Alcohols
AS & A Level

Model Answers 3

Level	A Level
Subject	Chemistry
Exam Board	OCR
Module	Core Organic Chemistry
Topic	Alcohols
Paper	AS & A Level
Booklet	Model Answers 3

Time allowed: **53 minutes**

Score: **/39**

Percentage: **/100**

Grade Boundaries:

A*	A	B	C	D	E
>85%	73%	60%	47%	34%	21%

This question is about alcohols.

(a) Construct an equation for the complete combustion of an unsaturated alcohol with 5 carbon atoms.

[1]

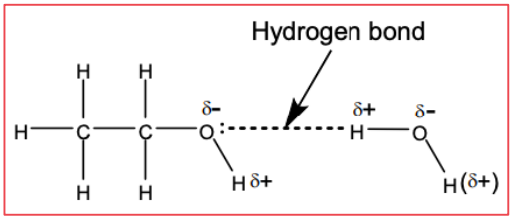
$C_5H_{10}O + 7O_2 \longrightarrow 5CO_2 + 5H_2O$

(b) Many alcohols, including ethanol, are soluble in water.

(i) Explain, with the aid of a diagram, why ethanol is soluble in water.

Include relevant dipoles and lone pairs.

[2]



The diagram must show a water molecule and an ethanol molecule with at least one $H^{\delta+}$ and one $O^{\delta-}$ on BOTH molecules.

Hydrogen bond **between one lone pair** on an O atom in one of the molecules and the H atom of another. **AND** Hydrogen bonding stated or labelled on diagram.

(ii) The solubility of hexan-1-ol and hexane-1,6-diol in water is shown below in **Table 19.1**.

Alcohol	Solubility in water/g dm^{-3}
hexan-1-ol	5.9
hexane-1,6-diol	500

Table 19.1

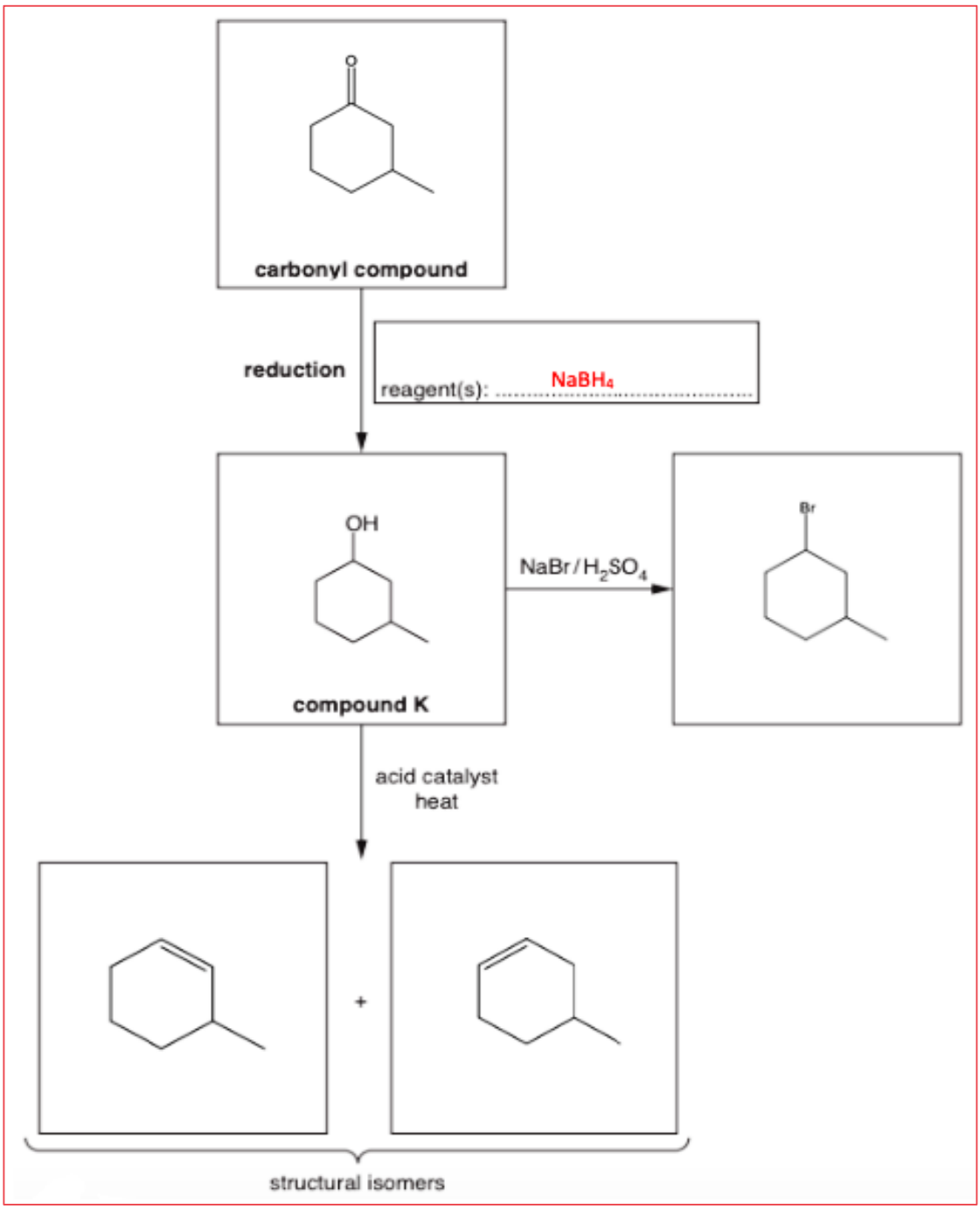
Explain the difference in solubility of hexan-1-ol and hexane-1,6-diol.

[1]

Hexane-1,6-diol has more OH groups than hexan-1-ol so forms more hydrogen bonds with water which makes it more soluble.

(c) Alcohols are important in organic synthesis and can be formed by the reduction of carbonyl compounds.

(i) Complete the flowchart by filling in each box. **[5]**



(ii) What is the name of compound **K**? **[1]**

3-methylcyclohexanol

There is a methyl group on carbon number 3 and an -OH group on carbon number 1.

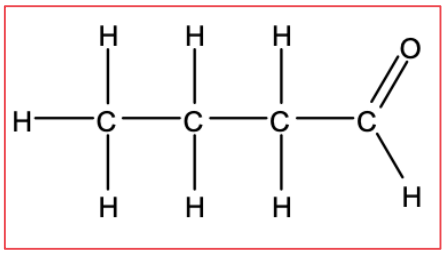
(d) Butan-1-ol can be oxidised to form two different organic products, depending on the reaction conditions used.

Describe both oxidation reactions of butan-1-ol.

For each reaction include

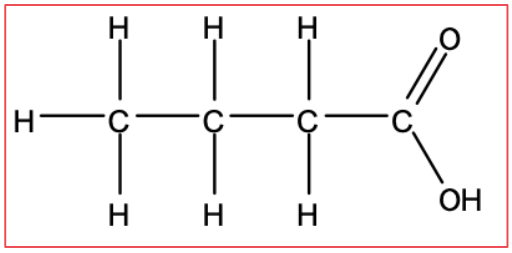
- the structure of the organic product
- a balanced equation
- the essential reaction conditions.

In your equations you may use [O] to represent the oxidising agent. **[5]**



$CH_3CH_2CH_2CH_2OH + [O] \longrightarrow CH_3CH_2CH_2CHO + H_2O$

Butan-1-ol is a primary alcohol which undergoes oxidation in acidic conditions and distillation to produce an aldehyde product, in this case butanal.



$CH_3CH_2CH_2CH_2OH + 2[O] \longrightarrow CH_3CH_2CH_2COOH + H_2O$

If butan-e-ol is refluxed and the product is not removed via distillation, then the reaction continues on and produces a carboxylic acid, in this case butanoic acid. The oxidising agent most commonly used is potassium dichromate (VI) acidified with dilute H_2SO_4.

(Total 15 marks)

The hydroxyl group, –OH, is responsible for many properties of alcohols.

(a) Methanol, CH_3OH, is soluble in water because it has polar bonds.

Pauling electronegativity values for carbon, oxygen and hydrogen are shown below.

Element	Electronegativity
Carbon	2.5
Oxygen	3.5
Hydrogen	2.1

Use a labelled diagram to explain why methanol is soluble in water.

- Use displayed formulae showing one molecule of methanol and one molecule of water.
- Add partial charges d+ and d– to show the **two** most polar bonds in a methanol molecule and the polar bonds in a water molecule.
- Show all lone pairs.
- Label the most important intermolecular bond between the molecules.

[2]

Displayed formulae of CH_3OH and H_2O

AND

C–O **AND** O–H polar bonds shown on CH_3OH molecule with δ+ and δ– make sure these are clearly labelled.

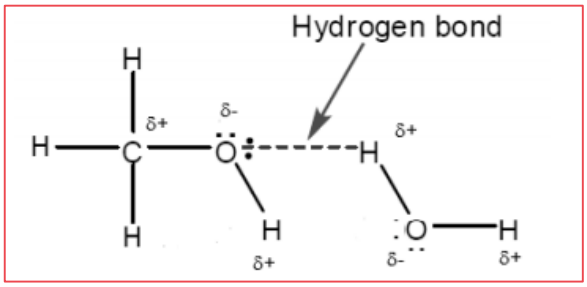
AND

Both O–H polar bonds shown on H_2O molecule with δ+ and δ– as both bonds are polar, not just one.

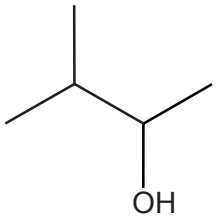
Two lone pairs shown on both oxygen atoms

AND

Hydrogen bond/H-bond labelled and in the correct position between the H on water and the oxygen lone pair on methanol



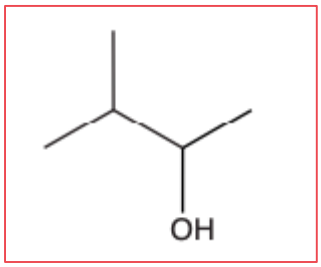
(b) Alcohol **C** is analysed using mass spectrometry.



alcohol C

(i) Give the systematic name of alcohol **C**. **[1]**

3-methylbutan-2-ol



The methyl group is on carbon atom number 3 from RHS while the alcohol group is placed on carbon number 2.

(c)* Describe the oxidation reactions of butan-1-ol forming an aldehyde and a carboxylic acid.

Explain, using a diagram, how the aldehyde can be produced in the laboratory by controlling the reaction conditions.

[6]

Indicative scientific points

Butan-1-ol is a primary alcohol which can be oxidised to either an aldehyde or a carboxylic acid. The product is determined by the conditions used during the reaction.

1. Oxidation reaction forming aldehyde

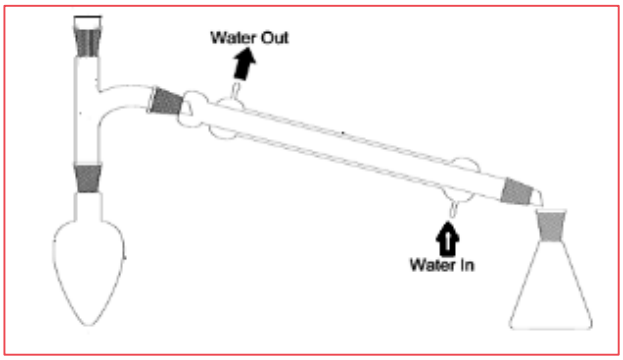
- acid/H^+ **AND** dichromate/$Cr_2O_7^{2-}$ which changes colour from orange to green as the oxidising agent is itself reduced, leaving a green solution of chromium(III) ions.
- heat **AND** distillation as the aldehyde product must be distilled out of the reaction mixture as it is formed, to prevent **further oxidation** to a carboxylic acid.
- organic product is butanal/$CH_3CH_2CH_2CHO$
- $CH_3CH_2CH_2CH_2OH + [O] \longrightarrow CH_3CH_2CH_2CHO + H_2O$ where [O] represents the oxidising agent.

2. Oxidation reaction forming carboxylic acid

- acid/H^+ **AND** dichromate/$Cr_2O_7^{2-}$ potassium dichromate (VI) must be present in excess.
- heat under reflux which ensures the initial aldehyde product undergoes oxidation to produce the carboxylic acid.
- organic product is butanoic acid/$CH_3CH_2CH_2COOH$
- $CH_3CH_2CH_2CH_2OH + 2[O] \longrightarrow CH_3CH_2CH_2COOH + H_2O$

3. Distillation

- diagram of apparatus with condenser
- condenser has water flow which is clearly labelled as water in and water out.
- collection of organic product with suitable glassware such as a conical flask.
- product is separated to prevent further oxidation (to carboxylic acid) which is the purpose of the distillation apparatus.



Exam Tip

Condensers

Remember to always add the water-in and water-out labels to condensers. The water-in label always goes on at the bottom as when the water enters here it ensures that the condenser is always filled with cold water.

(Total 9 marks)

This question is about the homologous series of alcohols.

(a) What is meant by the term *homologous series*? [2]

A homologous series is a series of compounds with the same functional group or same/similar chemical properties/reactions and each **successive** member differs by CH_2

(b) Ethanol is used more than any other alcohol. One method of preparing ethanol uses yeast.

Write the equation for this preparation and state the essential conditions. [2]

The equation for fermentation is

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$$

Fermentation is carried out in warm conditions (between 20°C and 45°C) and in anaerobic conditions (i.e. in the absence of oxygen)

Both points are necessary here for the mark.

(c) At room temperature and pressure, the first four members of the alkanes are all gases butthe first four alcohols are all liquids.

Explain this difference in terms of intermolecular forces. [2]

The strongest intermolecular forces present in alcohols are hydrogen bonds. The strongest intermolecular forces in alkanes are van der Waals forces. Hydrogen bonds are stronger than van der Waals forces meaning that more energy is required to overcome them and hence alcohols have a higher boiling point.

Tip: When comparing the boiling (or melting) point of molecules always approach by identifying the intermolecular forces present and comparing their strength.

(d) The boiling points of 2-methylpropan-1-ol and butan-1-ol are shown below.

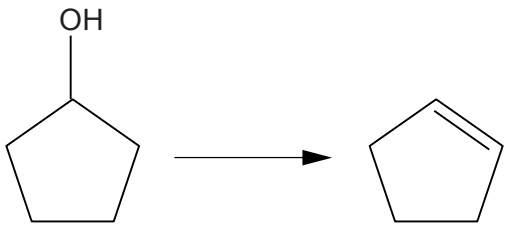
Alcohol	Boiling point/°C
2-methylpropan-1-ol	108
butan-1-ol	117

Explain why the boiling points are different. [2]

2-methylpropan-1-ol has a smaller surface area than 2-methylpropan-1-ol which means that there are weaker van der Waals forces between the molecules and so less energy is required to break the van der Waals forces in 2-methylpropan-1-ol

Tip: Straight chain molecules have a more regular structure than branched molecules. This means that the molecules are able to get closer together enabling stronger forces to be formed between the molecules.

(e) Alkenes can be prepared from alcohols. Cyclopentene can be prepared from cyclopentanol as shown in the equation below.



A student plans to prepare 5.00 g of cyclopentene from cyclopentanol. The percentage yield of this reaction is 45.0%.

(i) What is the name of this type of reaction? [1]

In this reaction water is being removed from cyclopentanol. This is therefore an example of a dehydration reaction.

(ii) Calculate the mass of cyclopentanol that the student should use.

Show your working. [3]

This is a moles calculation. We are asked to calculate the quantity of one chemical (in this case cyclopentanol) from information provided about another chemical (in this case we are given the mass of the cyclopentene required).

Moles of cyclopentene = $\frac{5}{68}$ = 0.0375 mol (68.0 is the M_r of cyclopentene)

One mole of cyclohexanol forms one mole of cyclopentene. Taking into account the 45% yield the number of moles of cyclohexanol required is calculated in the next step:

Therefore the number of moles of cyclopentanol required = 0.0375 x $\frac{100}{45}$ = 0.163

Therefore the mass of cyclopentanol required = 0.163 x 86.0 = 14.0g (86.0 is the M_r of cyclopentanol)

Tip: You can draw structural, displayed or a combination of both when answering questions that ask you to show structures. It is a good idea to draw displayed formulae to ensure no atoms are inadvertently missed out!

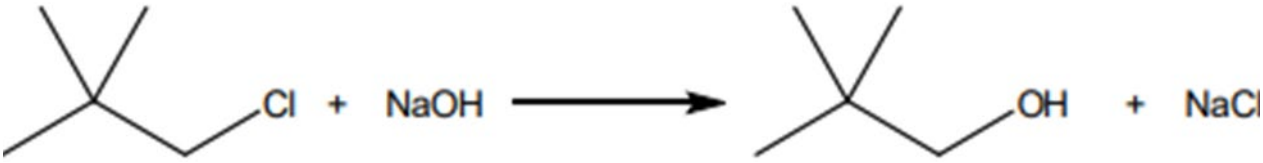
Tip: In a question like this, many candidates get confused about how to deal with the percentage yield. When the reactant and product are in a 1:1 ratio, if we are only getting 45% (i.e. 45/100) of the expected amount of product then we need to increase the amount of reactant by (100/45)

(f) Alcohols can be prepared from halogenoalkanes. 2,2-dimethylpropan-1-ol can be prepared by hydrolysis of a chloroalkane with aqueous sodium hydroxide.

(i) Write the equation for this reaction.

Use structures for the organic compounds. [1]

The formation of an alcohol from a haloalkane using aqueous sodium hydroxide is an example of a nucleophilic substitution reaction. Therefore, the chloroalkane required is 1-chloro-2,2-dimethylpropane.

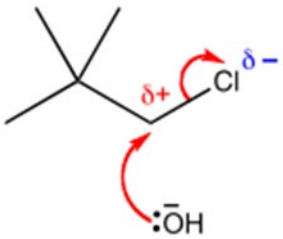


(ii) Outline the mechanism for this reaction.

Show curly arrows and relevant dipoles. [2]

The curly arrow should be shown starting from the lone pair of electrons on the OH^- ion moving to the C atom of the C-Cl bond.

The correct dipole needs to be shown on the C-Cl bond i.e. $C^{\delta+}$ and $Cl^{\delta-}$ and a curly arrow needs to be shown starting from the C-Cl bond to the Cl atom



[Total 15 Marks]