

Alcohols, Carboxylic Acids and Esters Notes

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Alcohols, carboxylic acids, and esters are important groups of organic compounds, each with their own structures, properties, and uses. Let's look at alcohols first.

Alcohols

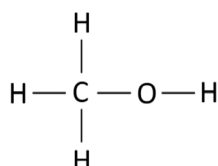
An alcohol: a homologous series of compounds that all contain -OH functional group.

The general formula of an alcohol is $\text{C}_n\text{H}_{2n+2}\text{O}$.

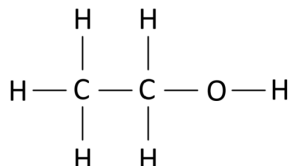
That's a single O. The 2 belongs to the H. All alcohols have names that end in **-ol**.

A quick reminder that a homologous series of compounds is a group of compounds with the same general formula, that have similar chemical properties meaning that they react the same way as each other and that they show a gradual variation in their physical properties.

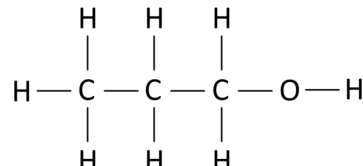
1. Methanol, CH_3OH



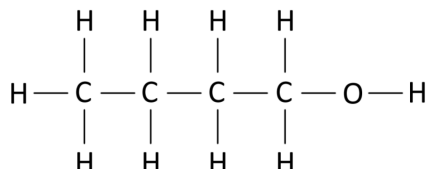
2. Ethanol, $\text{C}_2\text{H}_5\text{OH}$



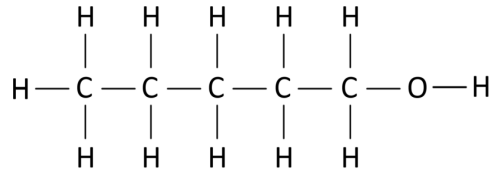
3. Propanol, $\text{C}_3\text{H}_7\text{OH}$



4. Butanol, $\text{C}_4\text{H}_9\text{OH}$



5. Pentanol, $\text{C}_5\text{H}_{11}\text{OH}$



Reactions of Alcohols

We could see exam questions on the reactions of alcohols. We are required to know four reactions involving alcohols, the reaction with sodium, combustion, addition of water and oxidation of alcohols. Let's look at each in detail.

Reaction of alcohols with sodium

Alcohols are weak acids and can react with reactive metals like sodium to form a sodium alkoxide and hydrogen gas.

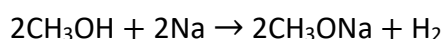
What is a weak acid? A weak acid will only partially dissociate when they are dissolved in water. For example ethanoic acid, CH_3COOH .

Dissociate means to split up and you **must** use this key word, though the exam board will also accept "ionise" instead.

Let's explain this a bit further. Let's say we have 1000 molecules of ethanoic acid, CH_3COOH , and we added these to some water then maybe only around 20 molecules would dissociate into 20 H^+ ions and 20 CH_3COO^- ions. The rest would not dissociate and just remain as CH_3COOH molecules in solution. This is why ethanoic acid is a weak acid as it doesn't give us many H^+ ions use.

Check out the example below.

methanol + sodium $\rightarrow$ sodium methoxide + hydrogen gas

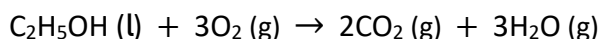


Ethanol, propanol and butanol will all react with sodium in a very similar way.

Combustion of Alcohols

Like most organic compounds, alcohols can burn in air. Check out the example of the combustion of ethanol below.

ethanol + oxygen → carbon dioxide + water



This is complete combustion. There are two types of combustion, **complete combustion** and **incomplete combustion**.

Complete combustion – occurs when a fuel fully reacts with a sufficient supply of oxygen. It results in the formation of two main products, carbon dioxide, CO₂ and water, H₂O.

Incomplete combustion – occurs when a fuel burns in an insufficient supply of oxygen. As a result, the fuel is not fully oxidised. This leads to the formation of harmful products, such as carbon monoxide, CO and soot (carbon particles), in addition to water, H₂O.

Mixing Alcohols with Water

Alcohols don't really react with water as such. This sort of 'reaction' is more about which alcohols are soluble in water.

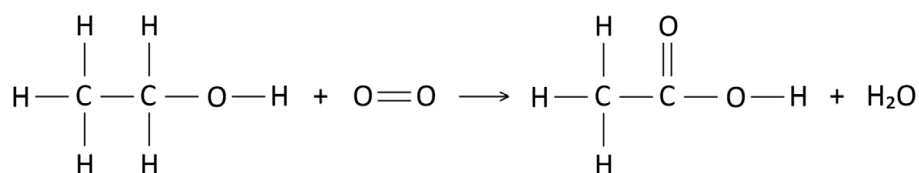
Short chain alcohols such as methanol, ethanol and propanol are all soluble in water so will form a solution when we mix them with water. This property is used to make alcoholic drinks. Alcoholic drinks are a solution of ethanol and water. Larger chain alcohols such as hexanol, are less soluble in water than the short chained alcohols.

Oxidation of Alcohols

If a solution of ethanol is left to stand in air it is oxidised by oxygen. This is why wine turns into vinegar if left in contact with air. When alcohols are oxidised they are converted into carboxylic acids.

Check out the reaction shown below.

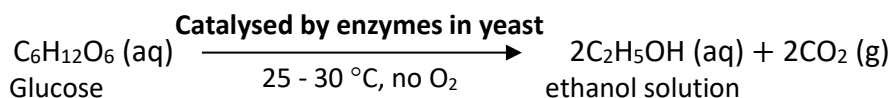
ethanol + oxygen → ethanoic acid + water



What is this reaction used for? To produce ethanoic acid (vinegar) which is used to flavour food and as a preservative in other foods like pickled eggs for example. Pickled means conserved in vinegar.

Fermentation

Fermentation is a process where microorganisms, like yeast, break down sugars to make ethanol and carbon dioxide. Ethanol is used in making drinks and fuels. The equation below shows the fermentation reaction.



Conditions:

- **Catalyst is the enzymes present in the yeast.**
- **Room temperature is best. The reaction will take place above 10°C.**

The reaction must be anaerobic (there must be no O₂ present) otherwise the ethanol will be oxidised to ethanoic acid.

Fermentation gives a solution of ethanol. Fractional distillation can be used to give pure ethanol.

Fermentation is used to make all alcoholic drinks. But if hydration of ethene gives a pure product that doesn't need any separation processes, why would people use fermentation?

1. Fermentation is a cheap process as we don't need to have a complicated infrastructure to do it.
2. We don't have to heat the reaction as it happens at room temperature.
3. Fermentation doesn't need to be pressurised, so complicated infrastructure isn't needed.

Carboxylic Acids

Carboxylic acids: are a homologous series of compounds that all contain the **–COOH** functional group.

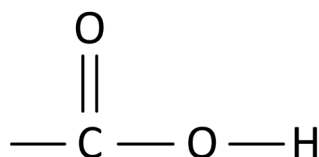
They all have names that end in **–anoic acid**. Carboxylic acids are weak acids and partially dissociate in solution.

What is a functional group? It can be an atom, or a group of atoms, that determines the chemical properties and reactions of an organic compound. In simpler terms it's the reactive part of a compound that gives the compound its specific chemical properties 😊

A quick reminder about weak acids. A weak acid will only partially dissociate when they are dissolved in water. For example ethanoic acid, CH_3COOH .

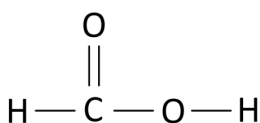
Dissociate means to split up and you **must** use this key word, though the exam board will also accept ionise instead.

We could be asked to draw the **–COOH** functional group in the exam. The figure below shows this functional group.

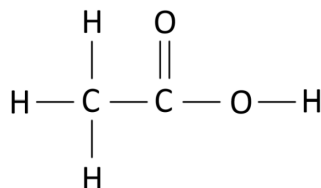


The figure below shows the names, molecular formulae and structures of the first **three** carboxylic acids.

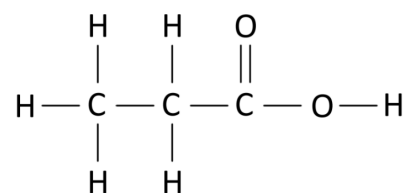
1. Methanoic acid, HCOOH



2. Ethanoic acid, CH_3COOH



3. Propanoic acid, $\text{C}_2\text{H}_5\text{COOH}$



Reactions of Carboxylic Acids

Mixing Carboxylic Acids with Water

Small carboxylic acids, such as methanoic acid and ethanoic acid, are highly soluble in water so when we mix them with water they dissolve completely.

Larger carboxylic acids are less soluble in water than smaller carboxylic acids. This is all we have to know about this particular interaction.

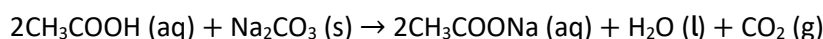
Reacting Carboxylic Acids with Metal Carbonates

Like all acids, carboxylic acids react with metal carbonates to produce metal salts, carbon dioxide and water.

The salts formed from this type of reaction have names that end in **–anoate** for example methanoate and ethanoate.

Check out the example below 😊

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



Reacting Carboxylic Acids with Alcohols

Carboxylic acids react with alcohols in the presence of an acid catalyst to form esters. This reaction is known as **esterification**. The word equation for the reaction is:

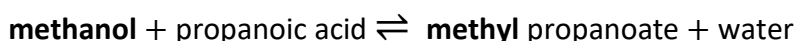


Note about this reaction: this reaction won't form esters quickly at room temperature so we would heat it in a water bath. It's not heated with a Bunsen burner as alcohols are flammable. The catalyst used is concentrated sulfuric acid.

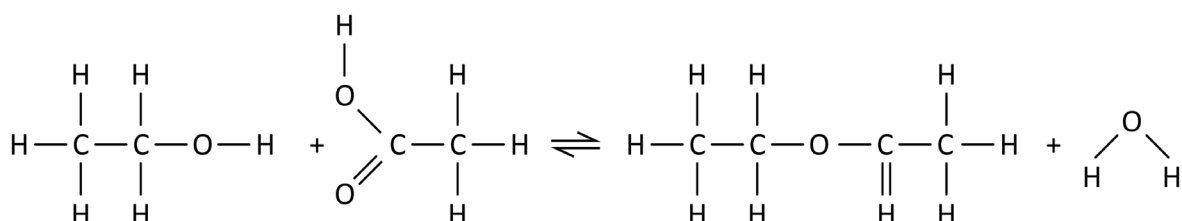
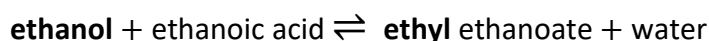
Naming esters: the name of an ester is found from:

1. The alcohol provides the first part of the name (alkyl group).
2. The carboxylic acid provides the second part (ending in **-oate**).

Take the example of methanol reacting with propanoic acid.



Also let's look at the example of ethanol reacting with ethanoic acid.



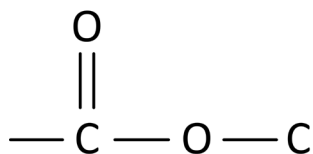
In both examples above we have put the alcohol in bold so that you can see that the first part of the name of the ester is down to the alcohol in the reactants.

Esters

Esters themselves are not covered in depth for the GCSE specification anymore, which is a shame, there is some wonderful chemistry involving esters. I have included them in this booklet because esters are cool and if you're going on to A level chemistry it's not bad to have a bit of an introduction prior to that.

An ester: a homologous series of compounds that all contain the **-COOC functional group**.

The **-COOC** functional group is drawn as follows:



As we saw in the previous section esters are formed by the reaction of a carboxylic acid with an alcohol.

That's it 😊 That's all we need to know about esters for the GCSE 😊