Surname	Centre Number	Candidate Number
First name(s)		2

GCE A LEVEL

A410U20-1

S25-A410U20-1

MONDAY, 16 JUNE 2025 – MORNING

CHEMISTRY – A level component 2

Organic Chemistry and Analysis

2 hours 30 minutes

For Examiner's use only		
Question	Maximum Mark	Mark Awarded
1. to 6.	15	
7.	17	
8.	16	
9.	17	
10.	17	
11.	19	
12.	19	
Total	120	

Section A
Section B

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01

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 120.

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 **Q10**(d) and **Q12**(b).

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SECTION A

Answer **all** questions.

1. An aqueous solution of some α-amino acids is analysed by thin layer chromatography.

The R_f value for leucine is 0.73 when a particular solvent is used.

If the solvent front has moved 12.2 cm from the start line, calculate the distance from the start line where the leucine spot should be seen. [1]

Distance = ... cm

2. (a) State why benzene is normally resistant to addition reactions. [1]

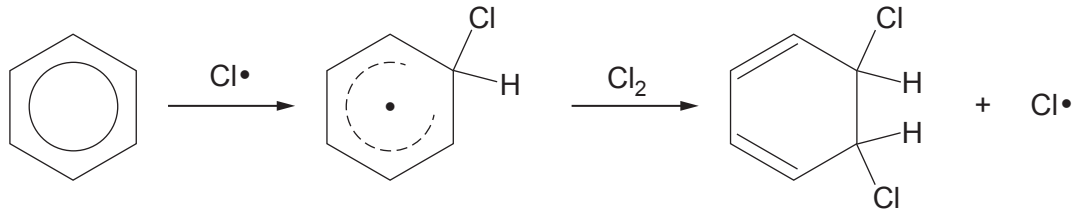
.....

.....

(b) Benzene and chlorine react together in the presence of ultraviolet light to produce chlorinated cyclohexadiene derivatives.

The first stage of this reaction is the production of chlorine radicals, Cl•.

These then react with benzene in a propagation stage.



Explain why these steps are called propagation stages. [1]

.....

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3. 0.0350 mol of the dipotassium salt of an aliphatic dicarboxylic acid has a mass of 5.81 g.

(a) Calculate the relative molecular mass of this compound. [1]

M_r = ...

(b) Use your answer to part (a) to suggest a structure for this compound. [1]

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4. The mass spectrum of a primary amine, R—NH_2, shows a strong signal at m/z 91 and a molecular ion at m/z 107.

It reacts with cold nitric(III) acid to give nitrogen gas, rather than a diazonium compound.

Use this information to suggest a structure for this amine and for the fragment at m/z 91.

Explain your answer. [3]

.....

.....

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5. The melting and boiling temperatures of three compounds are shown in the table.

Compound	Formula	Melting temperature / °C	Boiling temperature / °C
benzoic acid	C_6H_5COOH	122	249
methyl benzoate	$C_6H_5COOCH_3$	–12	198
ethyl benzoate	$C_6H_5COOCH_2CH_3$	–34	212

(a) In terms of intermolecular bonding, explain why benzoic acid has the highest melting and boiling temperatures of these compounds. [2]

.....

.....

.....

(b) In terms of intermolecular bonding, explain why ethyl benzoate has a higher boiling temperature than methyl benzoate. [1]

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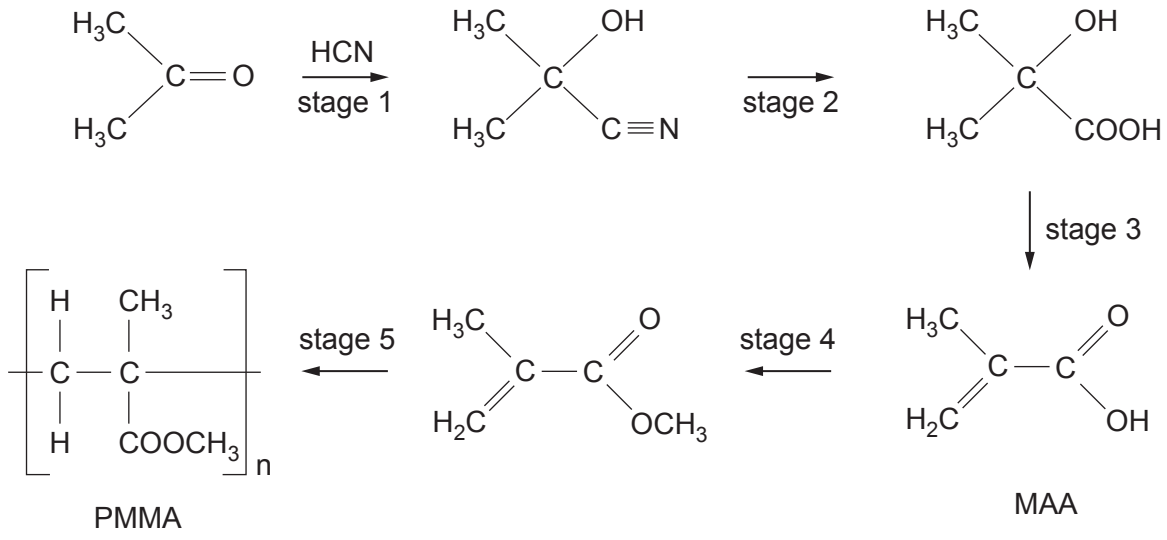
6. The flow chart shows an outline synthesis of poly(methylmethacrylate) (PMMA) starting from propanone.



(a) State the name of the reaction mechanism occurring in stage 1. [1]

.....

(b) Suggest the structure of an intermediate product in stage 2. [1]

(c) State why stage 5 is described as addition polymerisation and not condensation polymerisation. [1]

.....

.....

(d) Give the **skeletal** formula of methacrylic acid (MAA). [1]

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SECTION B

Answer **all** questions.

7. (a) Alcohols react with sodium, giving hydrogen as one of the products.

$$2\,Na + 2\,R{-}OH \longrightarrow 2\,RO^{-}Na^{+} + H_2$$

1.23 g of a tertiary alcohol, compound **W**, reacted with sodium and produced 171 cm^3 of hydrogen measured at 25 °C and 1 atm pressure.

(i) Calculate the relative molecular mass of compound **W**. [2]

M_r = ...

(ii) Deduce the molecular formula of compound **W**. [1]

Molecular formula .....

(iii) Compound **W** is a tertiary alcohol.

Deduce its structure. [1]

Examiner only

(iv) I. State a dehydrating agent that will react with compound **W** to give an alkene. [1]

.....

II. Give the systematic name and the structure of an alkene produced by the dehydration of compound **W**. [2]

Name .....

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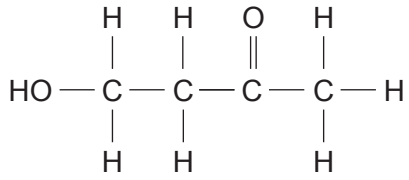
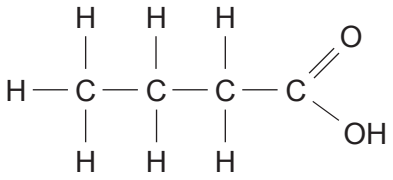
(b) (i) The compounds shown below are two of many with the molecular formula $C_4H_8O_2$.



4-hydroxybutan-2-one



butanoic acid

Give the results observed when these two compounds are treated in turn with the four reagents in the table. [4]

Reagent	4-hydroxybutan-2-one	butanoic acid
sodium hydrogencarbonate		
acidified potassium dichromate		
universal indicator solution		
aqueous alkaline iodine		

(ii) Suggest a structure for another compound of molecular formula $C_4H_8O_2$ that has no reaction with any of the reagents listed in part (i). [1]

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(c) (i) In industry, butanoic acid is obtained by oxidation of butan-1-ol. To separate the acid, a saturated solution of calcium chloride is added, giving calcium butanoate.

Complete the equation for this reaction. [1]

.....$CH_3CH_2CH_2COOH$ + ... ⟶ $(CH_3CH_2CH_2COO)_2Ca$ + ...

(ii) Unusually, calcium butanoate is less soluble in hot water than in cold water.

You are given a sample of cold water and impure solid calcium butanoate.

Suggest a method to give a purified sample of calcium butanoate. [2]

.....

.....

.....

.....

(iii) On strong heating, calcium butanoate undergoes decarboxylation to give calcium carbonate and a ketone.

Give the equation for this reaction and name the ketone produced. [2]

.....

Name of ketone .....

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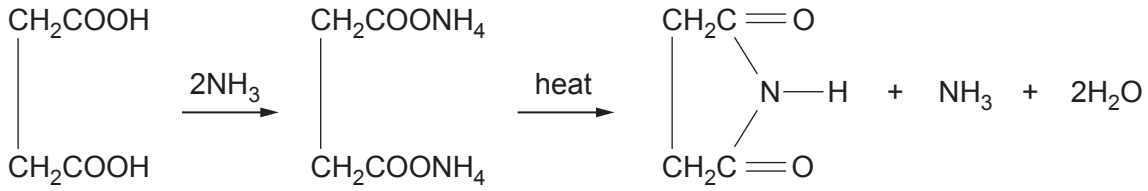
8. (a) One method of producing an amide is to neutralise a carboxylic acid with ammonia and heat the resulting salt of the acid.

In an experiment, a sample of butanedioic acid (succinic acid) was neutralised by ammonia and the product heated to produce the corresponding cyclic amide (succinimide).



succinic acid succinimide

The melting temperature of the crude cyclic amide is 116-122 °C. After recrystallisation, the pure amide melted at 125 °C.

(i) Suggest **one** impurity that could be present in the crude amide. [1]

.....

(ii) The low resolution ^{1}H NMR spectrum of the purified amide showed signals at 2.8 ppm and at 8.9 ppm.

Suggest the protons responsible for these two signals and their relative peak areas. [2]

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.....

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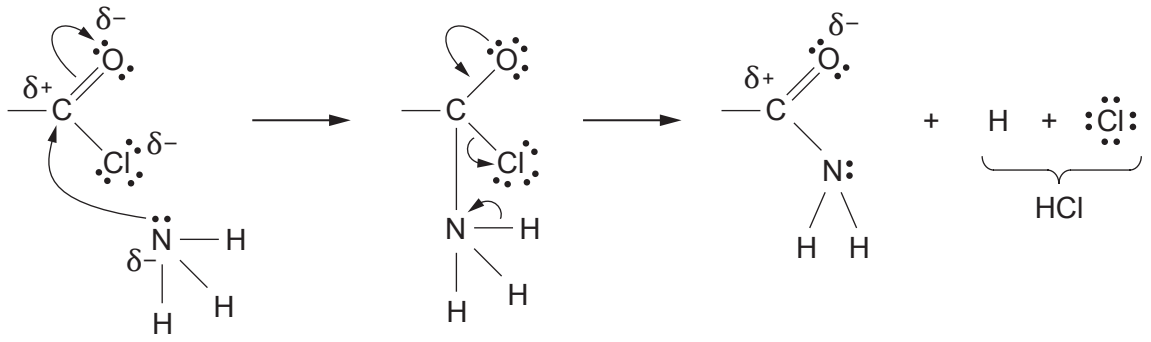
Examiner only

(b) Another method to produce an amide is to react the corresponding acid chloride with ammonia.

An outline mechanism for the reaction is shown below.



(i) **Complete the mechanism** by adding full charges as appropriate. [2]

(ii) Complete the missing words in the sentence below. [1]

This reaction is a ..... reaction, where the attacking reagent is acting as a ..... .

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(c) Compound **T** is an acid chloride of formula R—COCl, where R is a group containing carbon, hydrogen and chlorine.

(i) Addition of water to 11.76 g of compound **T** hydrolysed only the acid chloride group.

The resulting mixture was treated with aqueous silver nitrate, giving 8.61 g of silver chloride, AgCl.

Use this information to calculate the relative molecular mass of compound **T** and hence the relative mass of the R group. [3]

Relative mass of R = ...

Examiner only

(ii) The high resolution ^{1}H NMR spectrum of compound **T** shows only a singlet and the ^{13}C NMR spectrum shows three signals.

Use this information and your answer to part (i) to suggest a structure for compound **T**. Give your reasoning. [3]

.....

.....

.....

.....

Structure

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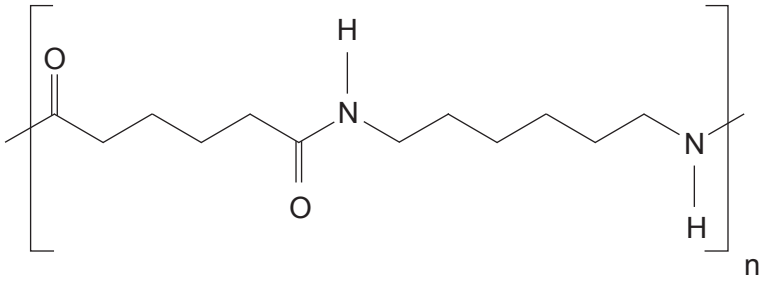
(d) The formula below shows the repeating structure of the polyamide PA66 (nylon 66).

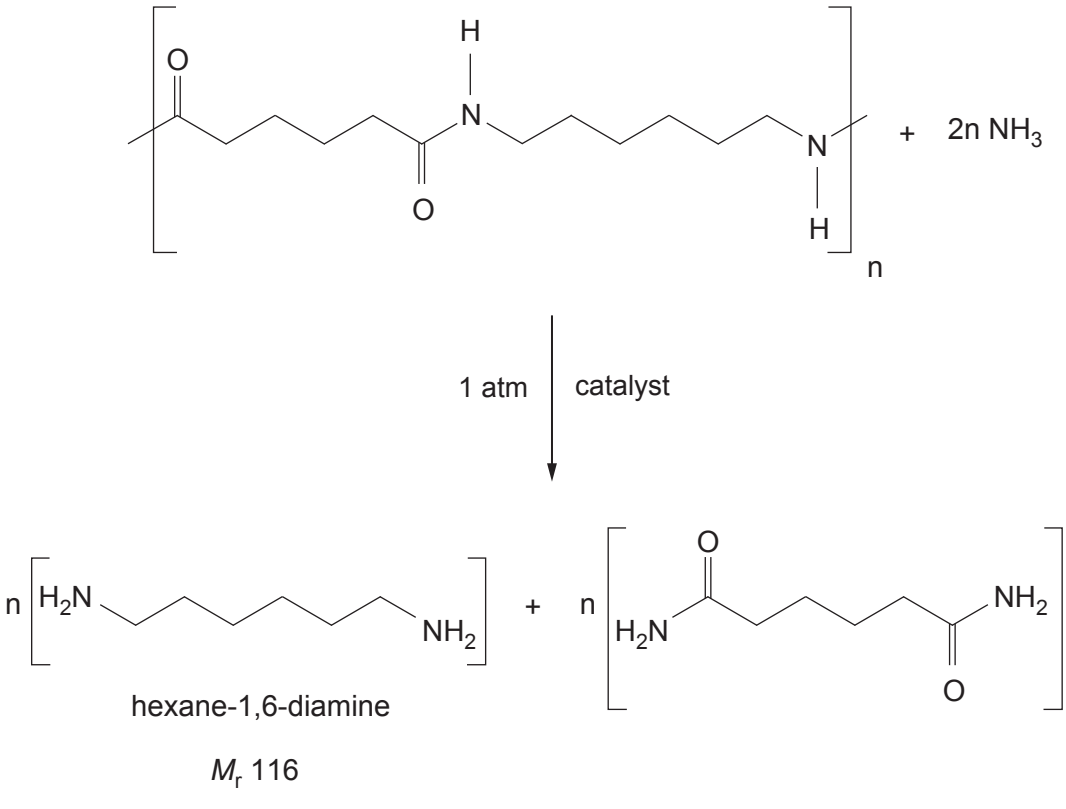


(i) State the **name** of the dicarboxylic acid that is reacted with the diamine to give this polyamide. [1]

.....

(ii) PA66 is a very stable polyamide and is resistant to many of the usual methods used to recycle polymers.

A new method has recently been used to recycle PA66. It is carried out at atmospheric pressure in the presence of a suitable catalyst. The method uses propane-1,2,3-triol as the solvent (obtained as a waste product from another process) and a temperature of 200 °C, as compared to 300 °C in other methods.



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I. Suggest **two** reasons why this method can be described as a **green** method. [2]

.....

.....

II. The yield from this process is 68%.

Calculate the mass of the diamine (M_r 116) produced from 0.5 mol of PA66. [1]

Mass = ... g

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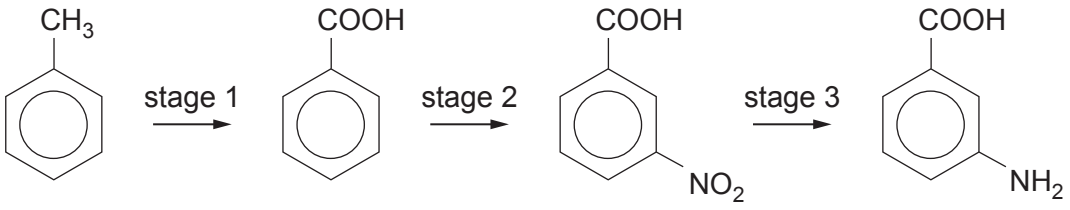
9. (a) 3-Aminobenzoic acid can be produced in several stages from methylbenzene.



(i) In stage 1, methylbenzene is heated with aqueous alkaline potassium manganate(VII) and then acidified.

State why it is necessary to acidify the mixture to obtain benzoic acid. [1]

.....

.....

(ii) 3-Nitrobenzoic acid is produced during stage 2. The reaction is described as an electrophilic substitution.

I. Give the nitrating agent used in stage 2. [1]

.....

II. Give the formula of the electrophile formed in stage 2. [1]

.....

(iii) 3-Nitrobenzoic acid obtained in stage 2 is contaminated with some 2-nitrobenzoic acid.

State how the presence of this impurity would affect the melting temperature of 3-nitrobenzoic acid. [1]

.....

.....

(iv) 3-Nitrobenzoic acid is reduced to 3-aminobenzoic acid in stage 3.

State the reducing agent for this reaction. [1]

.....

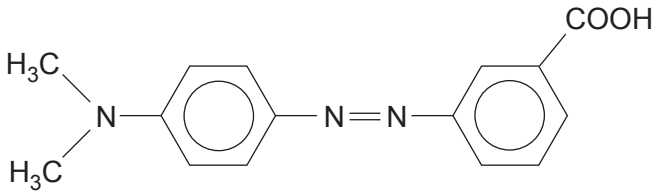
Examiner only

(b) A diazonium compound can be produced from 3-aminobenzoic acid by reaction with nitric(III) acid.

(i) State the temperature used for this reaction. [1]

..... °C

(ii) The diazonium compound reacts with an aromatic amine to produce the azo dye whose formula is shown below.



I. Azo dyes contain a chromophore, which is partly responsible for their colour.

(Circle) the chromophore present in the azo dye shown above. [1]

II. Draw the structure of the aromatic amine used to produce this azo dye.

[1]

Examiner only

(iii) This azo dye is red in colour and has a maximum absorption in the visible spectrum at 420 nm.

I. State why the dye is red in colour. [1]

.....

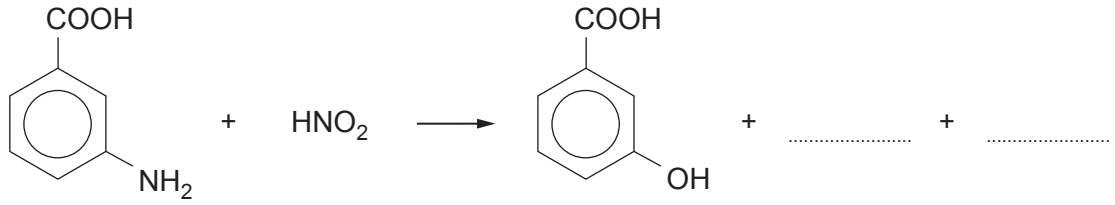
.....

II. Calculate the energy, in $kJ\,mol^{-1}$, associated with this absorption at 420 nm. [2]

Energy = ... $kJ\,mol^{-1}$

(iv) The diazonium compound produced from 3-aminobenzoic acid by reaction with nitric(III) acid is not stable at higher temperatures. It breaks down to form 3-hydroxybenzoic acid.

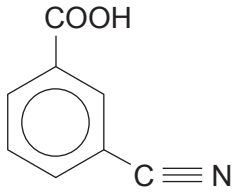
Complete the equation for this reaction. [1]



Examiner only

(v) Diazonium compounds have many reactions other than producing azo dyes.

3-Cyanobenzoic acid can be produced from a diazonium intermediate.



This can then be hydrolysed to produce benzene-1,3-dioic acid.

I. State a reagent that can be used for this hydrolysis. [1]

.....

II. The progress of this reaction can be monitored using infrared spectroscopy.

Suggest how you would confirm that this hydrolysis is complete. Use information from the **Data Booklet**. [1]

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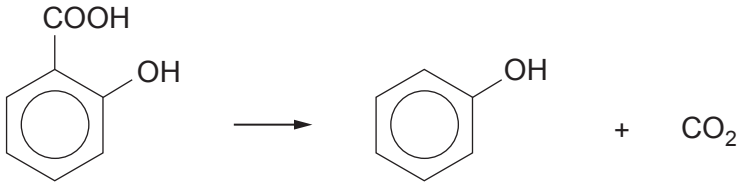
Examiner only

(c) 2-Hydroxybenzoic acid decomposes when heated to 200 °C.



If phenol is removed from the reaction mixture as it is formed, then the yield can be above 50%.

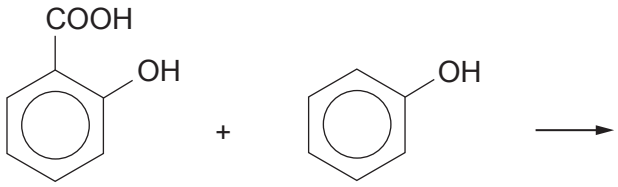
(i) In a reaction, 6.90 g of 2-hydroxybenzoic acid was heated.

Calculate the mass of phenol produced if the yield is 60%. [2]

Mass = ... g

(ii) The yield of phenol in this reaction is relatively low because some of the phenol produced reacts with unreacted 2-hydroxybenzoic acid to give phenyl 2-hydroxybenzoate.

Complete the equation for this esterification reaction. [1]



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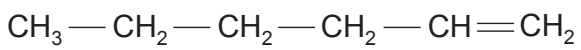
10. (a) Hex-1-ene reacts with hydrogen bromide to form 2-bromohexane (boiling temperature 143 °C) and small amounts of 1-bromohexane (boiling temperature 155 °C).



hex-1-ene

(i) State the name of the mechanism occurring during this reaction. [1]

.....

(ii) Explain why 2-bromohexane is the major product of this reaction. [1]

.....

.....

(iii) Suggest a method that can be used to separate these two isomers. [1]

.....

(iv) A gas-liquid chromatogram of the products shows the presence of 1-bromohexane and 2-bromohexane (M_r 165) and some unreacted hex-1-ene.

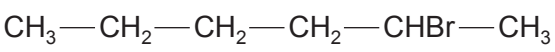
Analysis of the mixture shows that 6.11 g of the mixture contains 2.85 g of bromine.

Calculate the percentage of unreacted hex-1-ene present. [2]

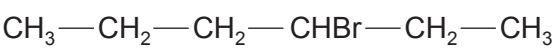
Percentage = ... %

Examiner only

(b) The reaction of hex-2-ene with hydrogen bromide gives a mixture of 2-bromohexane and 3-bromohexane in roughly equal proportions.



2-bromohexane



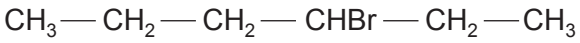
3-bromohexane

(i) Suggest why this reaction produces two products in roughly equal proportions unlike the reaction in part (a). [1]

.....

.....

(ii) I. Indicate the position of the chiral centre in 3-bromohexane by using an asterisk (*) on the structure below. [1]



II. Suggest why a sample of 3-bromohexane prepared in this way appears optically inactive when placed in a polarimeter. [1]

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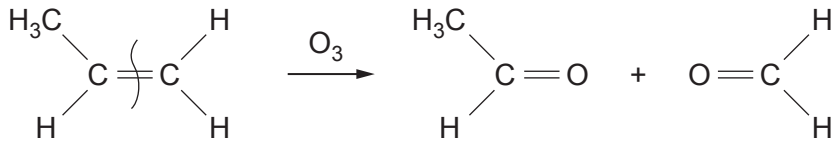
Examiner only

(c) (i) Ozone can be used in analysis to find the position of a carbon-carbon double bond in a compound.

In the reaction, the double bond is broken, giving aldehydes and/or ketones.

For example, from propene



An alkene of formula C_5H_{10} reacts with ozone to produce ethanal and propanone.

Deduce the structure of the alkene. Show your reasoning. [2]

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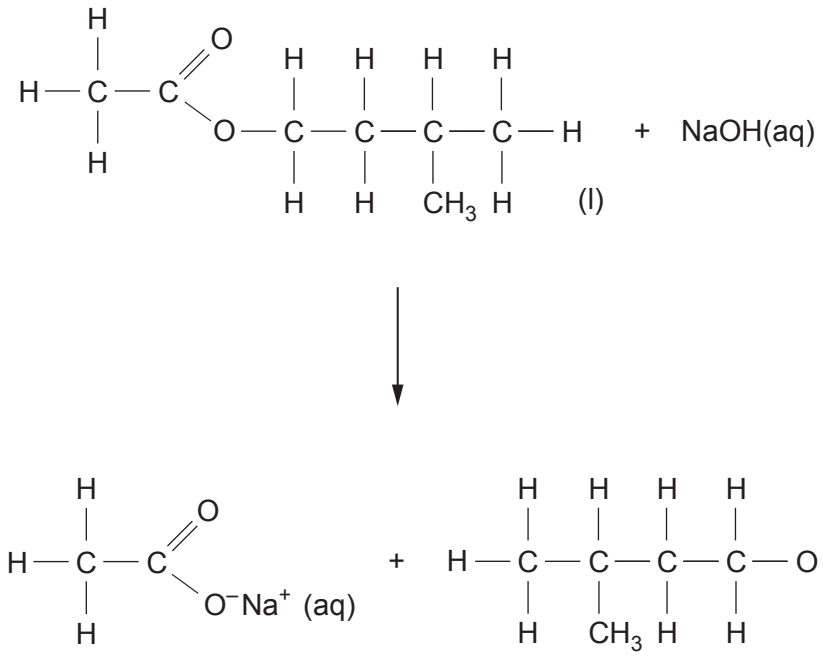
.....

.....

(ii) Give the structure of an alkene of formula C_5H_{10} that shows *E*-*Z* isomerism. [1]

(d) 3-Methylbutyl ethanoate is used as a banana flavouring in the food industry.

When it is refluxed with aqueous sodium hydroxide it produces sodium ethanoate and 3-methylbutan-1-ol.



Sodium ethanoate is soluble in the reaction mixture whereas 3-methylbutan-1-ol is only slightly soluble.

3-Methylbutan-1-ol can be extracted from the reaction mixture by solvent extraction with ethoxyethane, using a separating funnel. Evaporation of the ethoxyethane will leave 3-methylbutan-1-ol, which can then be further purified.

Examiner only

Outline the method that you would use to obtain pure 3-methylbutan-1-ol.

Use the following information in planning your answer.

- 3-Methylbutan-1-ol is much more soluble in ethoxyethane than in water
- Ethoxyethane is less dense than the aqueous mixture
- Ethoxyethane is immiscible with the aqueous reaction products
- Solid anhydrous magnesium sulfate is used to dry the ethoxyethane layer
- Ethoxyethane is very flammable
- The boiling temperature of ethoxyethane is 35 °C [6 QER]

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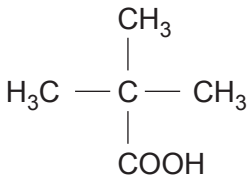
Examiner only

11. (a) The formula of pivalic acid is shown below.



(i) Give the systematic name of this acid. [1]

.....

(ii) Pivalic acid reacts with methanol to give the ester methyl pivalate, $(CH_3)_3CC(O)OCH_3$.

I. State a catalyst used for this reaction. [1]

.....

II. Describe the high resolution ^1H NMR spectrum of methyl pivalate.

Include approximate chemical shifts and details of any peak splitting. Explain your reasoning. [3]

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Examiner only

(iii) The acid reacts with phosphorus(V) chloride to give the corresponding acid chloride, pivaloyl chloride.

$(CH_3)_3C—COOH(l) + PCl_5(s) \longrightarrow (CH_3)_3C—COCl(l) + POCl_3(l) + HCl(g)$

boiling temp 106°C — boiling temp 106°C

Suggest **two** problems with this method to produce pivaloyl chloride. [2]

1. .....

.....

2. .....

.....

(iv) One method to produce pivalamide, $(CH_3)_3C—CONH_2$, is to slowly add pivaloyl chloride to a dilute aqueous solution of ammonia.

Suggest why this method may give a poor yield of pivalamide. [1]

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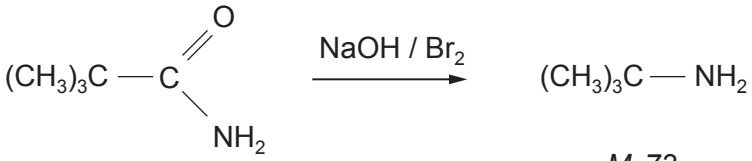
(v) Amides, such as pivalamide, react with an alkaline solution of bromine producing an amine.



M_r 73

In a reaction, 0.10 mol of pivalamide gave an 82% yield of $(CH_3)_3C—NH_2$.

Calculate the mass of the amine obtained. Give your answer to an **appropriate** number of significant figures. [2]

Mass = ... g

Examiner only

(b) Explain why an aqueous solution of the amine produced in part (a)(v) has a pH greater than 7. Give an equation as part of your answer. [2]

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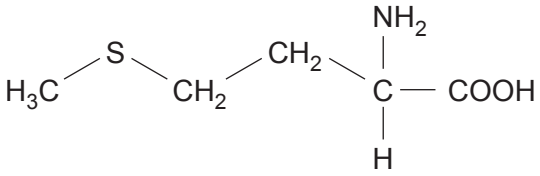
.....

(c) The structure of the α-amino acid methionine is shown below.

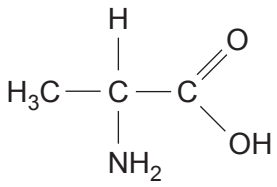


(i) Give the structure of the species formed from methionine in a strongly alkaline solution. [1]

(ii) Give the structure of one of the dipeptides formed between methionine and glycine (aminoethanoic acid). [1]

Examiner only

(d) The structure of the α-amino acid alanine is shown below.



Explain why this compound has a very high melting temperature. [2]

.....

.....

(e) Propanoic acid reacts with chlorine giving 2-chloropropanoic acid.

$$CH_3CH_2COOH + Cl_2 \longrightarrow CH_3CHClCOOH + HCl$$

The yield of 2-chloropropanoic acid is around 85% as other chlorinated propanoic acids are also produced.

(i) Suggest the structure of a monochlorinated propanoic acid that does **not** contain a chiral centre. [1]

(ii) Another product of this reaction is a chlorine-containing propanoic acid that contains 49.7% chlorine by mass.

Show that this compound could be 2,2-dichloropropanoic acid.

Give its structure as part of your answer. [2]

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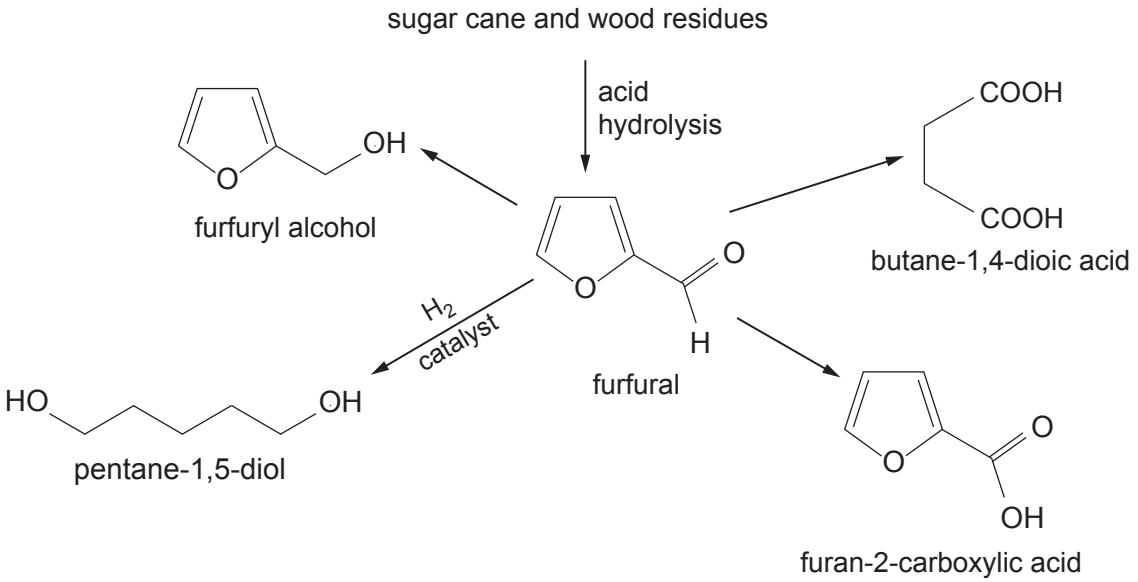
Examiner only

12. (a) The preparation and some of the reactions of the aldehyde furfural are shown below.



(i) Wood residues contain pentose sugars, mainly xylose and arabinose. Both of these sugars are reducing agents and give a positive test with Fehling's reagent.

State what is seen during this test. Give the appearance of the reagent before and after the test. [1]

.....

.....

(ii) Furfural behaves like benzaldehyde in many of its reactions.

I. Suggest a reagent that will produce furan-2-carboxylic acid when reacted with furfural. Give any observations. [1]

.....

.....

II. State a reagent that can be used to produce furfuryl alcohol from furfural. [1]

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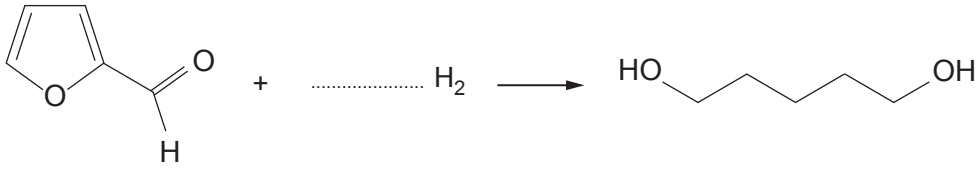
Examiner only

(iii) I. Furfural can be hydrogenated in a number of stages to give pentane-1,5-diol.

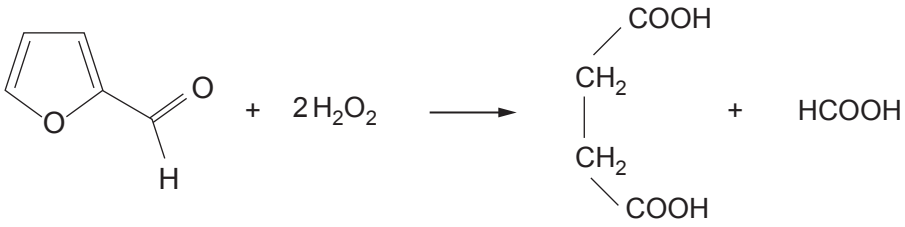


Balance the equation by inserting the number of moles of hydrogen required. [1]

II. Pentane-1,5-diol reacts with butane-1,4-dioic acid to produce a polyester.

Give the structure of the repeating unit of the polyester. [1]

(iv) Butane-1,4-dioic acid is produced by the reaction of aqueous furfural and hydrogen peroxide.



Calculate the atom economy of this reaction to produce butane-1,4-dioic acid. [1]

Atom economy = ... %

Examiner only

(b) You are given a sample of sodium benzoate that is contaminated with sodium hydroxide.

Devise a method to produce pure benzoic acid from this sample. Describe how you would find the percentage of sodium benzoate in the original sample.

Use the following information in planning your answer.

- Sodium benzoate is soluble in cold water
- Sodium benzoate reacts with hydrochloric acid to produce benzoic acid

$$C_6H_5COO^-Na^+(aq) + HCl(aq) \longrightarrow C_6H_5COOH(s) + NaCl(aq)$$

- Benzoic acid is insoluble in cold water
- The conversion of sodium benzoate to benzoic acid is 100% [6 QER]

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(c) When aqueous bromine is added dropwise to an aqueous solution of phenol, the red-brown colour of the bromine disappears and a white precipitate appears.

Name the white precipitate formed and give an equation for the reaction. [2]

Name .....

(d) The concentration of phenols in dilute aqueous solutions can be found using colorimetry.

Analysis of a sewage sample showed that the concentration of 4-nitrophenol present was 235 μg dm^{-3}.

Calculate the concentration of 4-nitrophenol in this sample in mol dm^{-3}. [2]

Concentration = ... mol dm^{-3}

Examiner only

(e) (i) Suggest why phenylethanoic acid ($C_6H_5CH_2COOH$) has a relatively low solubility in water. [1]

.....

.....

.....

(ii) A saturated aqueous solution of phenylethanoic acid ($C_6H_5CH_2COOH$) was titrated against sodium hydroxide solution.

$25.0\,cm^3$ of the phenylethanoic acid solution was just neutralised by $24.50\,cm^3$ of $0.100\ mol\,dm^{-3}$ sodium hydroxide solution.

Show that the solubility of phenylethanoic acid in water at this temperature is $13.3\,g\,dm^{-3}$. [2]

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END OF PAPER

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