FACTFILE:
GCE CHEMISTRY

2.6 ALCOHOLS

Rewarding Learning

Learning Outcomes

Students should be able to:

2.6.1 refer to the effect of hydrogen bonding on boiling point and solubility of alcohols with water;

2.6.2 classify an alcohol as primary, secondary or tertiary;

2.6.3 recall the preparation of alcohols from halogenoalkanes;

2.6.4 describe the complete and incomplete combustion of alcohols and their use as an alternative fuel;

2.6.5 describe reaction of alcohols with sodium, hydrogen bromide and phosphorus pentachloride;

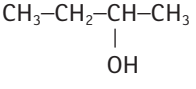
2.6.6 describe the oxidation of alcohols using acidified potassium dichromate(VI) with reference to formation of aldehydes and carboxylic acids from primary alcohols, formation of ketones from secondary alcohols and resistance to oxidation of tertiary alcohols;

Alcohols

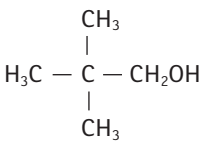
Alcohols have the **–OH** functional group. This is known as the hydroxyl group and is the alcohol functional group.

Alcohols are named according to IUPAC rules:

- Name the longest carbon chain containing the –OH functional group and add the suffix –ol.
- Number the chain so that the attachment position is as low as possible.
- For more than one –OH present, indicate their numbers with, di, tri etc and indicate their positions by numbering the chain so that the attachment numbers are as low as possible.
- Indicate the presence of any alkyl groups in the usual manner.

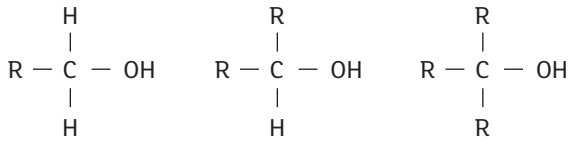


butan-2-ol



2,2-dimethylpropan-1-ol

Alcohols can be classified as primary, secondary or tertiary:



Primary (1°) Secondary (2°) Tertiary (3°)

- A **primary alcohol** has one carbon atom bonded directly to the carbon atom that is bonded to the –OH group (exception is methanol).
- A **secondary alcohol** has two carbon atoms bonded directly to the carbon atom that is bonded to the –OH group.
- A **primary alcohol** has three carbon atoms bonded directly to the carbon atom that is bonded to the –OH group.

The boiling point of a particular alcohol is higher than the corresponding alkane with the same number of carbon atoms. This is due to the ability of an alcohol to exhibit hydrogen bonding between alcohol molecules in addition to van der Waals' forces.

In the laboratory, alcohols are often produced via nucleophilic substitution of halogenoalkanes by aqueous alkali.

Alcohols such as ethanol are increasingly used as fuels as they are renewable, carbon-neutral and have high enthalpies of combustion:

$C_2H_5OH + 3O_2 \longrightarrow 2CO_2 + 3H_2O \quad \Delta H = -1371 \text{ kJ mol}^{-1}$

Alcohols completely combust to give carbon dioxide and water and incompletely combust to give carbon monoxide, water and sometimes soot (unburnt carbon).

A non-smoky/blue flame is indicative of complete combustion and low carbon content. A smoky flame is indicative of incomplete combustion/high carbon content.

Reactions of alcohols

1. with sodium

$2C_2H_5OH + 2Na \rightarrow 2C_2H_5ONa + H_2$

C_2H_5ONa is sodium ethoxide. The observations are that the sodium disappears, fizzing occurs and the mixture warms up.

2. with HBr

$C_2H_5OH + HBr \rightarrow C_2H_5Br + H_2O$

3. with PCl_5

$C_2H_5OH + PCl_5 \rightarrow C_2H_5Cl + POCl_3 + HCl$

The observations for this reaction are that the solid disappears and the mixture warms up, steamy/misty fumes are released and there is a hissing noise.

The reaction between phosphorus pentachloride and an alcohol can be used as a diagnostic test for alcohols as white, steamy fumes are observed which turn damp litmus paper red.

4. Oxidation

Alcohols can also undergo oxidation reactions, resulting in a number of different products depending on the alcohol and conditions used. Primary (1°), secondary (2°) and tertiary (3°) alcohols behave differently towards typical oxidising agents such as acidified potassium dichromate(VI) ($K_2Cr_2O_7$) and this can be used to distinguish between the alcohols. [O] can be used to represent the oxidising agent in an equation.

Primary alcohols can be oxidised to **aldehydes** a series of compounds which have the structure:

For example:

$CH_3CH_2OH + [O] \rightarrow CH_3CHO + H_2O$

ethanol ethanal

During this reaction using acidified potassium dichromate(VI) solution, the solution changes from orange to green and there is a change in smell.

It is essential to distil off the aldehyde as it is formed before it is oxidised to the corresponding **carboxylic acid**.

$CH_3CHO + [O] \rightarrow CH_3COOH$
ethanal ethanoic acid

The oxidation from the alcohol to the carboxylic acid can be written as one step:

$CH_3CH_2OH + 2[O] \rightarrow CH_3COOH + H_2O$

Secondary alcohols are oxidised to **ketones**, which have the structure:

During this reaction using acidified potassium dichromate(VI) solution, the solution changes from orange to green and there is a change in smell.

Tertiary alcohols are resistant to oxidation.

Revision Questions

1 Which one of the following is a tertiary alcohol?

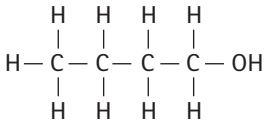
A. 2-methylbutan-2-ol

B. 2-methylbutan-3-ol

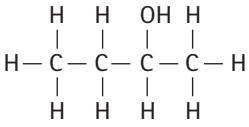
C. pentan-2-ol

D. pentan-3-ol [1]

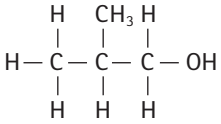
2 C_4H_9OH has four isomers; butan-1-ol, butan-2-ol and two others **A** and **B**.



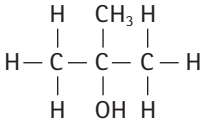
butan-1-ol



butan-2-ol



A



B

(a) (i) Give the IUPAC names of isomers **A** and **B**

A .....

B .....[2]

(ii) Name a reagent you could use to distinguish between isomers **A** and **B**. Include any observations that occur when it is reacted with **A** and **B**.

.....

.....

.....

..... [3]

(b) Butan-1-ol has potential as a biofuel, which is an alternative fuel. Suggest why butan-1-ol can be considered as an alternative fuel.

.....

..... [1]

(c) Write an equation for the recation of butan-2-ol with phosphorus pentahchloride, PCl_5, and name the organic product.

.....

.....

..... [3]

3 3-methylpentan-1-ol is an alcohol.

(a) Draw the structural formula of 3-methylpentan-1-ol.

[1]

(b) Write an equation for the complete combustion of 3-methylpentan-1-ol.

..... [2]

(c) 3-methylpentan-1-ol is a primary alcohol. Name one secondary alcohol which is isomeric with 3-methylpentan-1-ol.

..... [1]