flask. This filtration removed any insoluble impurities. The flask was **left to cool to room temperature.**
The crystals formed were filtered off using a Buchner funnel and a clean cork was used **to compress the crystals in the funnel**. **A little cold water was then poured through the crystals.**
After a few minutes, the crystals were removed from the funnel and weighed.
A small sample was then used to find the melting point.

Give reasons for each of the following practical steps.

[4 marks]

The minimum quantity of hot water was used

_____

_____

_____

The flask was cooled to room temperature before the crystals were filtered off

_____

_____

_____

The crystals were compressed in the funnel

_____

_____

_____

A little cold water was poured through the crystals

_____

_____

_____

Question 9 continues on the next page

Turn over ▶

| 0 | 9 | . | 3 | The melting point of the sample in Question **9.2** was found to be slightly lower than a data-book value.

Suggest the most likely impurity to have caused this low value and an improvement to the method so that a more accurate value for the melting point would be obtained.
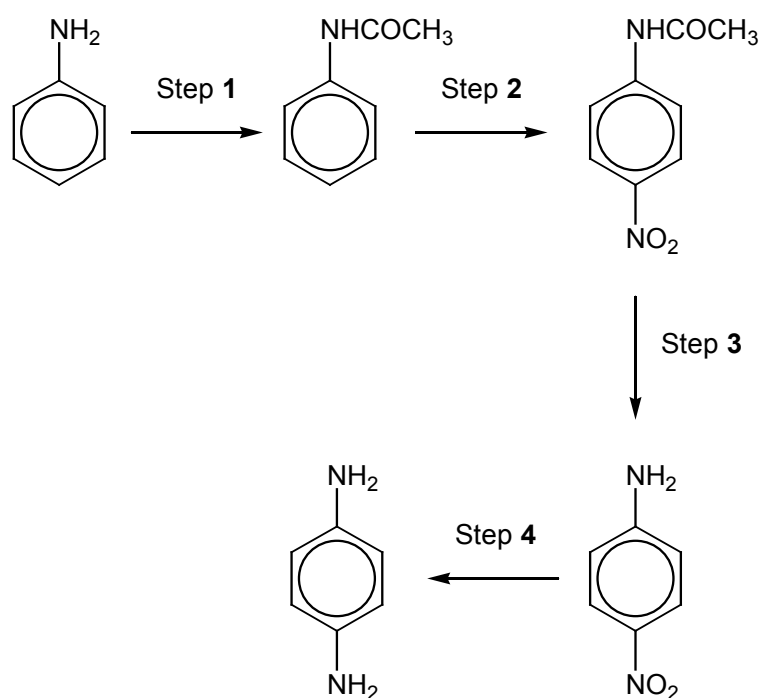
[2 marks]

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_____

Figure 8 is repeated here to help you answer the following questions.

Figure 8

0 9 . 4 In an experiment starting with 5.05 g of phenylamine, 4.82 g of purified product were obtained in step **1**.

Calculate the percentage yield in this reaction.
Give your answer to the appropriate number of significant figures.

[3 marks]

Percentage yield = _____ %

0 9 . 5 A reagent for step **2** is a mixture of concentrated nitric acid and concentrated sulfuric acid, which react together to form a reactive intermediate.

Write an equation for the reaction of this intermediate in step **2**.

[1 mark]

_____

0 9 . 6 Name a mechanism for the reaction in step **2**.

[1 mark]

_____

0 9 . 7 Suggest the type of reaction occurring in step **3**.

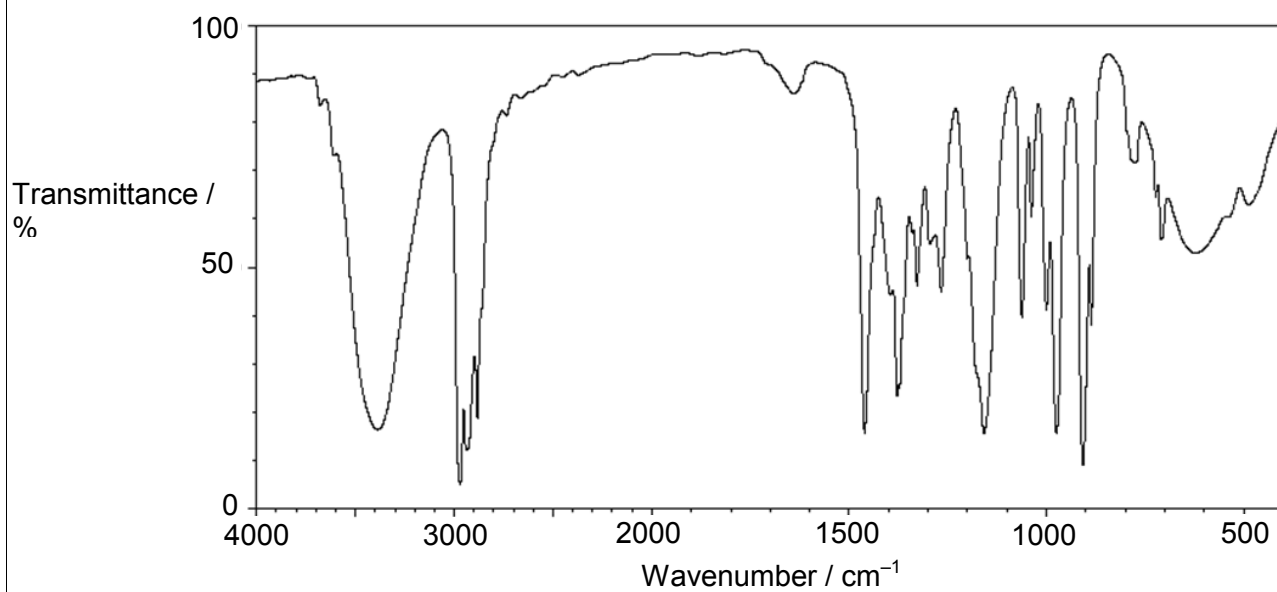**[1 mark]**

_____

0 9 . 8 Identify the reagents used in step **4**.

[1 mark]

_____

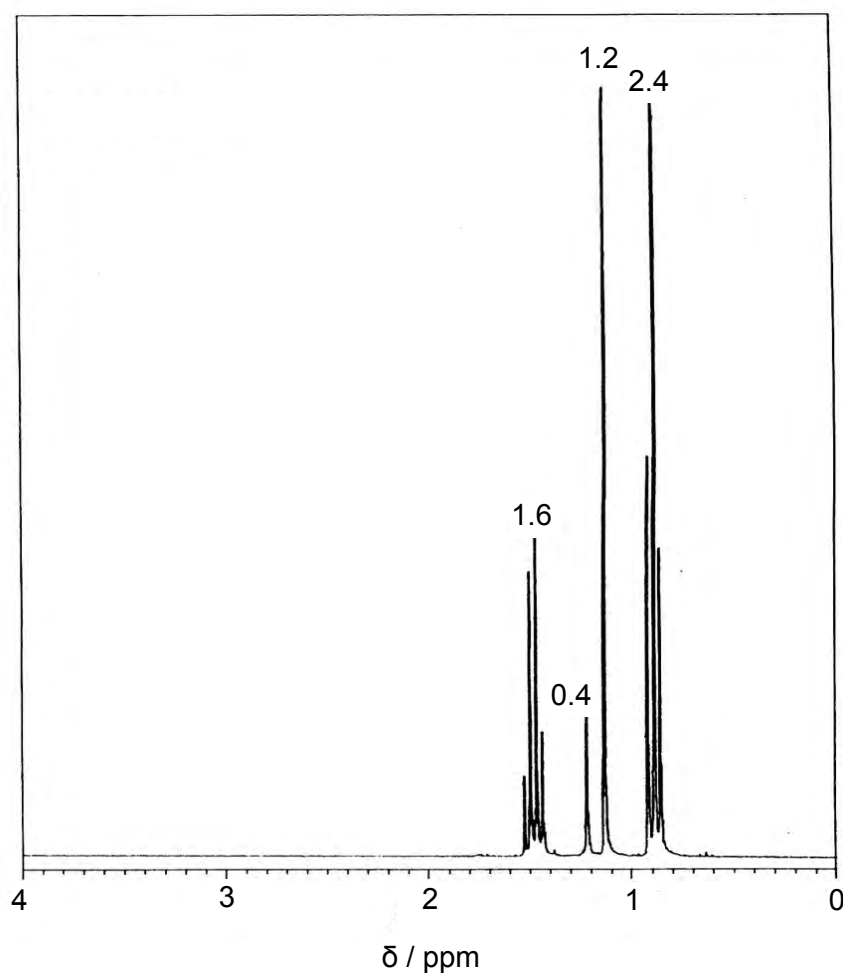**10** The infrared spectrum (**Figure 9**) and the ^{1}H NMR spectrum (**Figure 10**) of compound **R** with molecular formula $C_6H_{14}O$ are shown.

Figure 9

Figure 10

1 0 The relative integration values for the NMR peaks are shown on **Figure 10**.

Deduce the structure of compound **R** by analysing **Figure 9** and **Figure 10**. Explain each stage in your deductions.

Use **Table A** and **Table B** on the Data Sheet.

[8 marks]

Turn over for the next question

Turn over ▶

11 Butanone is reduced in a two-step reaction using $NaBH_4$ followed by dilute hydrochloric acid.

1 1 . 1 Write an overall equation for the reduction of butanone using [H] to represent the reductant.

[1 mark]

1 1 . 2 By considering the mechanism of the reaction, explain why the product has **no** effect on plane polarised light.

[6 marks]

12 But-1-ene reacts with a reagent of the form HY to form a saturated compound.

1 2 . 1 Suggest a reagent of the form HY which reacts with but-1-ene.

[1 mark]

_____

1 2 . 2 Name and draw a mechanism for the reaction in Question **12.1**.

[5 marks]

Name of mechanism _____

Mechanism

1 2 . 3 Explain how three isomeric products are formed when HY reacts with but-1-ene.

[3 marks]

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END OF QUESTIONS

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