OCR
Oxford Cambridge and RSA

Monday 19 June 2017 – Morning

A2 GCE CHEMISTRY B (SALTERS)

F335/01 Chemistry by Design

Candidates answer on the Question Paper.

OCR supplied materials:
- *Data Sheet for Chemistry B (Salters)* (inserted)

Other materials required:
- Scientific calculator

Duration: 2 hours

Candidate forename		Candidate surname	

Centre number						Candidate number				

INSTRUCTIONS TO CANDIDATES

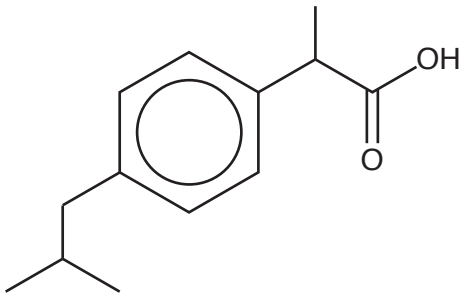
- The Insert will be found inside this document.
- Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters.
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Answer **all** the questions.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Write your answer to each question in the space provided. If additional space is required, you should use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.
- Do **not** write in the barcodes.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets **[ ]** at the end of each question or part question.
- Where you see this icon you will be awarded marks for the quality of written communication in your answer.
  This means for example you should:
  – ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear
  – organise information clearly and coherently, using specialist vocabulary when appropriate.
- You may use a scientific calculator.
- A copy of the *Data Sheet for Chemistry B (Salters)* is provided as an Insert with this Question Paper.
- You are advised to show all the steps in any calculations.
- The total number of marks for this paper is **120**.
- This document consists of **24** pages. Any blank pages are indicated.

Answer **all** the questions.

1 Ibuprofen is a medicine that reduces inflammation and acts as a painkiller.

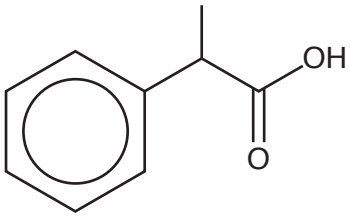


ibuprofen

(a) Give the **molecular formula** of ibuprofen.

..... **[1]**

(b) Ibuprofen can be synthesised from 2-phenylpropanoic acid.



2-phenylpropanoic acid

This synthesis can be carried out in the laboratory using a Friedel-Crafts reaction. A chloroalkane is reacted with 2-phenylpropanoic acid.

(i) Give the structural formula and name of the chloroalkane.

Structural formula

Name ..... **[2]**

(ii) Give the conditions for the Friedel-Crafts reaction.

.....

..... **[1]**

(c) Ibuprofen works by reversibly inhibiting an enzyme called COX which converts arachidonic acid to prostaglandins in the body.

(i) What is the name of the enzyme substrate?

..... **[1]**

(ii) Explain how the ibuprofen **inhibits** the enzyme and suggest how this can be **reversible**.

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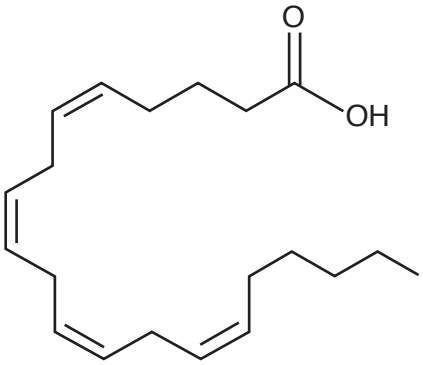
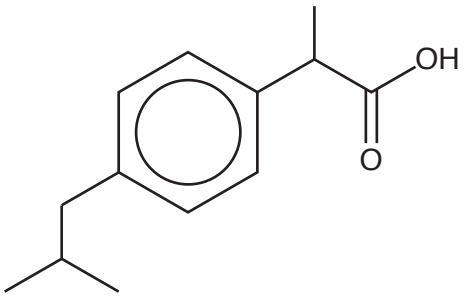
..... **[3]**

(d) Arachidonic acid has the structure shown below.



arachidonic acid



ibuprofen

Give a chemical test and the resulting observations for arachidonic acid that would **not** be shown by ibuprofen.

Test .....

Observations .....

..... **[2]**

(e) There are four sites of stereoisomerism in the arachidonic acid molecule.

(i) Explain what is meant by *stereoisomerism.*

.....

.....

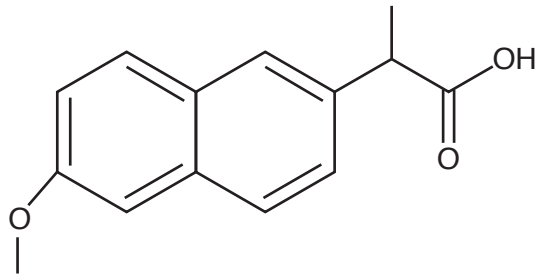
..... **[1]**

(ii) Give **two** ways of describing the stereoisomerism that is present at each site in arachidonic acid.

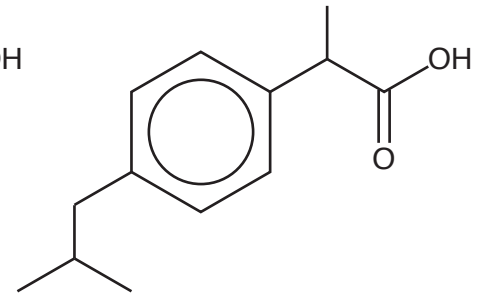
1 .....

2 ..... **[1]**

(f) Another medicine that works in a similar way to ibuprofen is naproxen.



naproxen



ibuprofen

(i) Name a **functional group**, other than the extended aromatic ring system, that naproxen has and ibuprofen does not.

..... **[1]**

(ii) Ibuprofen and naproxen share the same pharmacophore.

Explain what is meant by the term *pharmacophore.*

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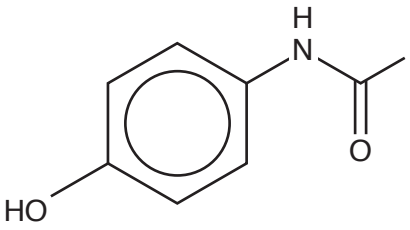
..... **[2]**

(iii) Circle the pharmacophore on the structure of **naproxen** above. **[1]**

(g) Paracetamol is another pain-relieving medicine.



paracetamol

The test for paracetamol in urine begins with **alkaline** hydrolysis of paracetamol.

Give the structures of the **two** organic ions formed.

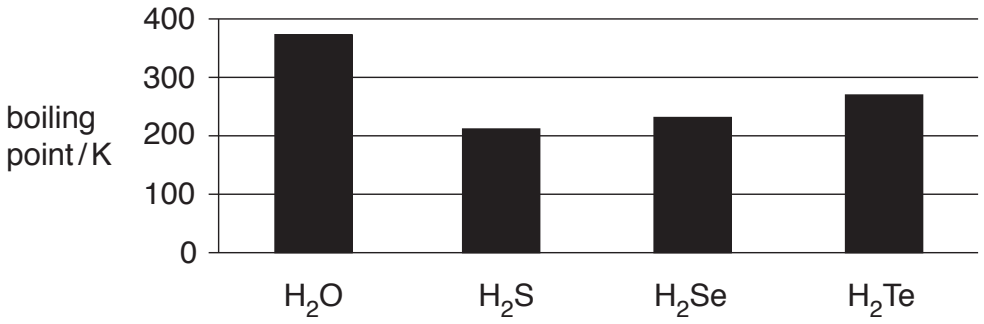
[2]

[Total: 18]

2 Water is the commonest solvent on Earth and it has several unusual properties.

(a) One unusual property is that it is a liquid at room temperature and pressure.

The trend of boiling points of the hydrides in Group 6 is as shown.



Explain, naming the intermolecular bonds involved:

- why the boiling points increase from H_2S to H_2Te
- why water has a higher boiling point than H_2S.

In your answer you should make it clear how the points link together.

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..... **[5]**

(b) Another unusual property is that ice is less dense than water.
Explain this.

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..... **[2]**

(c) Water is able to dissolve many substances.
CO_2 is slightly soluble in water.

(i) Explain why CO_2 has polar bonds but no dipole.

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..... **[2]**

(ii) Explain, in terms of intermolecular bonds broken and made, why CO_2 is slightly soluble in water.

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..... **[4]**

(d) Seas contain a variety of dissolved salts, notably sodium chloride.
Some data for dissolving sodium chloride are given below.

Enthalpy change	**ΔH/kJ mol^{-1}**
Lattice enthalpy of NaCl	–780
Enthalpy change of solution of NaCl	+5

(i) Draw an energy-level diagram connecting these two enthalpy changes to the enthalpy change of hydration of the ions.

Label the energy levels.

Calculate the enthalpy change of hydration of the ions.

enthalpy change of hydration of the ions = ... kJ mol^{-1} **[4]**

(ii) Name the bonds formed between water molecules and ions in solution.

..... **[1]**

(e) Water reacts with compounds consisting of a metal and a non-metal to give the metal hydroxide and the non-metal hydride.

Suggest the equation for the reaction between magnesium nitride and water. State symbols are not required.

[2]

[Total: 20]

3 The chemist Max Bodenstein investigated the equilibrium shown in **equation 3.1**.

$$2HI(g) \rightleftharpoons H_2(g) + I_2(g) \qquad \textbf{equation 3.1}$$

He placed known masses of HI in sealed tubes at high temperatures. The HI decomposed and equilibrium was reached. The tubes were rapidly cooled.
The iodine present was measured using a thiosulfate titration.

The reaction for the titration is shown below.

$$2Na_2S_2O_3 + I_2 \rightarrow Na_2S_4O_6 + 2NaI \qquad \textbf{equation 3.2}$$

(a) (i) Suggest and explain why he rapidly cooled the tubes.

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..... **[2]**

(ii) In one of his experiments, the iodine in a $100\,cm^3$ tube required $26.3\,cm^3$ of $0.0687\,mol\,dm^{-3}$ $Na_2S_2O_3$.

Calculate the concentration of I_2 in the tube.

$[I_2]$ = ... $mol\,dm^{-3}$ **[2]**

(b) In another experiment at 700 K, Bodenstein started with 0.00400 mol of HI in a 100 cm^3 tube.

$$2HI(g) \rightleftharpoons H_2(g) + I_2(g)$$ **equation 3.1**

When the equilibrium in **equation 3.1** had been reached, the concentration of I_2 in the tube was 0.00863 mol dm^{-3}.

(i) Show that the equilibrium concentration of HI in the tube was 0.0227 mol dm^{-3}.

Give all your working.

[2]

(ii) Work out a value of K_c for the equilibrium in **equation 3.1** at 700 K. Use the data given in **(b)** above.

Give your answer to an **appropriate** number of significant figures.

K_c = ... **[4]**

(c) Some students react sodium iodide with concentrated sulfuric acid, H_2SO_4. Some HI is produced but this reacts further with the sulfuric acid to form I_2 and H_2S, as shown below.

$$H_2SO_4 + 8HI \rightarrow 4I_2 + H_2S + 4H_2O$$

Which element has been oxidised and which has been reduced in this reaction?

Give the oxidation states of each element concerned.

..... is oxidised from ..... to .....

..... is reduced from ..... to ..... **[2]**

(d) The students then prepare HI by another method. They place a hot glass rod into the gas and see a purple vapour produced.

What information does this give about the forward reaction in **equation 3.1**?
Give a reason.

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..... **[2]**

(e) HI can be made by the action of hydrazine, H_2NNH_2, on iodine.

(i) Suggest an equation for this reaction.

[1]

(ii) Draw a *'dot-and-cross'* diagram for hydrazine.

[2]

(iii) State and explain the bond angle of the H-N-H bond in hydrazine. Name the shape around each nitrogen atom.

In your answer you should use appropriate technical terms, spelled correctly.

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..... **[4]**

(iv) Hydrazine, H_2NNH_2 forms a salt when it reacts 1:1 with sulfuric acid.

Give the formula of the salt, showing the ions.

[2]

(f) A student has a solution of HI. 25.00 cm^3 of this solution reacts with 26.25 cm^3 of 0.110 mol dm^{-3} NaOH.

$$NaOH + HI \rightarrow NaI + H_2O$$

The student wishes to make a 0.100 mol dm^{-3} solution of HI.

Calculate the volume of HI solution (in cm^3) that the student should dilute to 1.00 dm^3 to make a 0.100 mol dm^{-3} solution.

volume of HI solution = ... cm^3 **[3]**

[Total: 26]

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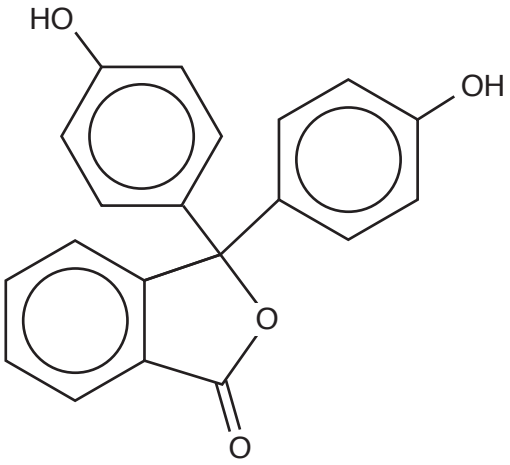
4 Phenolphthalein is a dye that is often used as an acid-base indicator.

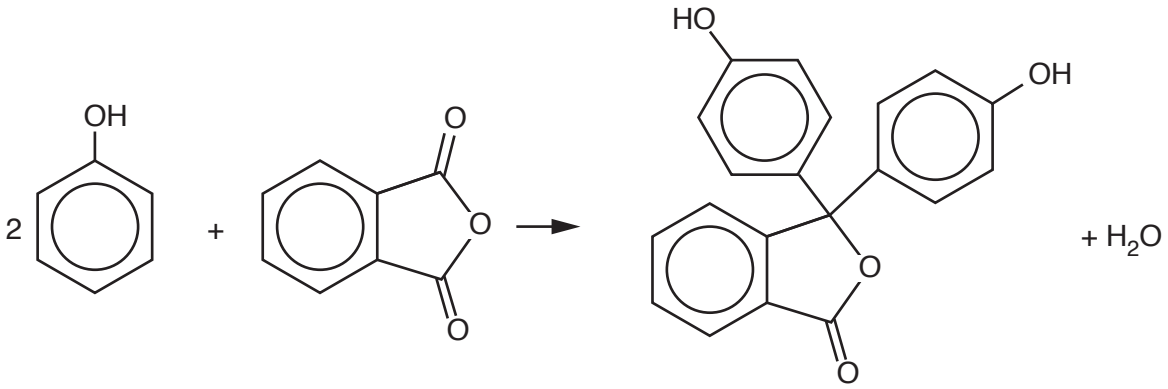


phenolphthalein

(a) Name a functional group (other than benzene rings and phenol groups) in phenolphthalein.

..... **[1]**

(b) In 1871 a method of synthesising phenolphthalein was discovered.



phenol
85 kg

compound A
69 kg

phenolphthalein M_r = 318

(i) Name the functional group (apart from the benzene ring) in compound **A**.

..... **[1]**

(ii) Calculate whether compound **A** or phenol is in excess or whether they are in exact reacting amounts.

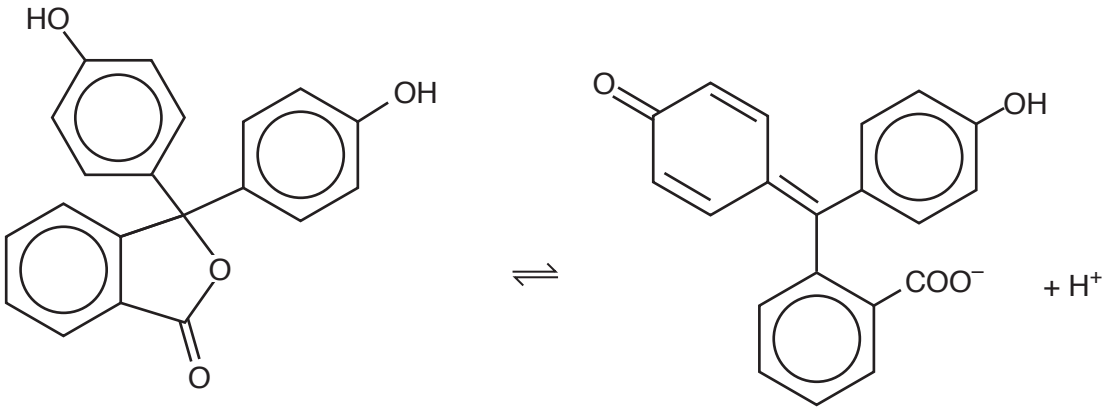
[3]

(iii) The yield of the process is 81%.

Calculate the mass of phenolphthalein formed in kg.

mass of phenolphthalein = ... kg **[2]**

(c) Phenolphthalein turns from a colourless molecule to a red ion when protons are removed.



colourless molecule, HIn **red ion In^-**

The delocalisation of the benzene rings can link through the double bond in the ion.

(i) Explain the origin and the arrangement of the delocalised electrons in a benzene ring.

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..... **[3]**

(ii) Suggest why the ion is coloured while the molecule is not.

In your answer you should make it clear how your points link together.

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..... **[5]**

The ionisation of phenolphthalein can be represented by the equation below.

$$HIn \rightleftharpoons H^+ + In^-$$

(d) At pH 9.3 there are equal amounts of colourless molecules, HIn, and red ions, In^-.

Calculate the K_a of phenolphthalein.

K_a = ... mol dm^{-3} **[2]**

(e) Phenolphthalein cannot be used in the titration of a strong acid with a weak base, for example 0.10 mol dm^{-3} HCl with 0.10 mol dm^{-3} NH_3.

$NH_3 + HCl \longrightarrow NH_4Cl$

A 0.050 mol dm^{-3} solution of NH_4Cl is formed at the end point of this reaction.

K_a for NH_4^+ = 5.6 × 10^{-10} mol dm^{-3}.

(i) Explain why the concentration of NH_4Cl is 0.050 mol dm^{-3}.

.....

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..... **[2]**

(ii) Write the equation for K_a of NH_4^+ in terms of concentrations.

K_a =

[1]

(iii) Calculate the pH of a 0.050 mol dm^{-3} solution of NH_4Cl.

pH = ... **[2]**

(iv) Suggest why phenolphthalein cannot be used to find the end point in a titration of HCl with NH_3.

.....

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..... **[2]**

(f) Phenol can be made from benzene in the following sequence:

$$C_6H_6 \longrightarrow \underset{\textbf{compound B}}{C_6H_5SO_3H} \xrightarrow{NaOH} C_6H_5OH$$

(i) Name compound **B**.

..... **[1]**

(ii) Give the reagent and conditions for making compound **B** from benzene.

.....

..... **[2]**

(iii) Name the mechanism of the reaction by which compound **B** is formed from benzene.

..... **[1]**

(iv) Describe the reaction (if any) of phenol with the reagents below.

sodium carbonate solution .....

.....

neutral iron(III) chloride .....

..... **[2]**

[Total: 30]

5 The compound 'n-butyraldehyde' is an intermediate in the synthesis of several useful organic products. It can be made by the reaction shown below.

$$CH_3CH{=}CH_2 + CO + H_2 \rightleftharpoons \underset{\textbf{n-butyraldehyde}}{CH_3(CH_2)_2CHO} \qquad \Delta H = -115\,kJ\,mol^{-1} \quad \textbf{equation 5.1}$$

(a) (i) State, with reasons, the effect of pressure on the equilibrium yield of n-butyraldehyde.

.....

.....

..... **[2]**

(ii) State, with reasons, the effect of temperature on the rate at which equilibrium is achieved.

.....

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..... **[2]**

(iii) Explain what is meant by the term *entropy*.
State and explain the sign of ΔS_{sys} for the forward reaction in **equation 5.1**.

.....

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..... **[2]**

(b) (i) Give the systematic name for n-butyraldehyde.

..... **[1]**

(ii) n-Butyraldehyde has a structural isomer 'isobutyraldehyde'.

Suggest the **full** structural formula and name of isobutyraldehyde.

Full structural formula:

Name: ..... **[2]**

(iii) Give the formula and name of the oxidation product of n-butyraldehyde.

Formula

Name ..... **[1]**

(c) Aldehydes react with nucleophiles that attack the carbon atom of the carbonyl group. The resulting product can then sometimes eliminate a small molecule such as water.

(i) n-Butyraldehyde reacts with hydride ions to form butan-1-ol. The mechanism is the same as for the attack of cyanide ions on aldehydes.

Suggest below the mechanism for the reaction of hydride ions with n-butyraldehyde.

Show curly arrows, partial charges and relevant lone pairs.

[4]

(ii) n-Butyraldehyde reacts with ammonia to give a compound with molecular formula C_4H_9N.

Suggest the structural formula of the final product.

[2]

(d) Butan-1-ol is used to make butyl ethanoate, an artificial apple flavouring.

(i) Give the conditions for a laboratory synthesis of butyl ethanoate, $C_6H_{12}O_2$, from butan-1-ol and ethanoic acid.

..... **[1]**

(ii) Write an equation for the reaction. Show the organic compounds as structural formulae.

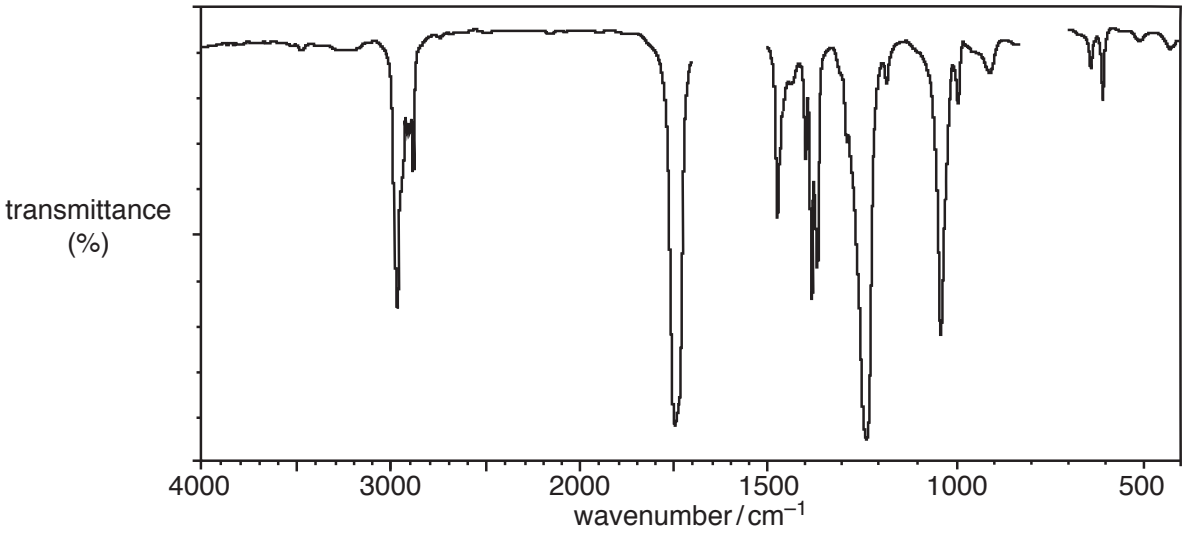
[2]

(e) Butyl ethanoate, $C_6H_{12}O_2$, has isomers that are acids or esters, some with branched chains.

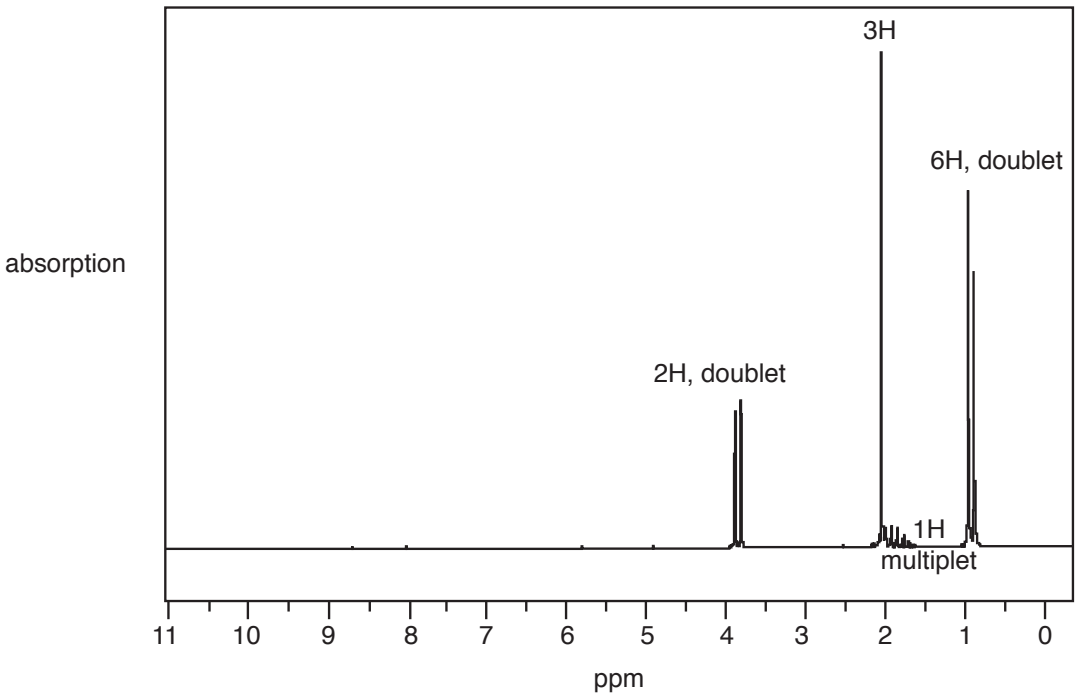
Compound **C** is one of these isomers of butyl ethanoate.

The infrared and proton NMR spectra of compound **C** are shown below.

Infrared spectrum



Proton NMR spectrum



Rough work may be done on this page but will not be marked.

Use the spectra on the opposite page to identify compound **C**, giving reasoning from both spectra.

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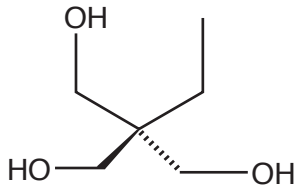
..... **[5]**

(f) Another use of n-butyraldehyde is its conversion to 'TMP'.



TMP

This forms cross-linked polymer resins when esterified with dicarboxylic acids.

Draw the structure of a TMP unit linked to three HOOC-R-COOH units, showing where the polymerisation continues.

[2]

[Total: 26]

END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).