

Surname	Centre Number	Candidate Number
First name(s)		2



GCE A LEVEL

1410U40-1



S25-1410U40-1

MONDAY, 16 JUNE 2025 – MORNING

CHEMISTRY – A2 unit 4
Organic Chemistry and Analysis

1 hour 45 minutes

Section A

Section B

For Examiner's use only		
Question	Maximum Mark	Mark Awarded
1. to 4.	10	
5.	14	
6.	16	
7.	15	
8.	13	
9.	12	
Total	80	

ADDITIONAL MATERIALS

- A calculator, pencil and ruler
- **Data Booklet** supplied by WJEC

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen or correction fluid.

You may use a pencil for graphs and diagrams only.

Write your name, centre number and candidate number in the spaces at the top of this page.

Section A Answer **all** questions.

Section B Answer **all** questions.

Write your answers in the spaces provided in this booklet. If you run out of space, use the additional page(s) at the back of the booklet, taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets at the end of each question or part-question.

The maximum mark for this paper is 80.

Your answers must be relevant and must make full use of the information given to be awarded full marks for a question.

The assessment of the quality of extended response (QER) will take place in **Q7(a)**.



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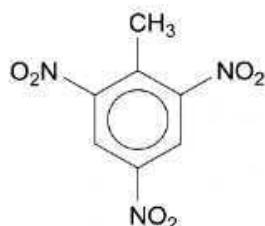
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BE*(Y21-1410U40-1)

1410U401
01

SECTION AAnswer **all** questions.

1. TNT (2,4,6-trinitrotoluene) is used as an explosive.



TNT

- (a) The first stage in its production is the nitration of toluene (methylbenzene).

State the reagent(s) used to nitrate aromatic hydrocarbons such as benzene and toluene.

[1]

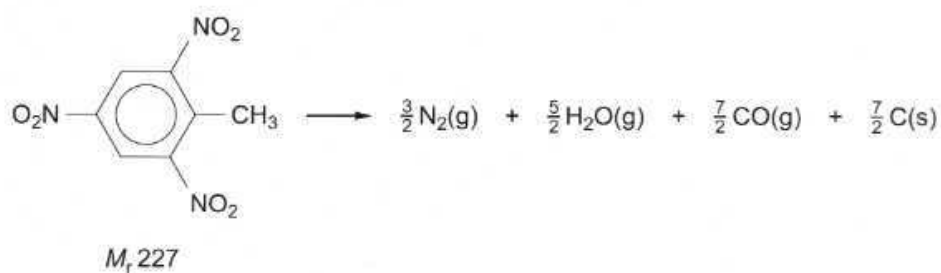
- (b) The final stage in the production of TNT is its purification. Pure TNT has a melting temperature of 80 °C.

State how this melting temperature will be affected if the TNT is slightly damp.

[1]



- (c) One equation for the explosive decomposition of TNT is shown below.



Calculate the number of moles of gaseous products obtained if 1.00 g of TNT decomposes as shown in the equation.

[2]

Number of moles = mol

2. Propan-2-ol is used as a solvent and in antibacterial wipes.

- (a) State what is seen, if anything, when propan-2-ol reacts with an alkaline solution of iodine.

[1]

- (b) Give the structure of the organic compound produced when propan-2-ol reacts with an acidified solution of potassium dichromate.

[1]



3. Bis(2-chloroethyl) sulfide has been used as a mustard gas. One way of destroying this material is by reacting it with hot water.



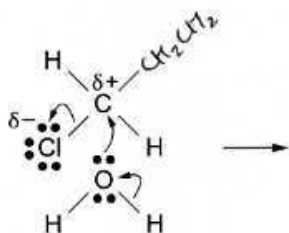
M_r 159

- (a) Calculate the minimum mass of water needed to destroy 477 tonnes of bis(2-chloroethyl) sulfide.

[1]

Mass = tonnes

- (b) Part of the mechanism is shown below.



Complete the equation showing the products of this stage of the mechanism.

[1]



4. 4-Bromophenol reacts with aqueous sodium hydroxide to give the products shown in the equation.



- (a) Explain why 4-bromophenol reacts with alkalis like sodium hydroxide. [1]

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- (b) Explain why the organic product from this reaction is **not** the compound shown below. [1]



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SECTION B

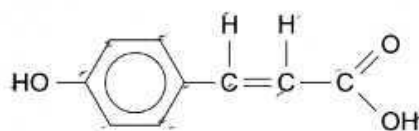
Answer all questions.

5. (a) Compound **E** is a carboxylic acid containing only one carboxylic acid group. Its relative molecular mass was found by a titration with aqueous sodium carbonate solution.

4.10 g of compound **E** was just neutralised by 25.00 cm³ of 0.500 mol dm⁻³ sodium carbonate. 2 mol of the acid reacts with 1 mol of sodium carbonate.

Use the information to show that the relative molecular mass of compound **E** is 164. [2]

- (b) Compound **E** has the formula below.



- (i) Draw the structure of the compound produced when compound **E** reacts with an excess of aqueous sodium hydroxide. [1]

- (ii) State what is seen when a solution of compound **E** is treated with aqueous iron(III) chloride solution. [1]
-



- (iii) Compound **E** reacts with bromine to give compound **F**.

Compound **F** does not contain an alkene functional group. Analysis of compounds **E** and **F** for the percentage of carbon by mass in each compound gave the following results.

Compound	Percentage of carbon
E	65.9
F	26.8

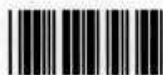
Use the information to suggest a structure for compound **F**. Show your reasoning.
[4]



(iv) The structure of compound **E** suggests that it can be polymerised.

I. Give the structure of the repeating section obtained when compound **E** produces an addition polymer. [1]

II. Give the structure of the repeating section obtained when compound **E** produces a condensation polymer. [1]



- (c) The boiling temperatures of some alkylbenzenes are given in the table.

Compound	Boiling temperature / °C
ethylbenzene	136
propylbenzene	159
butylbenzene	183

- (i) Explain why the boiling temperatures of these compounds increase as shown. [1]

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- (ii) Predict the boiling temperature of hexylbenzene. Give your reasoning. [2]

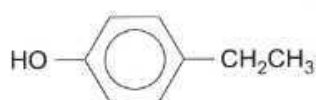
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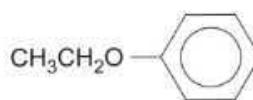
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- (iii) Explain why the boiling temperature of 4-ethylphenol is higher than that of ethoxybenzene, even though they are both isomers of formula $C_8H_{10}O$. [1]



4-ethylphenol



ethoxybenzene

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6. (a) (i) In ultraviolet light methane reacts with chlorine by a radical substitution reaction producing chloromethane and hydrogen chloride.



Give the equation for the initiation step of this reaction.

[1]

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- (ii) Further chlorination of methane produces CH_2Cl_2 , CHCl_3 and CCl_4 .

Give an equation to show how 1,2-dichloroethane might be another product of this chlorination reaction.

[1]

-
- (b) One method of finding the relative molecular mass of a volatile liquid is by measuring the volume of vapour obtained from a known mass of the liquid.

- (i) In an experiment 0.168 g of a chlorinated alkane was heated and produced 42.9 cm^3 of vapour measured at 363 K and at $9.86 \times 10^4 \text{ Pa}$.

Calculate the relative molecular mass of the chlorinated alkane.

[3]

Relative molecular mass =



- (ii) The traditional way of heating the flask containing the volatile liquid sample is to use a water bath.

I. Suggest why this method of heating may not be suitable to find the relative molecular mass of 1,1,2-trichloroethane, which has a boiling temperature of 112°C . [1]

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II. Suggest a modification to this method to enable the relative molecular mass of 1,1,2-trichloroethane to be found. [1]

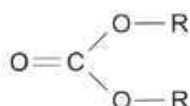
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- (c) (i) Tetrachloromethane has been used in the past in fire extinguishers. It is no longer used for this purpose because of its toxicity and also its tendency to react with water vapour at higher temperatures to give carbonyl dichloride, COCl_2 , and hydrogen chloride.

Suggest an equation for this reaction. [1]

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- (ii) Carbonyl dichloride reacts as an acid chloride and produces esters of carbonic acid when reacted with alcohols.



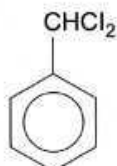
An ester of carbonic acid has a relative molecular mass of 146.

Use this information to suggest a formula for the alkyl group R. [2]

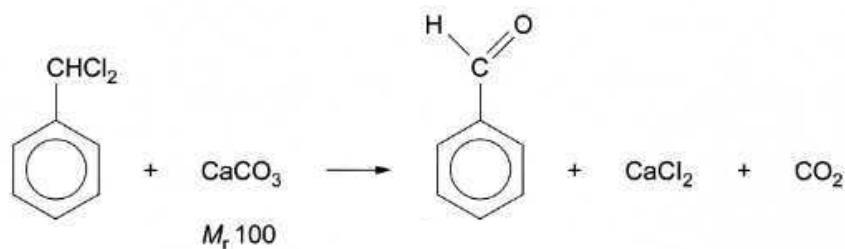
R has the formula



- (d) Methylbenzene also reacts with chlorine in a radical reaction to give chlorinated side chain products. One of these is (dichloromethyl)benzene.



This compound can be hydrolysed to prepare benzaldehyde using a suspension of calcium carbonate in water.



- (i) Calculate the atom economy of this reaction.

[2]

Atom economy = %

- (ii) This reaction is quite slow.

Suggest **two** ways by which the rate of this reaction could be studied.

[2]

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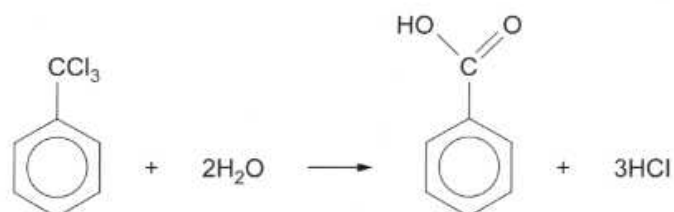
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- (e) Another chlorinated side chain product obtained from methylbenzene is (trichloromethyl)benzene. This reacts with water to give benzoic acid and hydrochloric acid.



0.050 mol of (trichloromethyl)benzene was completely hydrolysed to these two acids.

Calculate the volume of aqueous sodium hydroxide of concentration 2.50 mol dm^{-3} needed to completely neutralise the two acids produced in this reaction. [2]

Volume = cm^3



7. (a) You are provided with a 5g sample of sodium benzoate contaminated with a small quantity of sand.

Use the information below to devise a method that others could follow, to obtain crystals of pure benzoic acid from this sample.

- The solubility of sodium benzoate in water is 66 g / 100 g of water at 20 °C
- Sand is insoluble in water and in hydrochloric acid
- Sodium benzoate reacts with hydrochloric acid to give benzoic acid and sodium chloride
- The solubility of benzoic acid in water is 0.3 g / 100 g of water at 20 °C rising to 5.6 g / 100 g of water at 100 °C

In your answer you should explain the reasons for each step and suggest the volume of water used at each step. [6 QER]

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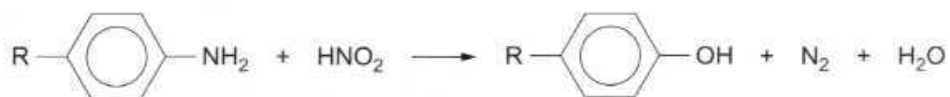
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- (b) (i) A primary aromatic amine, compound **V**, reacts with nitric(III) acid to give the corresponding phenol and nitrogen gas.



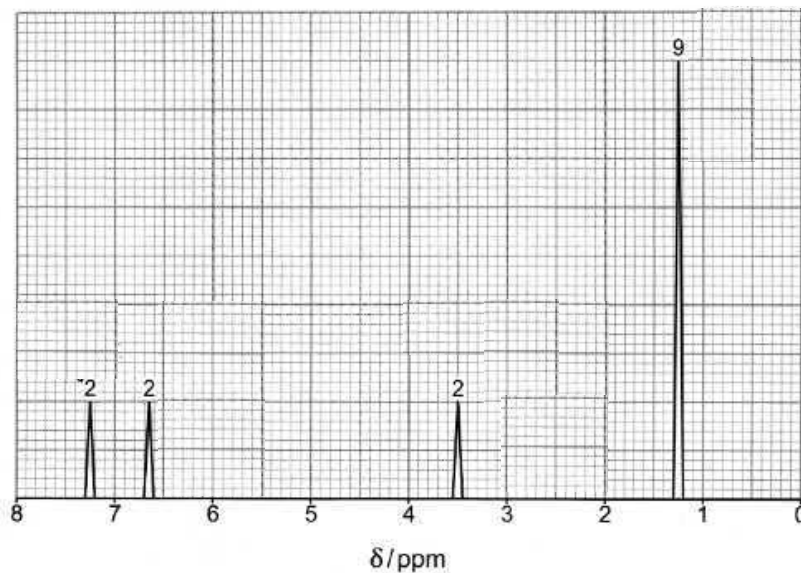
compound **V**

5.00 g of compound **V** gave 823.5 cm³ of nitrogen gas measured at 298 K and 1 atm pressure.

Use this information to show that the molar mass of compound **V** is 149 g mol⁻¹. [2]



- (ii) The high resolution ^1H NMR spectrum of compound **V** is shown below.
The signal due to the —NH_2 protons is at δ 3.5 ppm.

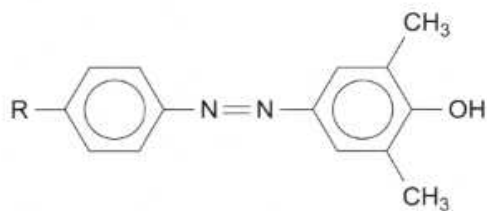


Use the molar mass from part (i) and this spectrum to deduce the structure of the alkyl group R. Give your reasoning. [3]

R has the structure



- (iii) At 5 °C compound **V** reacts with nitric(III) acid to give a diazonium compound which then reacts with compound **W** to give the azo dye below.



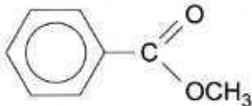
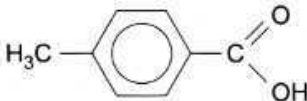

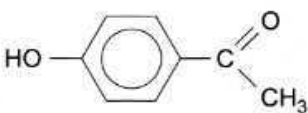
State the **name** of compound **W**.

[1]

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(c) Each of the four compounds whose formulae are shown below are isomers.

Compound	Formula
R	
S	
T	
U	

Select the compound that fits the descriptions below.

Give your reasoning in each case.

[3]

Produces carbon dioxide with sodium hydrogencarbonate.

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Gives an orange-red solid with 2,4-dinitrophenylhydrazine but does not react with Tollens' reagent.

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Produces methanol when heated with sodium hydroxide.

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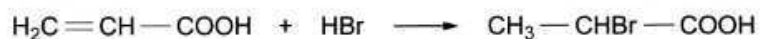
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8. (a) A student was asked how she would make 2-aminopropanoic acid (alanine) starting from propenoic acid.

She replied that she would firstly react propenoic acid with hydrogen bromide to give 2-bromopropanoic acid.



- (i) State the name of the reaction mechanism for this reaction. [1]

.....

- (ii) She predicted that the main product would be 2-bromopropanoic acid, rather than 3-bromopropanoic acid.

Explain, in terms of carbocations, why 2-bromopropanoic acid should be the main product. [1]

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- (iii) 2-Aminopropanoic acid can be obtained by reacting 2-bromopropanoic acid with ammonia in the mole ratio of 1:2 respectively.

Give the equation for this reaction. [1]

.....



- (b) (i) Give the structure of the species predominantly present in an aqueous solution of 2-aminopropanoic acid at pH 4.0. [1]

- (ii) 2-Aminopropanoic acid is an α -amino acid.

Write the **general** formula for α -amino acids. [1]

.....

- (iii) 2-Aminopropanoic acid forms a dipeptide with aminoethanoic acid, $\text{H}_2\text{C}(\text{NH}_2)\text{COOH}$.

Give the formula of a dipeptide formed from these two amino acids. [1]

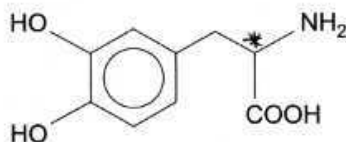
- (iv) 2-Aminopropanoic acid is one of the many amino acids that contribute to the structure of proteins.

State what is meant by the **secondary** structure of proteins. [1]

.....
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- (c) L-dopa is a compound that is used in the treatment of Parkinson's disease.



- (i) State the feature present in the molecule of L-dopa that enables it to rotate the plane of plane polarised light. [1]

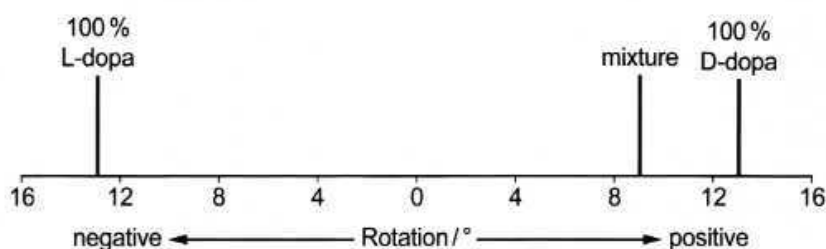
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- (ii) L-dopa rotates the plane of plane polarised light to the left (–) whereas D-dopa rotates it to the right (+).

At a certain concentration pure forms of the acid rotate the plane of plane polarised light by 13°.

A mixture of the L- and D- forms of dopa gave a rotation of +9°.

This information is shown in the diagram below.



Use the formula below to calculate the percentage of **each** enantiomer present in the mixture, where y is 13 and x is the rotation given by the mixture. [2]

$$\text{percentage of D-dopa} = \frac{100 (y + x)}{2y}$$

Percentage of D-dopa = %

Percentage of L-dopa = %



- (iii) Although L-dopa is used extensively in many countries in the treatment of Parkinson's disease, it remains too expensive to use in some developing countries.

Scientists have discovered that the beans of the *mucuna pruriens* plant contain useful quantities of L-dopa.

- I. State **one** advantage (apart from cost) of using mucuna beans as a source of L-dopa. [1]

.....

.....

- II. A sample of raw mucuna beans was ground and then analysed for L-dopa. This analysis showed that the beans contained 6% by mass of L-dopa.

Some patients suffering from Parkinson's disease need to take 250 mg of L-dopa **three** times each day.

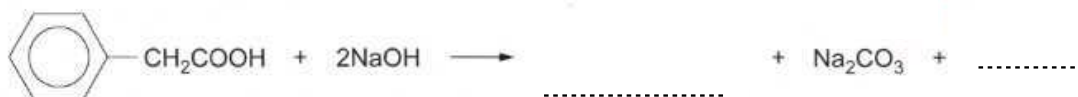
Use this information to calculate the mass of raw mucuna beans needed to produce the daily dose for one patient. [1]

Mass of beans = g

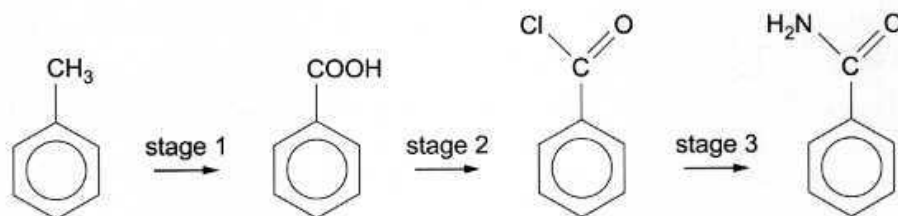
- (iv) In the body an enzyme converts L-dopa into dopamine by a decarboxylation reaction.



Use this information to help you complete the equation for the decarboxylation of phenylethanoic acid using sodium hydroxide. [1]



9. (a) Study the reaction sequence below and answer the questions that follow.



- (i) State reagent(s) that can be used for stage 1. [1]

.....

- (ii) State the type of reaction occurring in stage 1. [1]

.....

- (iii) One way of carrying out stage 2 is to react benzoic acid with phosphorus(V) chloride.

Explain why the yield of benzoyl chloride, $\text{C}_6\text{H}_5\text{COCl}$, will be lower if moisture enters the reaction vessel. [1]

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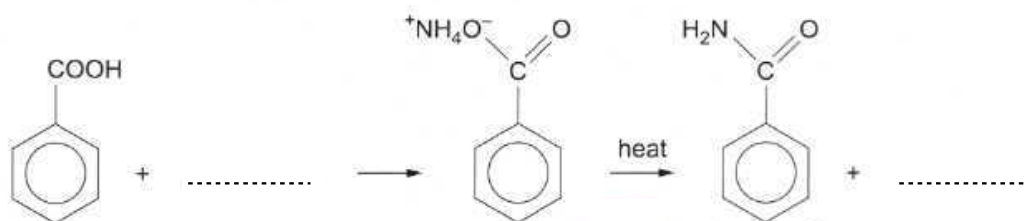
- (iv) In stage 3 benzamide is produced from benzoyl chloride by its reaction with ammonia.

Suggest the structure of the compound produced if benzoyl chloride reacts with methylamine, CH_3NH_2 , in place of ammonia. [1]



- (v) In the reaction sequence opposite, benzamide is made from benzoic acid via the acid chloride, benzoyl chloride. It can be made from benzoic acid by a different route as shown in the sequence below.

Complete this sequence by giving the formulae of the missing compounds. [1]



- (vi) Benzamide, $\text{C}_6\text{H}_5\text{CONH}_2$, undergoes the Hofmann degradation reaction.

This reaction produces an organic nitrogen-containing compound **Z**, that contains one carbon atom less per molecule than benzamide.

The mass spectrum of compound **Z** shows a molecular ion peak at m/z 93 and its infrared spectrum does **not** show a characteristic peak at 1661 cm^{-1} .

Use this information to suggest a structure for compound **Z**. Explain your answer. [3]

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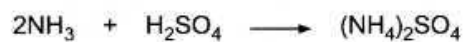
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(b) Another amide, $\text{R}-\text{C} \begin{smallmatrix} \text{O} \\ \parallel \\ \text{NH}_2 \end{smallmatrix}$, reacts with alkali to give ammonia as one of the products.

The ammonia produced can then be reacted with sulfuric acid.



In an experiment, 3.50 g of this amide reacted with sodium hydroxide. The ammonia produced required 16.0 cm³ of sulfuric acid of concentration 1.50 mol dm⁻³ for complete neutralisation.

Use this information to find the formula of the R group present in this amide.

[4]

R has the formula

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