Surname	StemUp Model Solution	Centre Number	Candidate Number
First name(s)			2

GCE A LEVEL

A410U20-1

O20-A410U20-1

TUESDAY, 13 OCTOBER 2020 – MORNING

CHEMISTRY – A level component 2
Organic Chemistry and Analysis

2 hours 30 minutes

	For Examiner's use only		
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1. to 5.**	**15**	
Section B	**6.**	**13**	
	7.	**18**	
	8.	**19**	
	9.	**22**	
	10.	**19**	
	11.	**14**	
	Total	**120**	

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ADDITIONAL MATERIALS

In addition to this examination paper, you will need a:
- calculator;
- **Data Booklet** supplied by WJEC.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen.

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

Section A Answer **all** questions in the spaces provided.
Section B Answer **all** questions in the spaces provided.

Candidates are advised to allocate their time appropriately between **Section A (15 marks)** and **Section B (105 marks)**.

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 **Q.8***(a)* and **Q.11***(b)*.

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.

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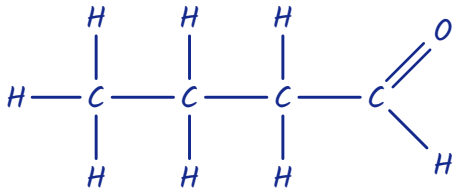
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SECTION A

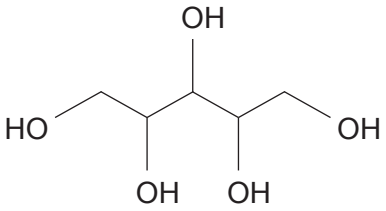
Answer **all** *questions in the spaces provided.*

1. Give the structure of a compound containing four carbon atoms that will give a red precipitate with Fehling's reagent. [1]



butanal, $CH_3CH_2CH_2CHO$

2. A stick of chewing gum for diabetics contains xylitol.



(a) Give the molecular formula of xylitol. [1]

$C_5H_{12}O_5$

(b) State the number of signals in the ^{13}C NMR spectrum of xylitol. Give your reasoning. [2]

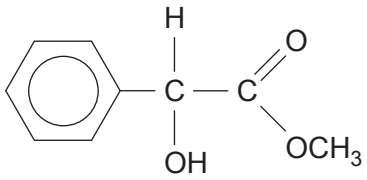
Three signals.

The two outer CH_2OH carbons are equivalent, the two carbons next to them are equivalent and the central carbon is different from all the others.

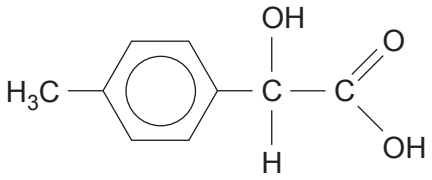
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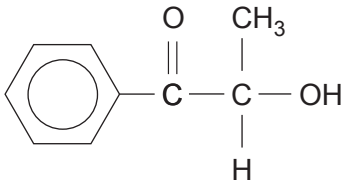
3. The formulae of three compounds are shown below.



compound **A**



compound **B**



compound **C**

(a) State which **one** of the compounds can be reduced by sodium tetrahydridoborate(III). [1]

C

(b) Complete each box in the table by giving an observation. If there is no observation, write 'no reaction'. [3]

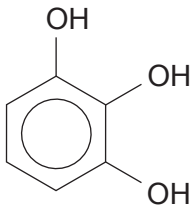
Compound	Reagent added		
	Aqueous sodium hydrogencarbonate	Acidified potassium dichromate	Aqueous 2,4-dinitrophenylhydrazine
A	no reaction	orange to green	no reaction
B	effervescence	orange to green	no reaction
C	no reaction	orange to green	orange / red ppt

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4. Benzene-1,2,3-triol can be used to find the percentage of oxygen in a gas mixture.



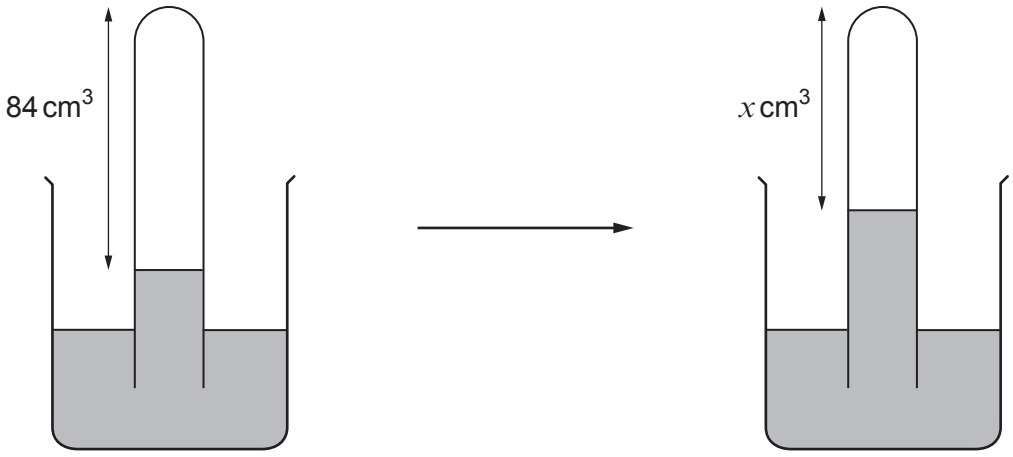
(a) Give the empirical formula of benzene-1,2,3-triol. [1]

C_2H_2O

(b) Oxygen reacts with an alkaline solution of benzene-1,2,3-triol.

A gas mixture contains 26 % of oxygen by volume, with the remaining gas being largely nitrogen with a smaller amount of helium.

When 84 cm^3 of this mixture reacts with alkaline benzene-1,2,3-triol, its volume is reduced to x cm^3 as shown in the diagram.



(i) Use the information given to calculate the value x in cm^3. [1]

O_2 removed = 26 % of 84 = 0.26 × 84 = 21.8 cm^3

x = 84 − 21.8 = 62 cm^3

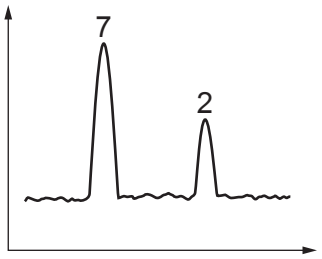
x = 62 cm^3

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(ii) After removal of oxygen the remaining gas was passed through a gas chromatograph and gave the following result, where the figures are relative peak areas.



Use your answer to part (i) and the chromatogram to calculate the volumes of helium and nitrogen in the original gas mixture. [2]

Remaining gas ratio N_2 : He = 7 : 2 by volume

nitrogen = 7/9 × 62 = 48 cm^3

helium = 2/9 × 62 = 14 cm^3

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Volume of nitrogen = ... 48 ..... cm^3

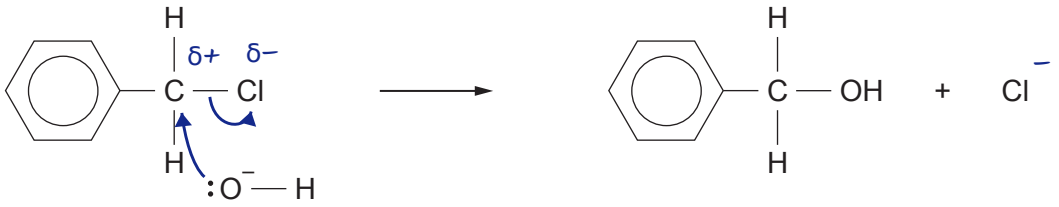
Volume of helium = ... 14 ..... cm^3

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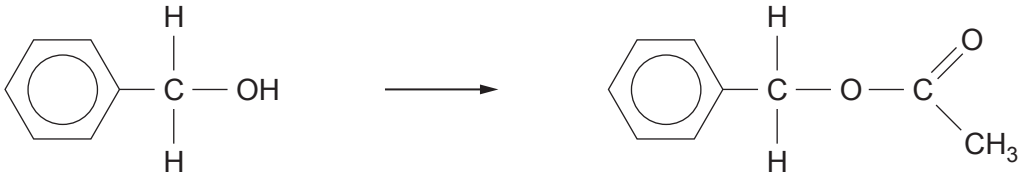
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5. *(a)* Complete the mechanism for the reaction below by adding suitable curly arrows and partial/full charges. You do **not** need to show lone pairs of electrons. [2]



(b) State a reagent for the following reaction. [1]



ethanoyl chloride, CH_3COCl

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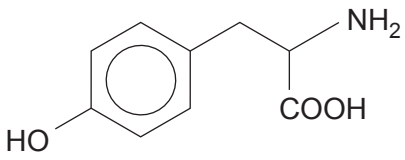
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SECTION B

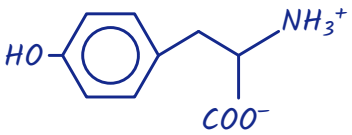
Answer **all** *questions in the spaces provided.*

6. *(a)* Tyrosine is an α-amino acid that occurs in many foods.



(i) In an aqueous solution tyrosine exists largely as the zwitterion.

Give the structure of this zwitterion. [1]

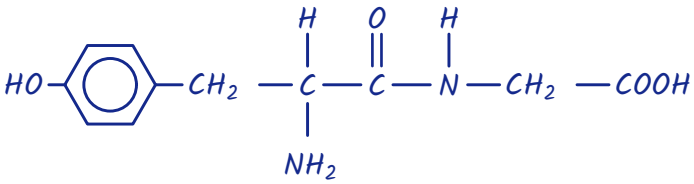


(ii) The melting temperature of tyrosine is 314 °C.

Explain how the structure of tyrosine contributes to this high melting temperature. [2]

Tyrosine exists as a zwitterion, so there is ionic bonding between the NH_3^+ and COO^- groups of neighbouring molecules. These strong forces between ions need a lot of energy to separate the ions, so the melting temperature is high.

(iii) Give the structure of **one** of the dipeptides formed between tyrosine and aminoethanoic acid. [1]



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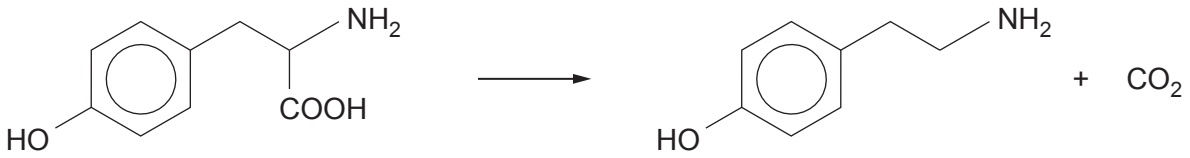
(iv) A few drops of aqueous iron(III) chloride are added to an aqueous solution of tyrosine.

State any observation made. [1]

purple colour

(v) In the body, tyrosine is converted by enzymes into tyramine.

One equation for this reaction is as follows.



tyrosine tyramine

M_r 181

Calculate the atom economy of this reaction to make tyramine, giving your answer to an **appropriate** number of significant figures. [2]

M_r of tyramine = 181 − 44 = 137

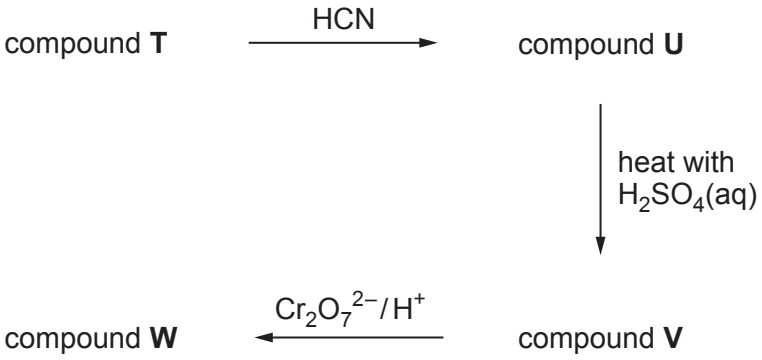
atom economy = (137 ÷ 181) × 100 = 75.69 %

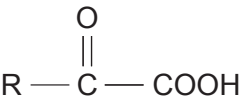
Atom economy = 75.7 %

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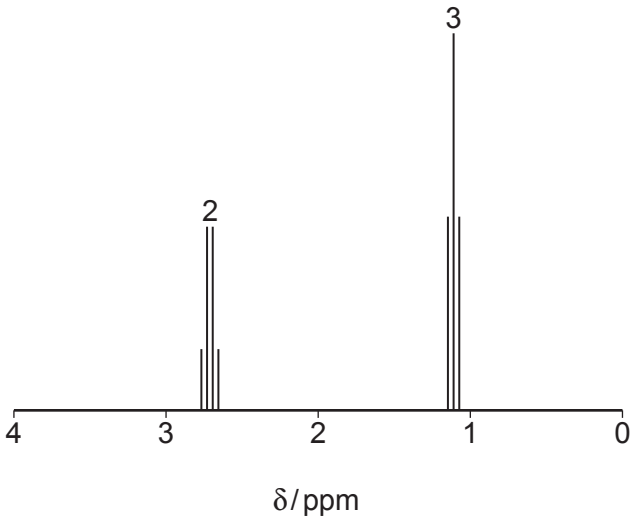
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(b) The diagram below shows a scheme for the synthesis of compound **W**.



Compound **W** is a carboxylic acid of general formula 

Its ^{1}H NMR spectrum is shown below with the peak for the O—H group omitted.



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(i) Use the NMR spectrum to deduce the formula of the R group in compound **W**. Give your reasoning.

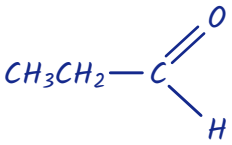
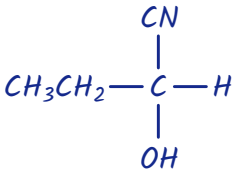
The numbers 2 and 3 represent relative peak areas. [3]

Triplet at δ 1.1 ppm (area 3): a CH_3 group next to a carbon with 2 protons.

Quartet at δ 2.8 ppm (area 2): a CH_2 group adjacent to a CH_3 group.

Peak area ratio 2 : 3, so this is an ethyl group: R is CH_3CH_2.

(ii) Use your answer to part (i) to deduce the structures of compounds **T**, **U** and **V**. [3]

Compound	Structure
T	
U	
V	$CH_3CH_2CH(OH)COOH$

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7. Liquefied petroleum gas (LPG) consists largely of propane (M_r 44) and butane (M_r 58).

(a) A sample of LPG has a mass of 10.48 g. It contains 3.52 g of propane with the rest being butane. The sample was completely burned, giving only carbon dioxide and water.

Calculate the total volume of carbon dioxide produced, measured at 298 K and 1 atm pressure. [5]

mass of butane = 10.48 − 3.52 = 6.96 g

n(propane) = 3.52 ÷ 44 = 0.0800 mol

n(butane) = 6.96 ÷ 58 = 0.120 mol

$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$: 1 mol propane gives 3 mol CO_2

CO_2 from propane = 3 × 0.0800 = 0.240 mol, volume = 0.240 × 24.5 = 5.88 dm^3

$2C_4H_{10} + 13O_2 \rightarrow 8CO_2 + 10H_2O$: 1 mol butane gives 4 mol CO_2

CO_2 from butane = 4 × 0.120 = 0.480 mol, volume = 0.480 × 24.5 = 11.76 dm^3

total volume of CO_2 = 5.88 + 11.76 = 17.64 dm^3

Volume = 17.6 dm^3

(b) In practice LPG contains small quantities of other materials including ethanethiol, C_2H_5SH (M_r 62). This is added to LPG so that any escape is detectable by its smell.

A 600 g sample of LPG contains 17 mg of ethanethiol.

Calculate the percentage by mass of sulfur in the LPG, assuming that all the sulfur comes from the ethanethiol. [3]

62 mg of ethanethiol contains 32 mg of sulfur

sulfur in 17 mg = (32 × 17) ÷ 62 = 8.8 mg

% S = (8.8 ÷ (600 × 1000)) × 100 = 1.5×10^{-3} %

Percentage = 1.5×10^{-3} %

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(c) The C_4 component of LPG contains both methylpropane (boiling temperature –12 °C) and butane (boiling temperature –0.5 °C).

Explain why these two compounds have different boiling temperatures even though they have the same molecular formula. [2]

Methylpropane is branched, so its molecules pack less closely and have less surface area in contact than straight-chain butane molecules. So the van der Waals forces between methylpropane molecules are weaker, less energy is needed to separate them, and the boiling temperature is lower.

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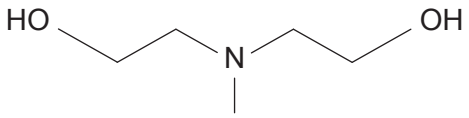
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(d) The combustion of LPG and other hydrocarbons causes the emission of carbon dioxide, which is a cause of global warming.

One method of removing carbon dioxide from power station emissions is by its absorption into a solution containing certain amines.

An amine that can be used for this method is N-methyldiethanolamine.



Some properties of **this** amine are shown below. Suggest a reason why each of the properties given are advantageous in this use. [4]

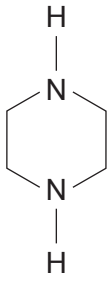
Property	Advantage
Reacts with both carbon dioxide and hydrogen sulfide	*removes both acidic gases in one process; other amines may not remove both, and poisonous H_2S is removed too*
It has a high boiling temperature	*it is not volatile, so very little amine is lost by evaporation: loss of the amine is minimised*
It is immiscible with hydrocarbons	*it does not mix with the hydrocarbons, so the amine solution is easily separated from them*
Its reaction with both carbon dioxide and hydrogen sulfide is exothermic	*the heat produced can be used elsewhere, giving lower operating costs and less equipment degradation*

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(e) Piperazine is sometimes used with N-methyldiethanolamine in the removal of carbon dioxide from power station flue gases.

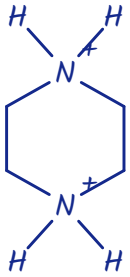


piperazine

(i) Explain why piperazine acts as a base. [1]

Each nitrogen atom has a lone pair of electrons, so it can accept a proton (H^+): it is a proton acceptor.

(ii) Give the structure of the compound formed when 1 mol of piperazine reacts with 2 mol of hydrochloric acid. [1]



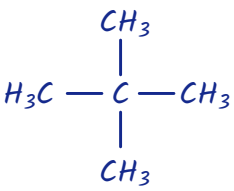
$2Cl^-$

(f) Alkanes react with chlorine in a radical reaction.

For example

$$C_5H_{12} + Cl_2 \longrightarrow C_5H_{11}Cl + HCl$$

Deduce the structure of an isomer of formula C_5H_{12} which will give only one possible monochloride, $C_5H_{11}Cl$, on reaction with chlorine. Explain your reasoning. [2]



2,2-dimethylpropane

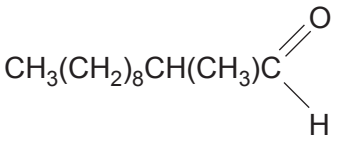
All 12 hydrogen atoms are equivalent (four identical CH_3 groups), so only one monochloride can form.

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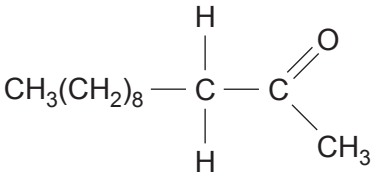
8. *(a)* A perfume contains 2-methylundecanal, $C_{12}H_{24}O$.



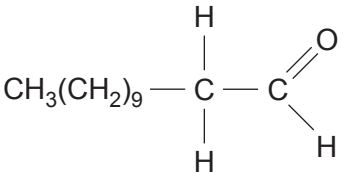
Compounds **D** to **G** all contain some features similar to 2-methylundecanal.

For **each** compound suggest how you could distinguish the structure from 2-methylundecanal.

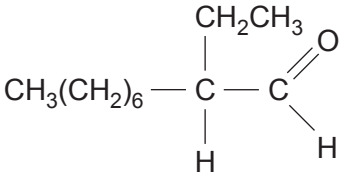
You may use physical and chemical tests but **not** spectroscopic methods in your answer.
[6 QER]



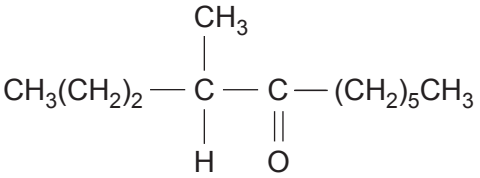
compound **D**



compound **E**



compound **F**



compound **G**

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2-methylundecanal is an aldehyde: it gives a silver mirror when warmed with Tollens' reagent (red solid with Fehling's, and turns acidified dichromate from orange to green). Compounds D and G are ketones and do not react in this way.

Compound D is a methyl ketone (CH_3CO group), so it gives a yellow precipitate (CHI_3) with alkaline iodine, whereas 2-methylundecanal does not react in this way.

Compound E has no chiral centre, so it will not rotate the plane of plane polarised light, whereas 2-methylundecanal has a chiral centre (C2) and rotates the plane of plane polarised light (polarimeter).

Compound F contains only 11 carbon atoms ($C_{11}H_{22}O$), so it cannot be 2-methylundecanal; it has a lower M_r and so a lower boiling temperature.

Compound G has a chiral centre, like 2-methylundecanal, but as a ketone it gives no silver mirror with Tollens' reagent (no red solid with Fehling's, dichromate stays orange).

All the compounds give an orange-red precipitate with 2,4-DNP, but each derivative would have a different melting temperature when purified and measured.

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(b) Lycopene, $C_{40}H_{56}$, is the compound responsible for the red colour in tomatoes. This unsaturated hydrocarbon contains 13 carbon to carbon double bonds in each molecule.

(i) 4.78 dm^3 of hydrogen measured at 298 K and 1 atm pressure was needed to fully hydrogenate a certain mass of lycopene.

Calculate the mass of lycopene used. [4]

$n(H_2) = 4.78 \div 24.5 = 0.195$ mol

each mol of lycopene needs 13 mol of H_2

$n(\text{lycopene}) = 0.195 \div 13 = 0.0150$ mol

$M_r(C_{40}H_{56}) = (40 \times 12.0) + (56 \times 1.01) = 536.6$

mass $= 0.0150 \times 536.6 = 8.05$ g

Mass = 8.05 g

(ii) Lycopene is a bright red solid when seen in white light.

State which colour(s) present in white light are absorbed to result in this red colour. [1]

All colours other than red are absorbed (mainly blue-green).

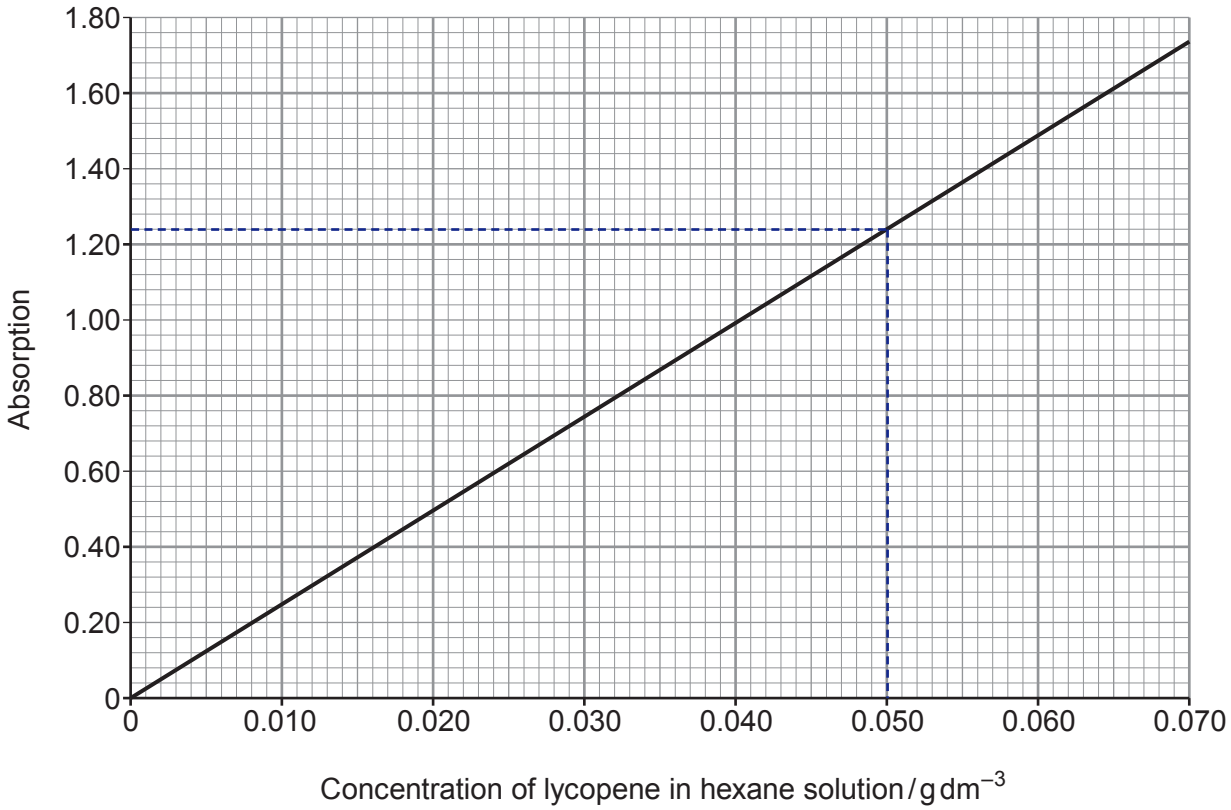
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(iii) The amount of lycopene present in tomatoes can be found by colorimetry.

The absorption values of a number of standard solutions are measured and their values used to produce a calibration graph.



A tomato of mass 20.0 g was treated and the lycopene extracted into 10 cm^3 of hexane. This solution gave an absorption reading of 1.24.

Use the graph to find the concentration of lycopene present and hence the percentage of lycopene in the tomato. [3]

from the graph, absorption 1.24 → 0.050 g dm^{-3}

mass in 10 cm^3 = 0.050 × 10 ÷ 1000 = 5.0 × 10^{-4} g

% = (5.0 × 10^{-4} ÷ 20.0) × 100 = 0.0025 %

Percentage = *0.0025* %

(iv) A solution of lycopene in hexane was used for the colorimetry in part (iii) as lycopene is insoluble in water.

Explain why lycopene is insoluble in water. [1]

Lycopene is a non-polar hydrocarbon with no polar groups that can hydrogen bond with water molecules.

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(c) Many compounds that contain a conjugated double bond system (alternating double and single carbon to carbon bonds) absorb in the ultraviolet and visible regions of the electromagnetic spectrum.

The table shows the structure of some conjugated polyenes and the wavelengths of their maximum absorption values (λ_{max}).

Compound	Number of C=C bonds	λ_{max} / nm	Colour seen in white light
$H_2C=CH-CH=C(CH_3)_2$	2	234	colourless
$CH_3-CH=CH-CH=CH-CH=CH-CH_3$	3	263	colourless
$CH_3-CH=CH-(CH=CH)_3-CH=CH-CH_3$	5	326	colourless
β-carotene	11	450	yellow / orange
lycopene	13	505	red

Fill the gaps in the sentence below, using the words **increases** or **decreases**.

'As the number of conjugated carbon to carbon double bonds *increases* ,

the wavelength of their absorption maxima *increases* ,

the frequency *decreases* and the energy *decreases* .' [2]

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(d) The table shows the concentrations of seven coloured compounds in a tomato. The values were obtained by HPLC.

Compound	Concentration /μg g^{-1}
1	0.60
2	1.15
3	1.22
4	1.87
5	4.16
6	6.13
7	57.91

The main coloured component in a tomato is lycopene.

Suggest **two** ways by which you would know which of the peaks is given by lycopene.

[2]

1. *The lycopene peak is very much larger than the others (compound 7, 57.91 μg g^{-1}) as it is the main coloured component.*

2. *Run a chromatogram of pure lycopene under the same conditions and compare retention times with the peaks.*

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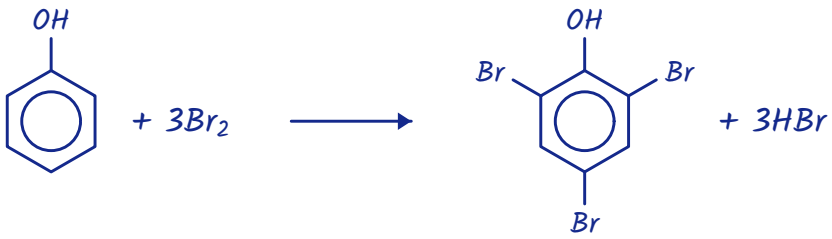
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9. *(a)* Phenol reacts with bromine to give 2,4,6-tribromophenol.

(i) Give the equation for this reaction. [1]



(ii) State what is seen during this reaction. [2]

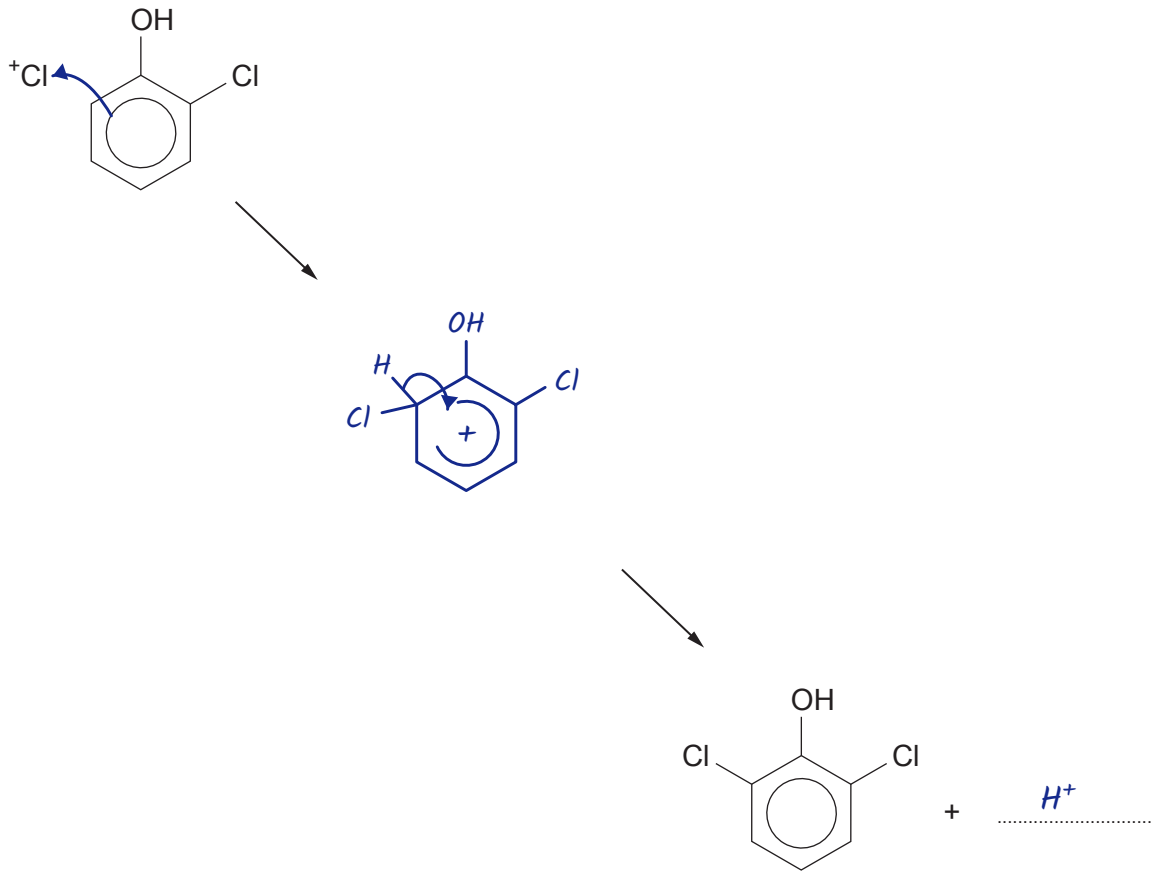
The orange bromine (water) is decolourised.

A white precipitate forms.

(b) Under suitable conditions 2-chlorophenol can be chlorinated giving 2,6-dichlorophenol.

Complete the mechanism for this reaction showing appropriate charges, curly arrows, the structure of the intermediate and the other product.

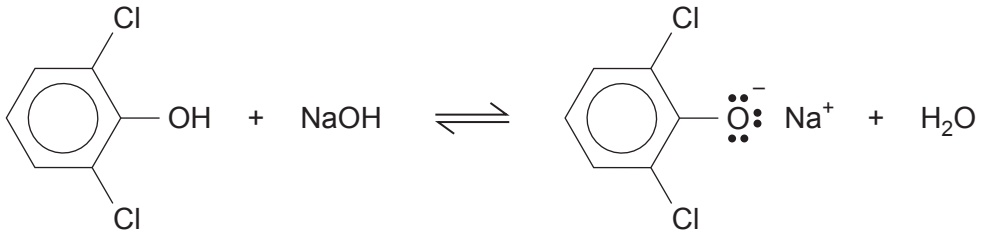
For simplicity the electrophile is shown as Cl^+. [3]



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(c) 2,6-Dichlorophenol is an acidic substance and will react with aqueous sodium hydroxide to give the corresponding anion, whereas ethanol does not react.

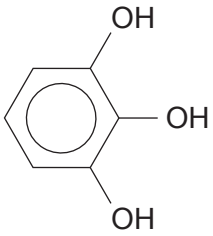


(i) Use this information to explain why 2,6-dichlorophenol is a stronger acid than ethanol. [2]

The anion is stabilised because a lone pair on the oxygen is delocalised into the ring (this weakens the O–H bond), so H^+ is lost easily.

Ethanol cannot react in this way, so it is not acidic.

(ii) Explain why 2,6-dichlorophenol does **not** react with aqueous sodium hydroxide to give compounds such as benzene-1,2,3-triol. [1]



It would need nucleophilic attack by OH^-, but the ring is electron rich and not attacked by nucleophiles.

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(d) Some information about a sample of 2,6-dichlorophenol produced by the chlorination of 2-chlorophenol is given below.

Calculated percentage of chlorine in 2,6-dichlorophenol	43.6 %
Percentage of chlorine in the sample of 2,6-dichlorophenol	43.7 %
Melting temperature of 2,6-dichlorophenol	65 °C
Melting temperature of the sample of 2,6-dichlorophenol	53-55 °C

The melting temperature of the sample of 2,6-dichlorophenol indicates that the sample is impure.

Suggest **two** reasons why the percentage of chlorine is however, close to the calculated value. [2]

Some 2-chlorophenol remains unreacted, compensated for by some polychlorination.

Other dichlorinated isomers (e.g. 2,4-) form, with the same % Cl.

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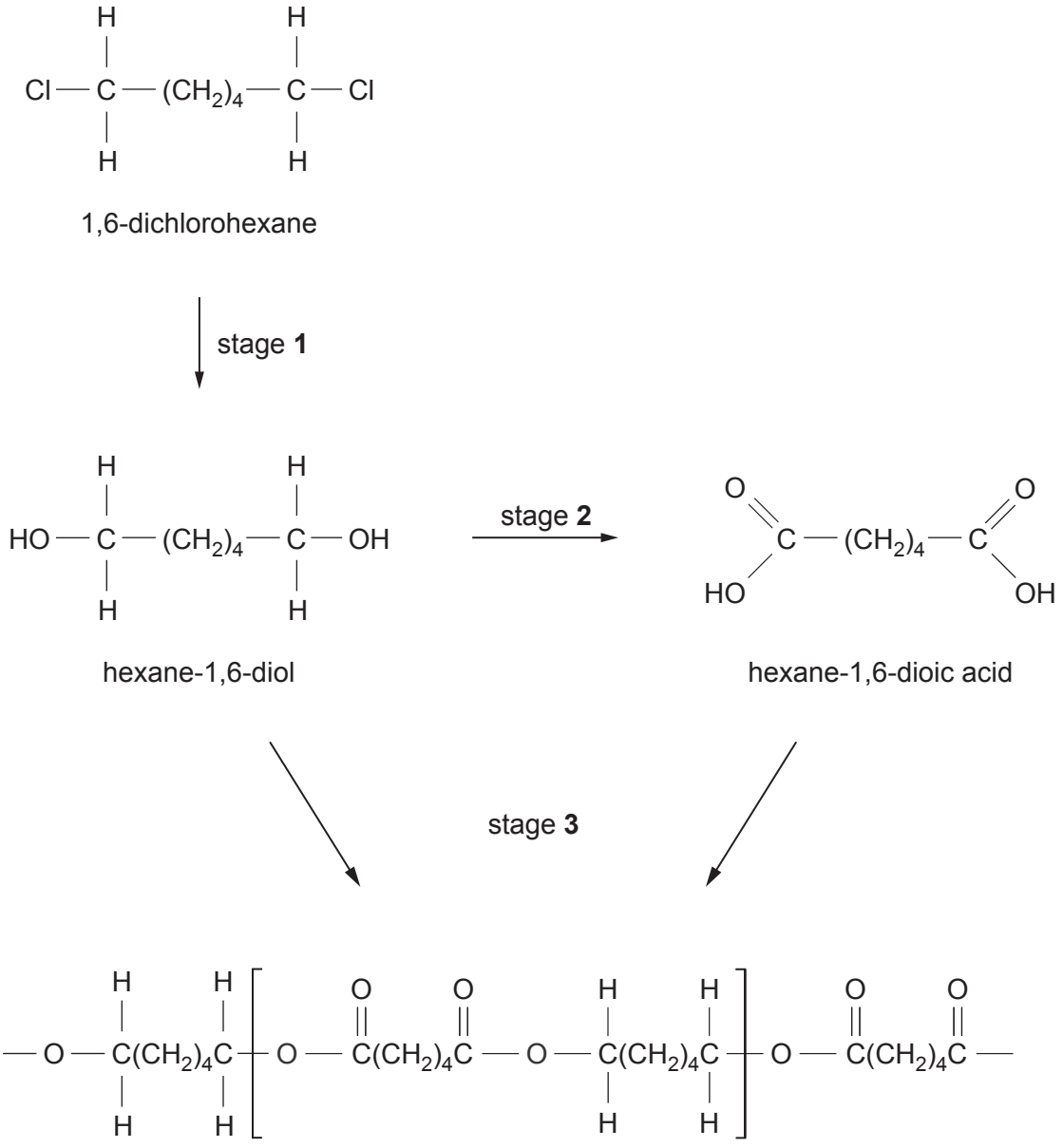
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QUESTION 9 CONTINUES
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(e) The flow chart shows a route for the preparation of a polyester.

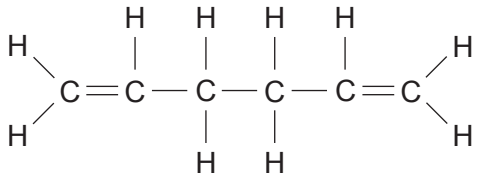


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(i) The starting point for the preparation of the polyester is 1,6-dichlorohexane.

David said that this could be prepared by reacting hexa-1,5-diene with hydrogen chloride.



hexa-1,5-diene

Explain why the yield of 1,6-dichlorohexane is small if this method is used. [2]

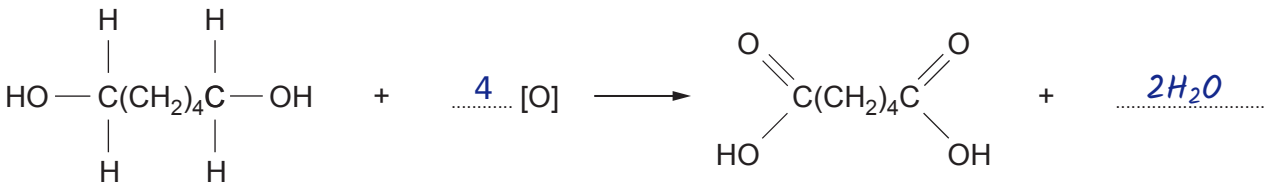
HCl adds via the more stable secondary carbocation (Markovnikov), so the major product is 2,5-dichlorohexane. The primary carbocation needed to form 1,6-dichlorohexane is much less stable / less easily formed, so the yield of 1,6-dichlorohexane is small.

(ii) State a reagent that will react with 1,6-dichlorohexane to give hexane-1,6-diol in stage **1**. [1]

aqueous sodium hydroxide, NaOH(aq)

(iii) Stage **2** is an oxidation reaction.

Using [O] to represent the formula of the oxidising agent, complete the equation below. [2]



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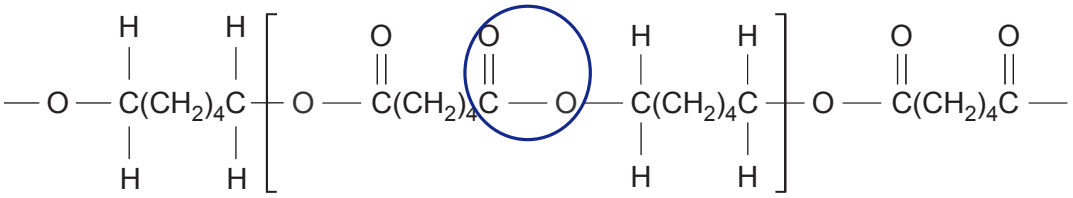
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(iv) In stage **3**, hexane-1,6-diol reacts with hexane-1,6-dioic acid to give the polyester.

I. State why this is a condensation reaction. [1]

a small molecule (water) is eliminated

II. Draw a ring around the part of the polymer structure that is an ester linkage. [1]



(v) If a polyamide were to be made instead of a polyester, 1,6-dichlorohexane would need to be converted to 1,6-diaminohexane.

State a reagent that would react with 1,6-dichlorohexane to give this diamine. [1]

ammonia, NH_3 (excess, in ethanol)

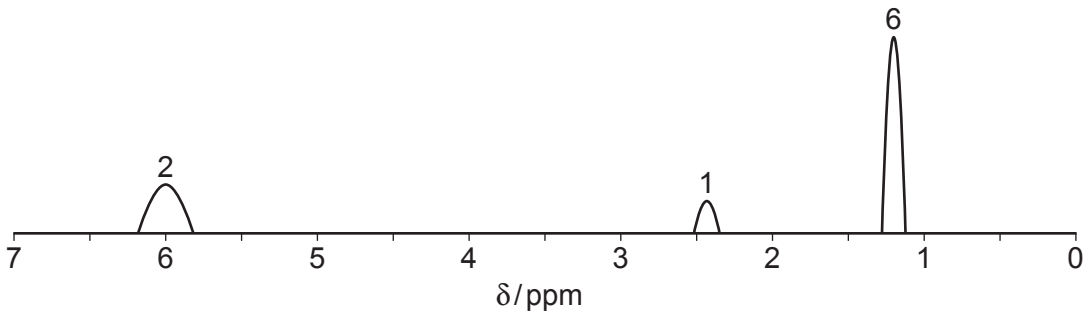
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(f) The low resolution ^{1}H NMR spectrum of an aliphatic amide, R—C(=O)—NH_2 is shown below.

The numbers indicate the relative peak areas for the protons.



The signal at 6 ppm is given by the $–NH_2$ protons.

Use the spectrum and the **Data Booklet** to deduce a structure for this amide. Give your reasoning. [3]

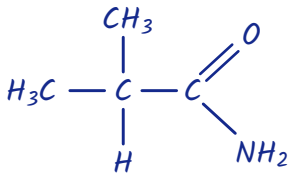
δ 1.2 ppm, area 6: R–CH_3, two equivalent CH_3 groups (6 equivalent protons).

δ 2.4 ppm, area 1: one H on the carbon next to C=O, H–C–C=O.

So R has 6 equivalent protons and 1 single proton: R is $(CH_3)_2CH$,

2-methylpropanamide.

Structure



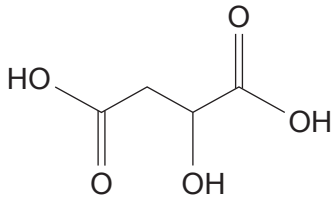
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10. *(a)* The acid present in apples is almost entirely malic acid (2-hydroxybutanedioic acid), M_r 134.



The amount of malic acid in apple juice was found using the following method.

- 6.80 g of apple juice was placed in a flask containing 50.0 cm^3 of water and the mixture stirred.
- The diluted apple juice was titrated with aqueous sodium hydroxide of concentration 0.120 mol dm^{-3} until the acid was just neutralised.
- The volume of aqueous sodium hydroxide needed was 5.60 cm^3.

(i) Calculate the percentage by mass of malic acid in the apple juice.

You should assume that both carboxylic acid groups in malic acid react in this titration. [3]

$n(NaOH) = 0.120 \times 5.60 \div 1000 = 6.72 \times 10^{-4}$ mol

$n(\text{malic acid}) = 6.72 \times 10^{-4} \div 2 = 3.36 \times 10^{-4}$ mol

mass of malic acid $= 3.36 \times 10^{-4} \times 134 = 0.0450$ g

% $= (0.0450 \times 100) \div 6.80 = 0.66$ %

Percentage = 0.66 %

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(ii) The experiment was repeated using 6.80 g of apple juice which was added to 100.0 cm^3 of water before mixing.

Explain why this change to the method would not give a different result for the percentage of malic acid present. [1]

The water does not take part in the reaction: the same number of moles of malic acid is present in 6.80 g of juice.

(iii) The amount of malic acid present in apple juice is generally less than 1 %.

Suggest **two** ways by which the method could be improved to give a more reliable result. Give reasons for your answers. [2]

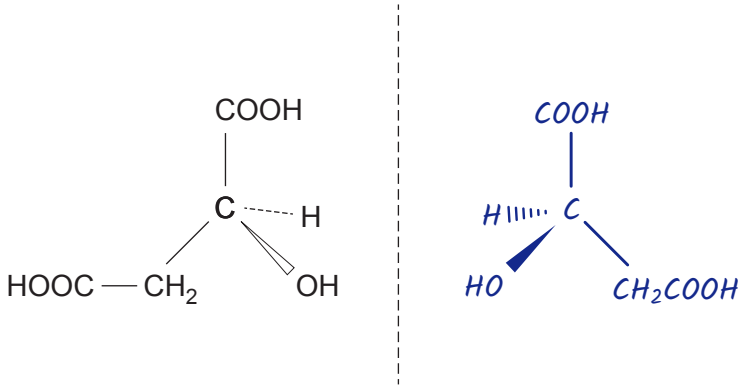
1. Use a larger sample of apple juice: this gives a larger titre, so the percentage error in the titre is smaller.

2. Use NaOH(aq) of lower concentration: this gives a larger titre (and repeat to get concordant titres).

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(b) (i) Naturally-occurring malic acid is one of two enantiomers. One is drawn below.

Draw the structure of the other enantiomer. [1]



(ii) The two enantiomers of malic acid rotate the plane of plane polarised light. The extent to which this occurs can be calculated from the formula

$$\left[\alpha^{20}{}_{D}\right] = \frac{100 \times \alpha}{c \times L}$$

where $[\alpha^{20}{}_{D}]$ has a value of 27 ° under the conditions used

α is the rotation in degrees

c is the concentration of the malic acid in g per 100 cm^3

L is the length of the polarimeter tube in dm

Use the formula to calculate the concentration in **mol dm^{-3}** of one enantiomer of malic acid when L has a length of 1 dm and α has a value of 4.5 °. The relative molecular mass of malic acid is 134. [3]

$c = (100 \times \alpha) \div ([\alpha] \times L) = (100 \times 4.5) \div (27 \times 1) = 16.67$ g per 100 cm^3

$c = 166.7$ g dm^{-3}

$c = 166.7 \div 134 = 1.24$ mol dm^{-3}

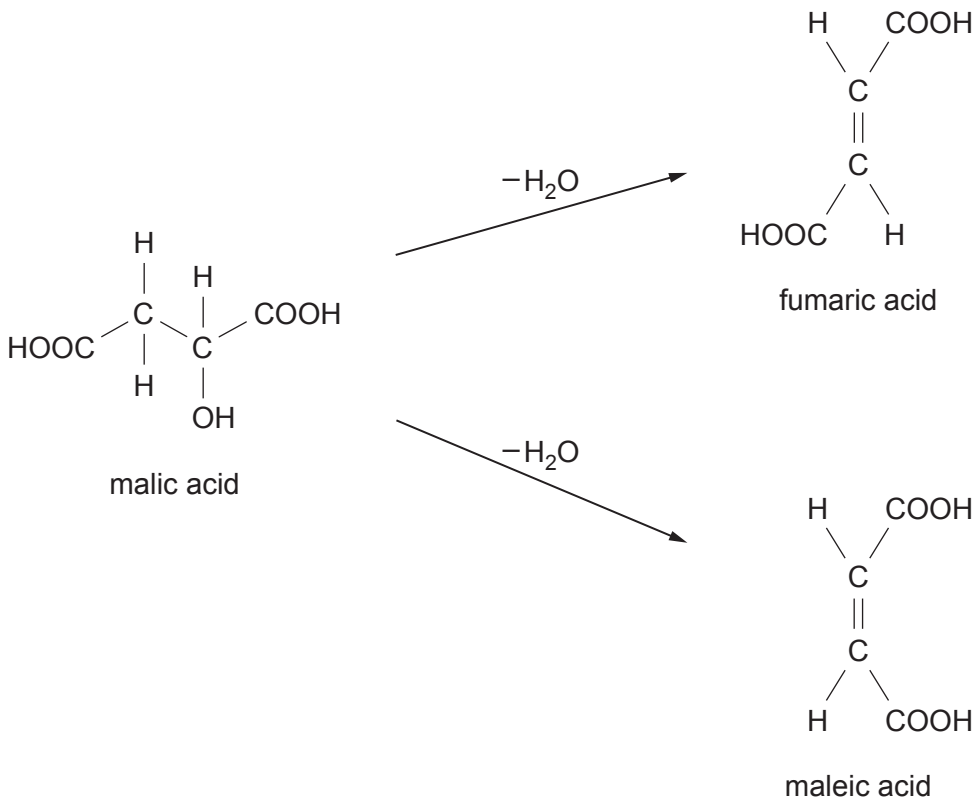
Concentration = 1.24 mol dm^{-3}

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(c) The action of heat on malic acid gives initially a mixture of two stereoisomers, maleic acid and fumaric acid.



(i) Explain the term stereoisomerism. [1]

Isomers with the same structural formula but the atoms arranged differently in space.

(ii) All three acids show stereoisomerism.

Explain how the type of stereoisomerism shown by malic acid differs from that shown by maleic acid and fumaric acid.

You should comment on both types of stereoisomerism in your answer. [2]

Malic acid shows optical isomerism as it has a chiral centre (an asymmetric carbon atom), giving non-superimposable mirror images.

Maleic and fumaric acids have no chiral centre; they show E-Z isomerism, differing only in the positions of the groups around the C=C double bond.

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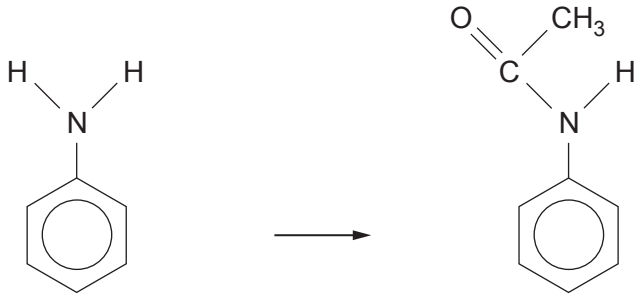
(d) (i) Phenylamine is made in the laboratory by the reduction of nitrobenzene.

State the reagents used for this reduction. [1]

tin and concentrated hydrochloric acid (Sn / conc. HCl)

(ii) The direct nitration of phenylamine gives a mixture of products as well as the required nitrophenylamine.

To obtain a better yield of nitrophenylamine, phenylamine is firstly converted to N-phenylethanamide.

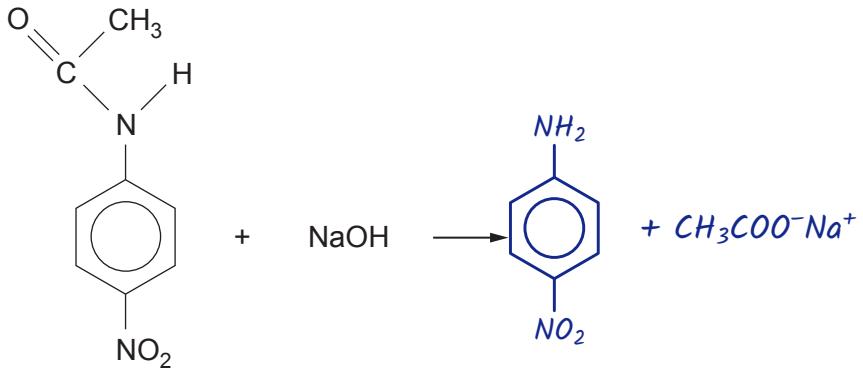


State a reagent that could be used for this reaction. [1]

ethanoyl chloride, CH_3COCl

(iii) Nitration of N-phenylethanamide gives N-(4-nitrophenyl)ethanamide which is then reacted with aqueous sodium hydroxide to give 4-nitrophenylamine.

Complete the equation for this reaction. [1]



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(e) A method for making an azo dye from 4-nitrophenylamine is shown below.

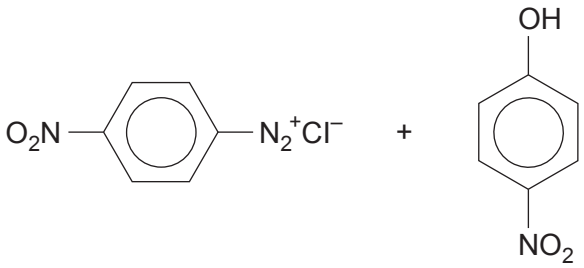
Stage **1**

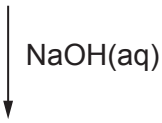


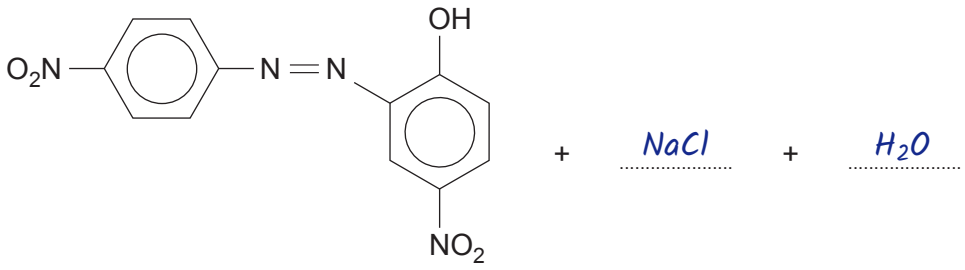
Stage **2**



Stage **3**







(i) State the temperature used for

Stage **1** *room temperature (about 20 °C)*

Stage **2** *5 to 10 °C* [2]

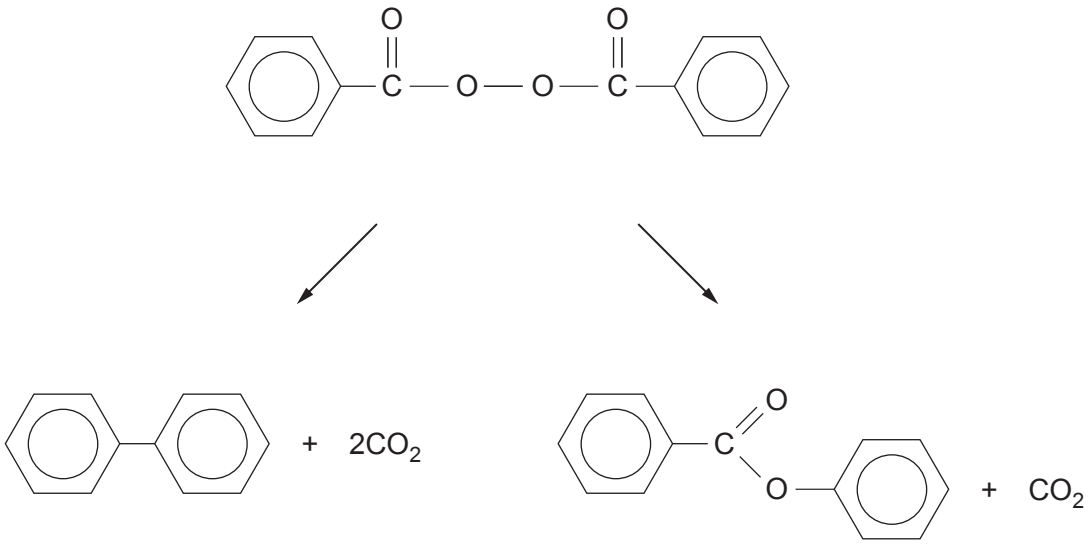
(ii) **Complete the equation** shown in stage **3** by giving the formulae of the other products formed. [1]

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11. *(a)* Di(benzoyl) peroxide has important industrial and medicinal uses. On heating it decomposes via two different routes as shown.



diphenyl phenyl benzoate

In an experiment 0.0350 mol of di(benzoyl) peroxide was heated and gave a 67.5 % yield of the ester phenyl benzoate.

(i) Calculate the mass of phenyl benzoate produced. [2]

n(phenyl benzoate) = 0.0350 × 67.5 ÷ 100 = 0.0236 mol

$M_r(C_{13}H_{10}O_2)$ = 198

mass = 198 × 0.0236 = 4.68 g

Mass = *4.68* g

(ii) Calculate the **total** volume of carbon dioxide produced measured at 298 K and 1 atm pressure, assuming that the di(benzoyl) peroxide decomposed by the two routes shown above. [4]

0.0236 mol CO_2 formed with 0.0236 mol phenyl benzoate

0.0350 − 0.0236 = 0.0114 mol decomposed to diphenyl

this gives 2 × 0.0114 = 0.0228 mol CO_2

total $n(CO_2)$ = 0.0236 + 0.0228 = 0.0464 mol

volume = 0.0464 × 24.5 = 1.14 dm^3

Volume = *1.14* dm^3

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(iii) After heating, a white solid containing only diphenyl and phenyl benzoate remained. To obtain diphenyl, the white solid was heated with aqueous sodium hydroxide. Only the ester reacted, giving an aqueous solution containing sodium phenoxide and sodium benzoate.

I. State the type of reaction occurring. [1]

hydrolysis

II. Describe how a dry sample of diphenyl was obtained from this mixture. [1]

filter off the diphenyl, wash with water and dry

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(b) Liquid **G** contains only carbon, hydrogen and oxygen.

The infrared spectrum of **G** showed **no** peaks at 1620–1670 cm^{-1}, 1650–1750 cm^{-1} or 3200–3550 cm^{-1}.

The ^{13}C NMR spectrum of **G** showed only two signals; at 25.8 and at 68.0 ppm.

Compound **G** contains 66.6 % of carbon by mass.

1.80 g of **G** was vapourised and the gas obtained occupied a volume of 936 cm^3 at a pressure of 7.80×10^4 Pa and at a temperature of 80 °C.

Use the information given to suggest a structure for compound **G**. Explain your reasoning. [6 QER]

pV = nRT, so n = pV ÷ RT = (7.80 × 10^4 × 936 × 10^{-6}) ÷ (8.31 × 353) = 0.0249 mol

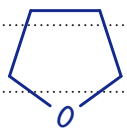
M_r = 1.80 ÷ 0.0249 = 72

66.6 % carbon: 0.666 × 72 = 48, so there are four carbon atoms per molecule.

Only one oxygen atom is possible (with two O atoms M_r would exceed 72), so there must be eight H atoms: molecular formula C_4H_8O.

IR: no C=C (1620 to 1670 cm^{-1}), no C=O (1650 to 1750 cm^{-1}) and no O–H (3200 to 3550 cm^{-1}), so the O must be in a C–O bond (an ether), and as there is no C=C the molecule must be a ring.

^{13}C NMR: only two carbon environments, so the molecule is symmetrical: 68.0 ppm is C–O carbon and 25.8 ppm is C–C carbon (CH_2 groups). G is tetrahydrofuran (oxolane):



(C_4H_8O, four CH_2 groups)

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