WJEC Chemistry A-level

4.3: Alcohols and Phenols

Practice Questions

Wales Specification

1. Chloromethane can be produced by the chlorination of methane gas.

(a)During the initiation stage of this process, chlorine free radicals are produced.

(i) Give the condition(s) required for this initiation stage.

[1]

(ii) State what is meant by a ***free radical.***

[1]

(b) Write the equation(s) for the propagation stage(s) to produce chloromethane starting with methane and chlorine free radicals.

[2]

(c) Apart from chloromethane, a range of other compounds are produced in small amounts during the reaction.

(i) One of the compounds produced in the reaction is ethane. Show how this compound is produced.

[1]

(ii) Another of the compounds produced contains 24.3 % carbon, 4.1 % hydrogen and 71.6 % chlorine by mass. Calculate the **empirical** formula of this compound.

2

Empirical formula ....

(d) Chloromethane can be converted into methanol by reaction with hydroxide ions

(i) Classify the mechanism of this reaction

[1]

(ii) The boiling temperatures of chloromethane and methanol are given in the table below.

Compound	Boiling temperature / K
chloromethane, CH_3Cl	249
methanol, CH_3OH	338

Explain why the boiling temperature of methanol is higher than the boiling temperature of chloromethane.

[3]

(iii) Methanol can then be converted to methanoic acid. Give the reagent(s) and condition(s) required for this reaction.

[2]

Reagent(s) ....

Condition(s) ....

(e) CFCs are another class of organic compounds. They contain chlorine, fluorine and carbon. These compounds once had a range of uses, however their use is now avoided due to their effect on the ozone layer which is part of the **upper** atmosphere.

The table shows the lifetime of some compounds in the **lower** atmosphere and their relative ozone depletion potential (RODP), taking CCl_3F as having a value of 1.0. The RODP is measured by mixing a compound with ozone in a laboratory experiment.

Compound	Formula	Lifetime in the lower atmosphere	Relative ozone depletion potential (RODP)
A	CHF_3	243 years	0.01
B	CCl_2F_2	20 years	0.86
C	CCl_3F	75 years	1.00
D	$CBrClF_2$	120 days	10.00

By referring to this table, explain why CFCs **B** and **C** are far more harmful than compounds **A** and **D**.

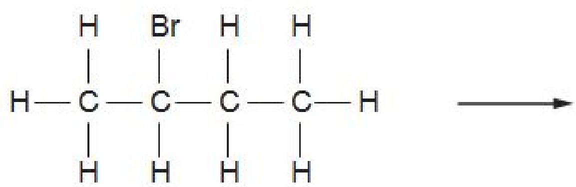
Your answer should explain how and why CFCs affect the ozone layer.

[3]

(Total 16)

2. 2-Bromobutane, C_4H_9Br, is a halogenoalkane that behaves in a similar way to 1-chlorobutane.

(a) (i) Complete the diagram below to show the mechanism for the reaction between 2-bromobutane and aqueous sodium hydroxide. You should include relevant charges, dipoles, lone pairs and curly arrows to show the movement of electron pairs. [4]



(ii) What **type** of mechanism is shown in *(a)*(i)?

[1]

(iii) The reaction involves heterolytic bond fission.

What is meant by ***heterolytic bond fission***?

[1]

(b) Bromoethane can be converted into ethene.

(i) Name the reagent and solvent needed to convert bromoethane into ethene.

[1]

(ii) What **type** of reaction occurs in *(b)*(i)?

[1]

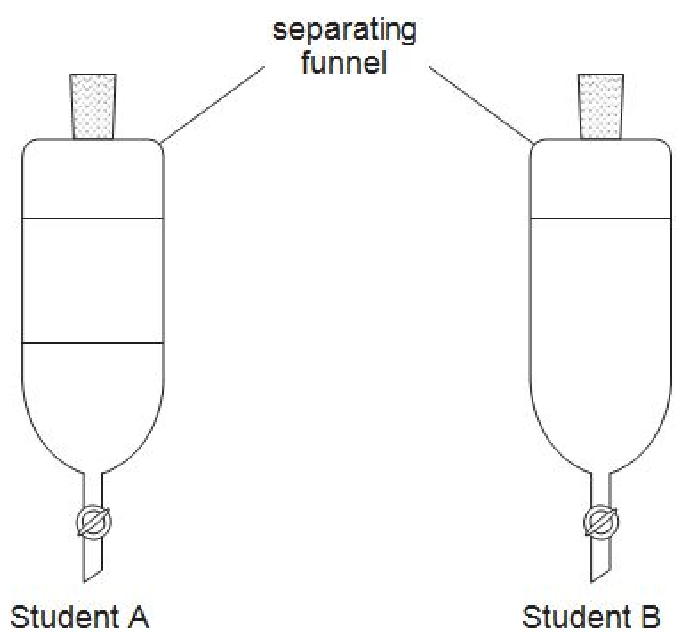
(iii) 2-Bromobutane behaves in a similar way to bromoethane in this type of reaction. When 2-bromobutane is reacted as described in *(b)*(i) two alkenes that are **structural** isomers are formed

Draw the displayed formulae of these two alkenes

[2]

(c) Two students were each given a different alcohol. They each added their alcohol to water in a separating funnel, shook the mixture and then left it to stand.

The diagrams show the results.

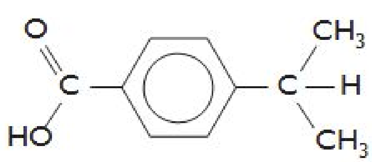


What can be deduced about the alcohols given to each student? You should explain why the alcohols behave differently in this experiment.

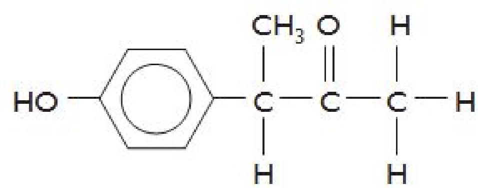
[5] QWC [1]

(Total 16)

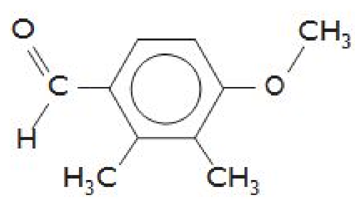
3. This question focuses on the chemistry of some of the many compounds which share the molecular formula $C_{10}H_{12}O_2$. Four compounds with this formula are shown below.



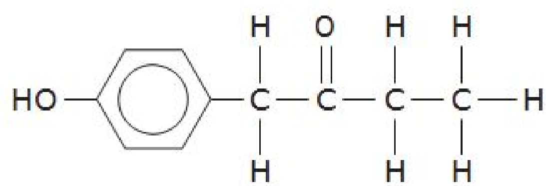
compound **W**



compound **x**



compound **y**



compound **Z**

(a) Draw an **ester** which is an isomer of the compounds above.

[1]

(b) Only one of the compounds shown can exhibit optical isomerism

(i) Identify which compound can exhibit optical isomerism.

[1]

(ii) Indicate the chiral centre in this molecule by labelling it with an asterisk (*).

[1]

(iii) State how the two enantiomers of this compound can be distinguished.

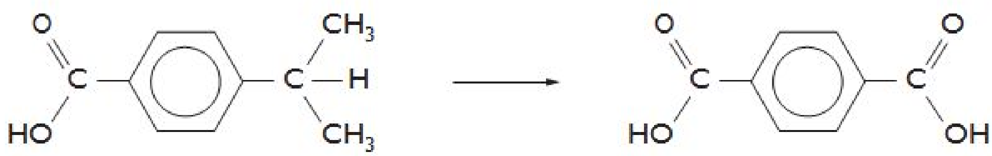
[1]

(c) The four compounds **W**, **x**, **y** and **Z** were tested using a series of reagents. For each of the tests listed below, describe what would be expected to be observed in a positive test. Indicate which compounds would be expected to give a positive result. [6]

All the tests listed will give positive results with at least one compound.

Reagent(s)	*Observation if the test is positive*	*Compounds that would give a positive result*
I_2/NaOH(aq)		
Na_2CO_3(aq)		
$FeCl_3$(aq)		

(d) Compound **W** can be oxidised to produce benzene-1,4-dioic acid *(terephthalic acid)*. This reaction can be undertaken in the same way as the oxidation of methylbenzene to form benzenecarboxylic acid.



compound **W**

benzene-1,4-dioic acid
(terephthalic acid)

(i) Give the reagent(s) and condition(s) required for this oxidation reaction.

[2]

(ii) Almost all the benzene-1,4-dioic acid produced worldwide is used in the production of condensation polymers

I. Give **two** differences between condensation polymerisation and addition polymerisation.

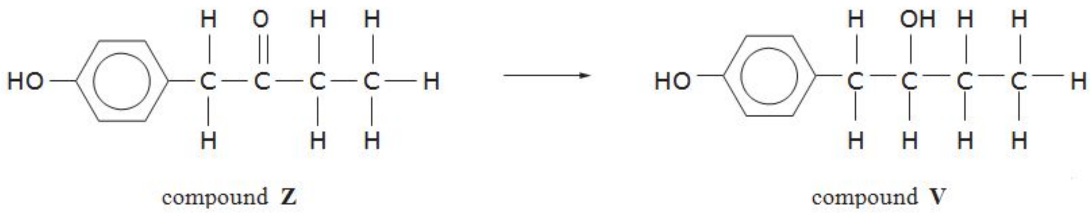
[2]

II. Draw the repeat unit for the polymer formed between benzene-1,4-dioic acid and ethane-1,2-diol. [1]

benzene-1,4-dioic acid
(terephthalic acid)

ethane-1,2-diol

(e) Compound **Z** may be converted into a secondary alcohol as shown below.



(i) Give a suitable reagent for this process and classify the reaction that occurs. [2]

Reagent ....

Classification of reaction ....

(ii) Compound **V** will react with ethanoyl chloride.Give the structure of a carbon-containing product of this reaction.

[1]

(iii) Compound **V** is insoluble in cold water, but reacts with sodium hydroxide solution and then dissolves.Give the structure of the carbon-containing species present in the resulting solution.

[1]

(Total 19)

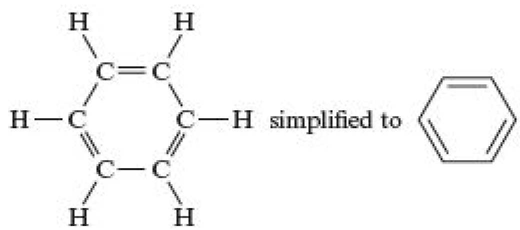
4.

Read the passage below and then answer the questions in the spaces provided.

Benzene

Benzene, C_6H_6, is a colourless, highly flammable liquid with a sweet smell, but it is carcinogenic. The word "benzene" derives historically from "gum benzoin", an aromatic resin known to European pharmacists and perfumers since the 15th century.

Discovering the structure of benzene proved to be quite difficult. Benzene was first isolated and identified by Michael Faraday in 1825 from the oily residue derived from the production of illuminating gas. However, it was not until 1865 that Kekulé proposed this structure for benzene.

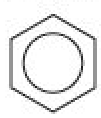


However this structure fails to explain why benzene does not react like an alkene. Ethene reacts readily with bromine as follows:

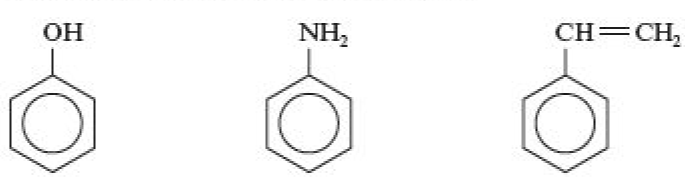
$$CH_2{=}CH_2 \;+\; Br_2 \longrightarrow CH_2Br\,CH_2Br$$

In contrast, benzene needs far more stringent conditions to react with bromine.

It was around 1930 that the structure of the benzene ring was finally confirmed using X-ray diffraction. It was shown that all the carbon-carbon bonds were of the same length. To account for this, it was proposed that three pairs of electrons were not localised in particular double bonds, but were shared equally amongst all six carbons. These electrons were said to be delocalised giving benzene great stability (delocalisation energy of benzene). The structure of benzene is therefore usually represented as:



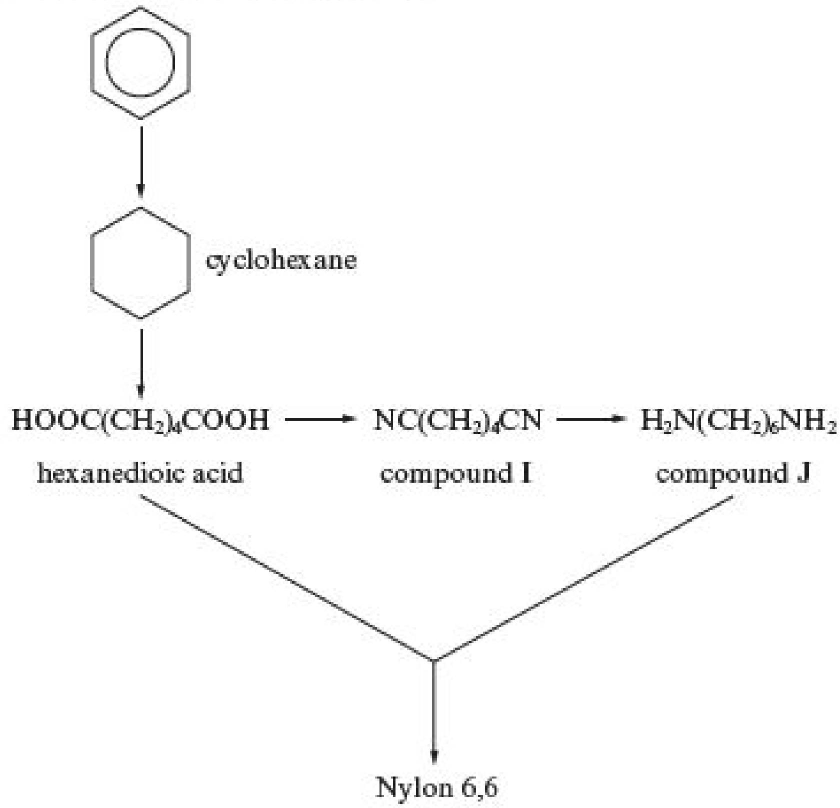
An understanding of the structure of benzene was crucial to early chemists since benzene is the parent molecule of all arene or 'aromatic' compounds and a huge variety of compounds are derived from benzene. Simple benzene derivatives include:



phenol phenylamine phenylethene

In the 19th and early 20th centuries, benzene was used as an after-shave lotion because of its pleasant smell, but today benzene is used to make other chemicals.

One of its most widely-produced derivatives is cyclohexane, which is used in the manufacture of Nylon 6,6 as shown in the scheme below:



– End of passage –

(a)Benzene reacts with bromine *(line 12)* in the presence of an iron(III) bromide catalyst to form bromobenzene.

(i) Classify the reaction mechanism.

[1]

(ii) Draw the mechanism for this reaction.

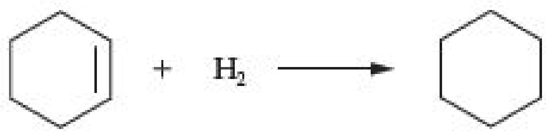
(The mechanism is similar to that for the chlorination of benzene.)

[3]

(b) (i) Explain what is meant by the ***delocalisation energy*** of benzene *(line 17)*

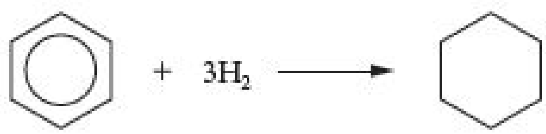
[1]

(ii) Given that the enthalpy change of hydrogenation of cyclohexene is $-120\,kJ\,mol^{-1}$ and that the enthalpy change of hydrogenation of benzene is $-208\,kJ\,mol^{-1}$, calculate the delocalisation energy of benzene. [2]



$\Delta H^{\ominus} = -120\,kJ\,mol^{-1}$

cyclohexane



$\Delta H^{\ominus} = -208\,kJ\,mol^{-1}$

benzene

$\Delta H^{\ominus} =$ .... $kJ\,mol^{-1}$

(c) Use the information in the passage to give a reason why benzene is no longer used in after-shave lotion.

[1]

(Total 8)

5. (a) 1-Chloropentane can be made by the free radical chlorination of pentane, in a similar way to the reaction of methane with chlorine.

(i) Give the equation for the reaction of pentane with chlorine, showing the displayed formula of 1-chloropentane as part of your answer.

[1]

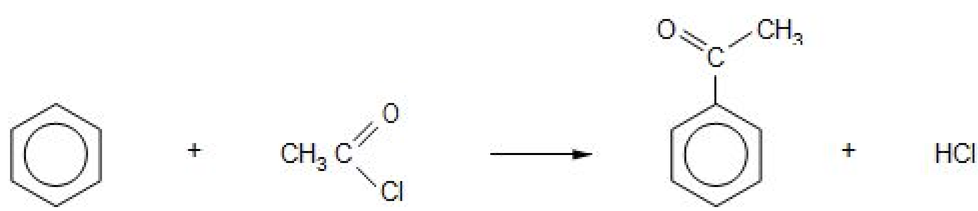
(ii) The free radical reaction of pentane with chlorine gives other chlorinated organic products. Give the structural formula of the carbon-containing free radical that leads to the formation of 2-chloropentane.

[1]

(b) Pentylbenzene can be produced by the reaction of 1-chloropentane and benzene in a Friedel-Crafts reaction. State the name of a catalyst that can be used in this reaction.

[1]

(c) A Friedel-Crafts reaction can be carried out with ethanoyl chloride in place of 1-chloropentane. This reaction gives phenylethanone as the main organic product.



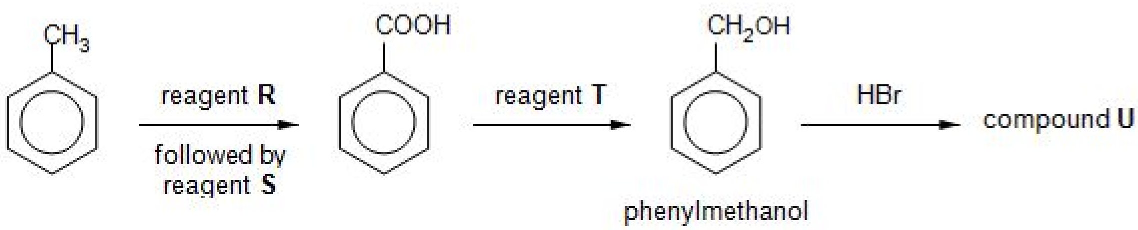
phenylethanone

(i) State what is seen when a few drops of phenylethanone are added to a solution of 2,4-dinitrophenylhydrazine.

[1]

(ii) This preparation of phenylethanone also gives small traces of an impurity. This impurity has a molecular formula $C_{10}H_{10}O_2$ and reacts in a similar way to phenylethanone when it is treated with 2,4-dinitrophenylhydrazine. It does not react with Tollens' reagent. Suggest a displayed formula for this impurity, giving a reason for your choice. [2]

(d) Methylbenzene can be oxidised to benzoic acid by heating it strongly with an alkaline solution of reagent **R** followed by treatment with reagent **S**. The benzoic acid can then be used to produce a number of other compounds. A reaction sequence is shown below.



(i) State the name of reagent **R.**

[1]

(ii) State the name of reagent **S.**

[1]

(iii) State the name of reagent **T**.

[1]

(iv) Give the displayed formula of the organic compound **U**.

[1]

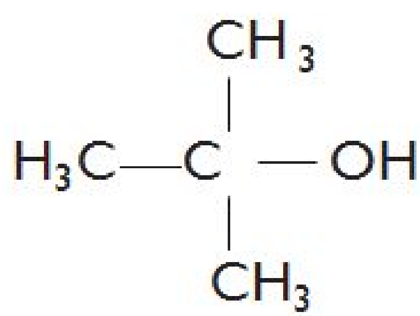
(e) State and explain how the infrared spectrum of benzoic acid would differ from that of phenylmethanol.

[2]

(Total 12)

6. (a) In 2012 an off-licence in Derby was prosecuted for selling fake vodka

(i) A report in the local paper stated that this 'vodka' was contaminated by 'tertiary butanol', the formula of which is shown below.



State the **systematic** name of this compound.

[1]

(ii) Analysis showed that the total alcohol content of a bottle of the fake vodka was 35 %.

A gas-liquid chromatogram showed a mixture of alcohols to be present in the following proportions:

- tertiary butanol 6 parts
- methanol 8 parts
- ethanol 86 parts

Calculate the percentage of ethanol by volume in the fake vodka.

[1]

.... %

(iii) Tertiary butanol can be dehydrated in an elimination reaction to produce 2-methylpropene. Suggest a suitable dehydrating agent for this reaction.

[1]

(iv) 2-Methylpropene can be polymerised to give poly(2-methylpropene). Draw the repeating unit of the polymer.

[1]

(v) Write the displayed formula of any isomer of tertiary butanol that contains a chiral centre. Identify the chiral centre by an asterisk (*).

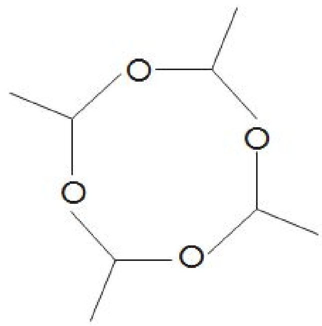
[2]

(vi) The main alcoholic compound of the fake vodka is ethanol. This can be oxidised to give ethanal.

I. State the reagent(s) used to oxidise ethanol to ethanal in the laboratory.

[1]

II Ethanal can be polymerised to 'metaldehyde', $(CH_3CHO)_4$, which is used to kill slugs.



Use the Data Sheet to describe how the infrared spectrum of 'metaldehyde' will differ from the infrared spectrum of its monomer, ethanal, giving the absorption values and the bonds involved. Reference to C —H bonds is not required. [2]

(b) The oxidation of tertiary alcohols is different from those of primary and secondary alcohols. 'Tertiary butanol' is oxidised to propanone and methanoic acid.

(i) State a test that will give a positive result for propanone but not methanoic acid.

[2]

Reagent

Observation

(ii) State a test, other than the use of an acid-base indicator, that will give a positive result for methanoic acid but not propanone.

2

Reagent

Observation

(Total 13)

7. (a) In March 2012 the UK Government proposed a minimum price of 40p per unit of alcohol in an effort to 'turn the tide' against binge drinking.

State **one** effect on the human body and **one** effect on society of the excessive use of alcoholic drinks.

[2]

Effect on the human body

Effect on society

(b) Butan-1-ol can be prepared by warming 1-chlorobutane with aqueous sodium hydroxide

(i) Classify the type of reaction occurring and give the mechanism for the reaction

[4]

Reaction type...

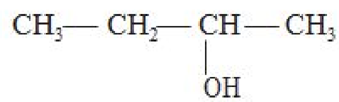
Mechanism:

(ii) Use the infrared absorption frequencies given in the Data Sheet to explain how you would know if all the 1-chlorobutane has been converted into butan-1-ol.

[2]

(c) Butan-1-ol has the molecular formula $C_4H_{10}O$.

Two other isomers of $C_4H_{10}O$ are butan-2-ol and methylpropan-1-ol.



butan-2-ol

(i) Draw the **skeletal** formula of methylpropan-1-ol.

[1]

(ii) Name the type of isomerism shown by these isomers.

[1]

(iii) Butan-1-ol can be oxidised by acidified potassium dichromate(VI) to form butanoic acid. State what you would **observe** during this reaction.

[1]

(iv) Butan-1-ol can also be dehydrated. Name a suitable dehydrating agent and write an equation for this reaction.

[2]

Dehydrating agent

Equation

(d) 1-Chlorobutane is an example of a halogenoalkane. One group of halogenoalkanes (CFCs) has been shown to play a role in ozone depletion. Most of these ozone-depleting substances contain chlorine. Halogenoalkanes containing only fluorine do not harm the ozone layer.

Due to the Montreal Protocol of 1987, CFCs have been largely banned and have been replaced in many applications by HFCs, which contain fluorine as the only halogen.

(i) Explain why CFCs deplete the ozone layer, but HFCs do not.

[2]

(ii) Suggest a reason why there is still concern about ozone depletion.

[1]

(Total 16)

8. Police use a breathalyser to test motorists for the presence of alcohol

(a) An early type of breathalyser required the motorist to breathe into a tube that contained acidified potassium dichromate. The alcohol in their breath was oxidised to ethanal and ethanoic acid. State the colour change that occurred if the test was positive.

[1]

.... to ....

(b) Modern breathalysers use infrared spectroscopy to detect and measure the concentration of alcohol in breath. An absorption frequency at 2940 cm-1 is used rather than the frequency caused by the O—H bond, as this is also present in water.

(i) Use the Data Sheet to identify the bond that causes the absorption at 2940 cm^{-1}

[1]

(ii) State which **one** of the following correctly describes any change in the absorption at 2940 cm^{-1} if the concentration of alcohol in the breath increases.

[1]

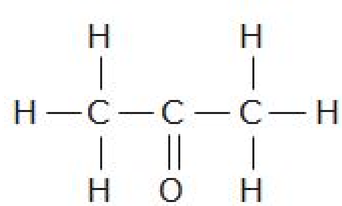
A the frequency decreases to 2900 cm^{-1}

B the frequency increases to 3000 cm^{-1}

C the intensity of the absorption at 2940 cm^{-1} increases

D the absorption covers the range 2900 to 3000 cm^{-1}

(iii) A false breathalyser reading can be given by a person who exhales propanone, as a result of an illness



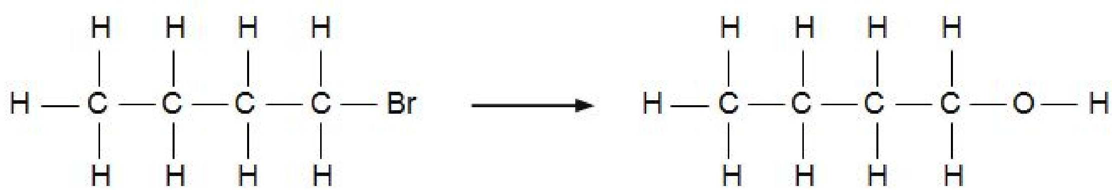
propanone

Identify the bond that would distinguish the infrared spectrum of propanone from that of an alcohol. Using the Data Sheet, state the absorption frequency of this bond.

[1]

(Total 4)

9. *(a)* 1-bromobutane is a liquid that is insoluble in water. It can be converted to butan-1-ol in a one-step reaction.



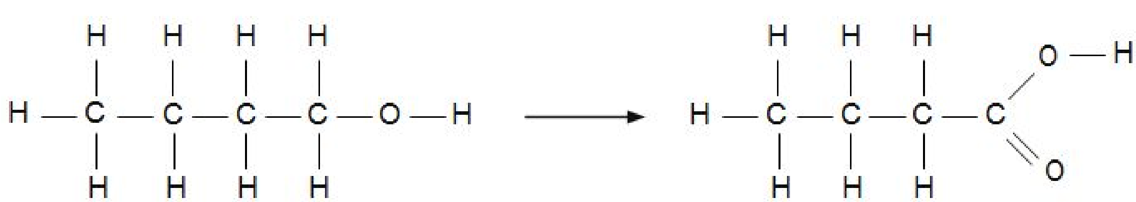
(i) Give the reagent(s) and condition(s) required for this reaction.

[2]

(ii) Explain why butan-1-ol is soluble in water whilst 1-bromobutane is not.

[3]

(b) Butan-1-ol can be converted into liquid butanoic acid in a one-step reaction.



(i) Give the reagent(s) and condition(s) required for this reaction. [2]

(II) Explain why butanoic acid has a much higher boiling temperature than 1-bromobutane.

[3]

(iii) The reaction above frequently produces a mixture containing unreacted butan-1-ol and butanoic acid. State how these two liquids could be separated

[1]

(Total 11)

10. State the reagent(s) used and the colour change seen when a primary alcohol is oxidised to give a carboxylic acid.

[2]

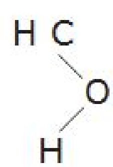
Reagent(s)..

Colour change from. . . . . *to* . . . .

11.

Ethanol, C_2H_5OH, is the alcohol that is present in alcoholic drinks.

(a) Ethanol is soluble in water. Complete the diagram below to show why ethanol is soluble in water. You should include relevant lone pairs and dipoles and label the bond responsible for this solubility. [3]



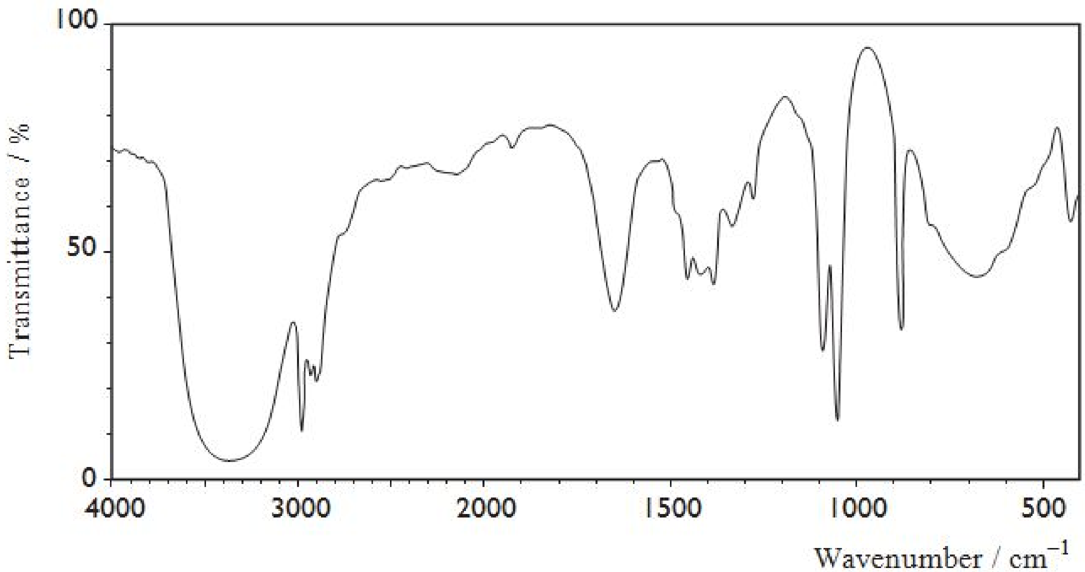
(b) If it is suspected that a driver has been drinking alcohol they can be tested in several ways.

(i) One method previously used to test for ethanol in breath involved blowing through acidified potassium dichromate(VI). A positive test was shown by the colour change from orange to green.

What type of reaction causes this colour change?

[1]

(ii) Another method uses IR spectroscopy. The IR spectrum for ethanol is shown below.



I. State which functional group is shown to be present in ethanol by the absorption at about 3350 cm^{-1}

[1]

II. A student suggested that this absorption should be used to test for the presence of ethanol in breath. Give a reason why this suggestion is not valid.

[1]

(c) If ethanol, in a drink such as wine, is left in an open bottle and exposed to air it becomes 'sour' and unpleasant to taste. This is because it forms ethanoic acid.

(i) Draw the **displayed** formula of ethanoic acid.

[1]

(ii) What significant change would be noticed if the IR spectrum of this product was compared with that of ethanol? Give the reason for this change.

[2]

(Total 9)