TOPIC 22 Alcohols and Carboxylic Acids

Objectives

Candidates should be able to:

(a) describe the alcohols as an homologous series containing the –OH group
(b) draw the structures of alcohols, C_1 to C_4, and name the unbranched alcohols methanol to butanol
(c) describe the properties of alcohols in terms of combustion and oxidation to carboxylic acids
(d) describe the formation of ethanol by the catalysed addition of steam to ethene and by fermentation of glucose
(e) state some uses of ethanol
(f) describe the carboxylic acids as an homologous series containing the $–CO_2H$ group
(g) draw the structures of carboxylic acids methanoic acid to butanoic acid and name the unbranched acids, methanoic acid to butanoic acid
(h) describe the carboxylic acids as weak acids, reacting with carbonates, bases and some metals
(i) describe the formation of ethanoic acid by the oxidation of ethanol by atmospheric oxygen or acidified potassium manganate(VII)
(j) describe the reaction of a carboxylic acid with an alcohol to form an ester
(k) state some commercial uses of esters

1. Alcohols

Alcohols are a homologous series of organic compounds that have the general formula $C_nH_{2n+1}OH$, where $n \geqslant 1$. They have the functional group $-OH$, which is also called the hydroxyl group.

Names of alcohols usually end with '-ol'. The first four members of the alcohol homologous series are listed in the following table.

Name	Methanol	Ethanol	Propanol	Butanol
n	1	2	3	4
Molecular formula	CH_3OH	C_2H_5OH	C_3H_7OH	C_4H_9OH

Alcohols are liquids at room temperature and pressure and are very volatile. As the molecular sizes of the alcohols increases down the series, the forces of attraction between the molecules become stronger. As a result, the melting and boiling points increase with larger molecular size.

Smaller alcohols are miscible in water. As the molecular size of the alcohols increases, solubility in water decreases.

An important member of the homologous series is ethanol, which is used in food and drinks, as a solvent for paints and perfumes, and as fuel.

2. Chemical Properties of Alcohols

Alcohols undergo complete combustion when there is sufficient oxygen to produce carbon dioxide and water.

When heated with oxidising agents such as acidified potassium manganate(VII), alcohols undergo oxidation to form carboxylic acids.

3. Production of Ethanol

Ethanol used for human consumption is usually produced through fermentation of glucose from fruits or grains. The process is carried out with yeast at 37 °C, in the absence of oxygen.

The temperature has to be kept at 37 °C as the enzymes in yeast work best at this temperature. Increasing the temperature would denature the enzymes and cause them to be unable to catalyse the reaction.

Fermentation produces a dilute solution of ethanol. High concentrations of ethanol cannot be obtained directly from this process as the yeast dies when the concentration of ethanol reaches about 15%.

Ethanol is also produced on a larger scale through the addition of steam to ethene. This takes place at 300 °C and 60 atm in the presence of phosphoric(V) acid as a catalyst. This process produces an ethanol solution of higher purity and concentration compared to fermentation.

4. Carboxylic Acids

Alcohols are a homologous series of organic acids that have the general formula $C_nH_{2n+1}COOH$, where $n \geqslant 0$. They have the functional group –COOH, which is also called the carboxyl group.

Names of carboxylic acids usually end with '-oic acid'. The first four members of the carboxylic acid homologous series are listed in the following table.

Name	Methanoic acid	Ethanoic acid	Propanoic acid	Butanoic acid
n	0	1	2	3
Molecular formula	HCOOH	CH_3COOH	C_2H_5COOH	C_3H_7COOH

5. Chemical Properties of Carboxylic Acids

Carboxylic acids are weak acids that partially dissociate in water to give hydrogen ions. Due to the presence of these hydrogen ions when carboxylic acids dissolve in water, they undergo reactions of acids.

Carboxylic acids react with metals that lie above hydrogen in the reactivity series to produce salt and water.

ethanoic acid + magnesium → magnesium ethanoate + hydrogen

$2CH_3COOH(aq) + Mg(s) \rightarrow (CH_3COO)_2Mg(aq) + H_2(g)$

Carboxylic acids react with metal carbonates to produce salt, carbon dioxide and water.

ethanoic acid + calcium carbonate → calcium ethanoate + carbon dioxide + water

$2CH_3COOH(aq) + CaCO_3(s) \rightarrow (CH_3COO)_2Ca(aq) + CO_2(g) + H_2O(l)$

Carboxylic acids react with metal hydroxides to produce salt and water.

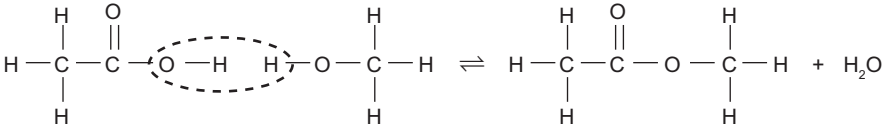
ethanoic acid + sodium hydroxide → sodium ethanoate + water

$CH_3COOH(aq) + NaOH(aq) \rightarrow CH_3COONa(aq) + H_2O(l)$

6. Esters

Esters are sweet-smelling liquids that are used as solvents for perfumes or for making artificial food flavourings. They can be produced through esterification from the reaction between alcohols and carboxylic acids.

Esterification requires heating an alcohol and a carboxylic acid with a few drops of concentrated sulfuric acid as a catalyst. This process is a reversible reaction as indicated by the ⇌ symbol.



ethanoic acid methanol methyl ethanoate water

Apart from acting as a catalyst in the reaction, concentrated sulfuric acid is a dehydrating agent and removes water produced. This also helps speeding up the rate of product formation.

Note that there are two parts to the name of an ester. The first part of the name is taken from the alcohol while the second part is taken from the carboxylic acid from which it is made.