

# WJEC Chemistry A-level

## 2.7: Alcohols and Carboxylic Acids

Detailed Notes

Welsh Specification

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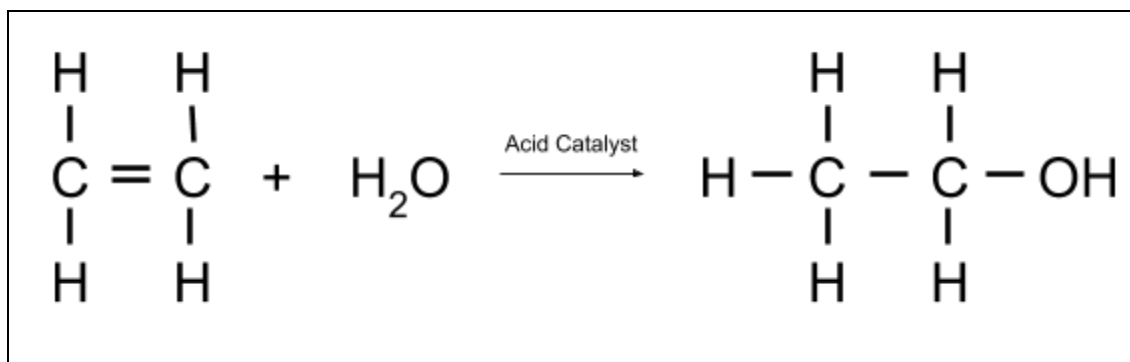
## Production of Alcohols

Alcohols contain an **-OH functional group** and follow the general formula  $C_nH_{2n+1}OH$ . They can be produced via two main methods.

### Hydration

This method produces alcohols from **alkenes** in the presence of an **acid catalyst**. Phosphoric acid is commonly used as the catalyst under **aqueous** conditions at **300°C** and high pressures.

*Example:*



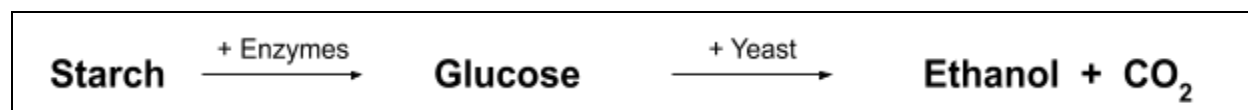
This process has a **very high percentage yield** as ethanol is the only product. Therefore the hydration method is favoured as an industrial process.

### Fermentation

In this process, **enzymes** break down starch from crops into **sugars** which can then be **fermented** and **distilled** to form alcohol. This method is **cheaper** than hydration as it can be carried out at a lower temperature. However, it has to be fermented in **batches**, meaning it is a much slower process with a **lower percentage yield**.

Ethanol is a common **biofuel** produced in this way. It is considered to be **carbon neutral** as the carbon given out when it is burned is equal to the carbon taken in by the crops during the growing process.

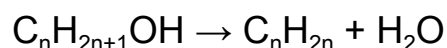
*Example:*





## Dehydration of Alcohols

Alkenes can be formed from the **dehydration** of alcohols, where a molecule of water is **eliminated** from the molecule. In order to do this, concentrated sulfuric acid is used as a catalyst.

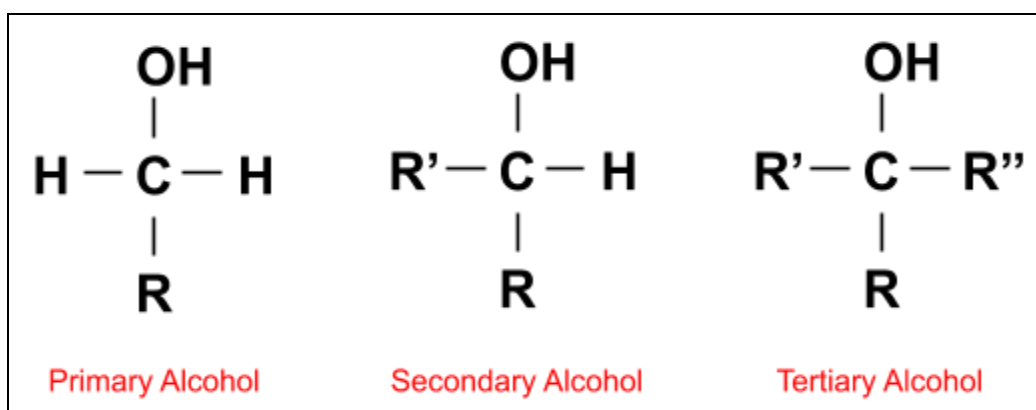


This reaction means that **addition polymers** can be produced from **fermentation** without the need for crude oil, a non-renewable resource. Fermentation produces the **primary alcohol** which is then **dehydrated** to produce an alkene used in the production of addition polymers.

## Oxidation of Alcohols

Alcohols can be **primary (1°)**, **secondary (2°)** or **tertiary (3°)**, depending on the position of the -OH alcohol group in the molecule. R groups represent basic hydrocarbon chains of any length and are often used when representing different degrees of alcohol as a simplification.

Example:

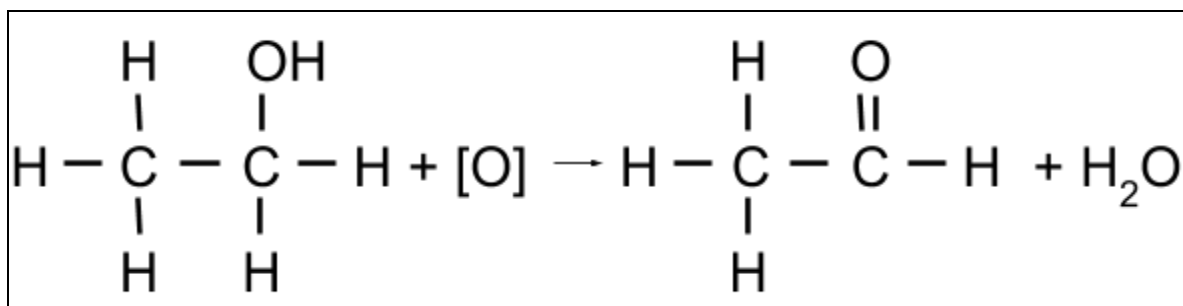


Primary and secondary alcohols can be **oxidised** to produce various products but tertiary alcohols are **not easily oxidised**.

## Formation of Aldehydes

**Primary** alcohols can be heated in the presence of **acidified potassium dichromate(VI)** and **distilled** to produce **aldehydes**.

Example:

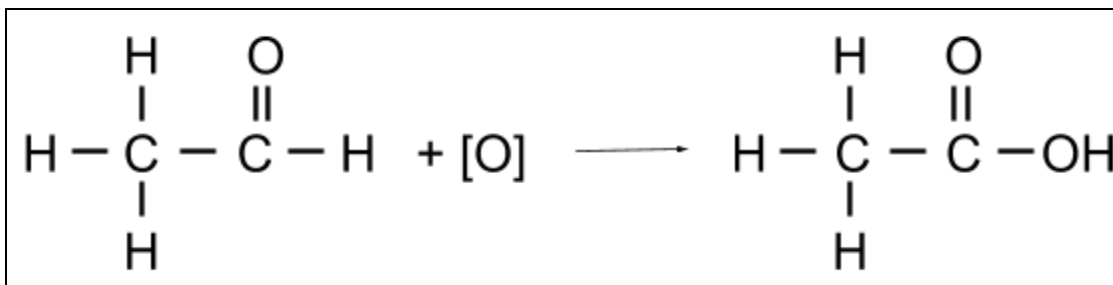




## Formation of Carboxylic Acids

When heated further under **reflux** conditions, primary alcohols will **oxidise further** to produce **carboxylic acids**. In particular, the **aldehyde** produced from the primary alcohol will undergo oxidation, forming a carboxylic acid.

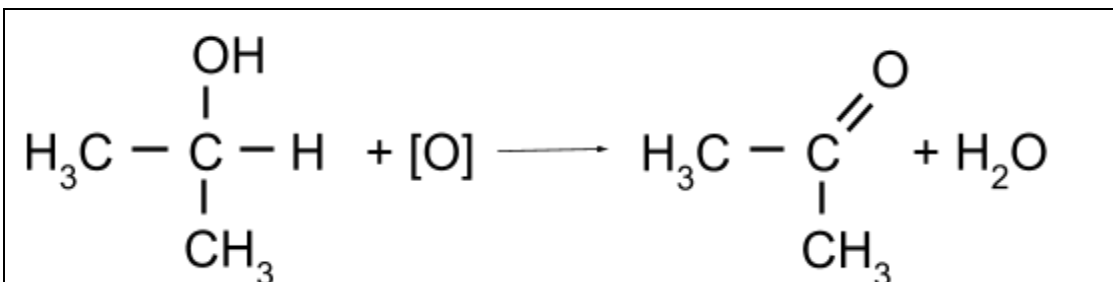
Example:



## Formation of Ketones

**Secondary** alcohols can be oxidised when heated in the presence of **acidified potassium dichromate(VI)** to produce **ketones**.

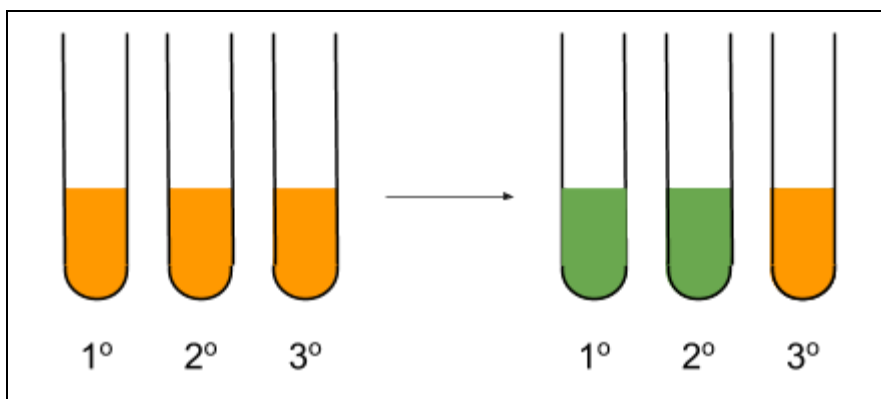
Example:



## Testing for Alcohols

**Potassium dichromate(VI)** ( $\text{K}_2\text{Cr}_2\text{O}_7$ ) is used as the oxidising agent in the oxidation of alcohols. It is reduced as the alcohol is oxidised.

This oxidation can be observed as a **colour change** from **orange to green** when the alcohol is oxidised:



The primary and secondary alcohols are **easily oxidised** so a colour change is observed. Any tertiary alcohol will remain **orange** as they are **not easily oxidised**.

### Testing for Carboxylic Acids

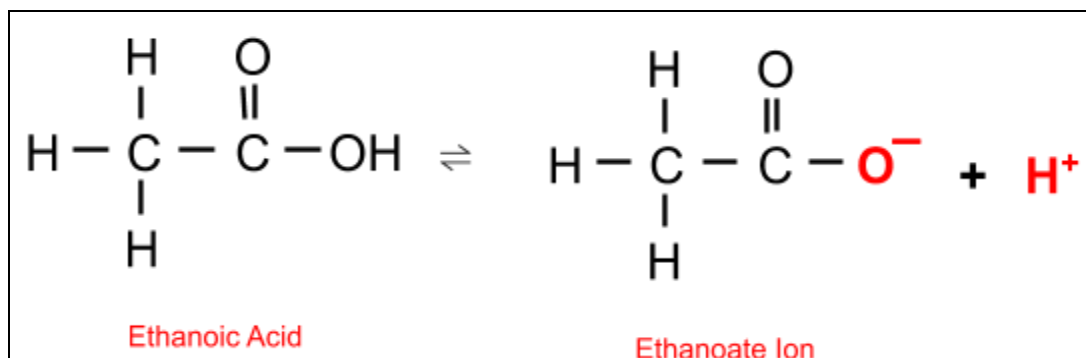
These compounds react as acids with **sodium hydrogencarbonate**, producing **CO<sub>2</sub> gas**. This gas can be collected and tested using **limewater**. The solution will turn **cloudy** if the gas is CO<sub>2</sub>.

### Reactions of Carboxylic Acids

Carboxylic acids are organic compounds recognised by the functional group **-COOH**, containing a **carbonyl group (C=O)** and an **-OH alcohol group**. They are produced from the oxidation of primary alcohols under reflux.

Carboxylic acids are **weak acids** meaning they only **slightly dissociate** in solution, forming a H<sup>+</sup> ion and a **carboxylate ion, RCOO<sup>-</sup>**. Therefore they can react like acids in reactions.

*Example:*



### Reactions with Carbonates

Carboxylic acids react with carbonates to produce a **carboxylate salt, water and CO<sub>2</sub>**.

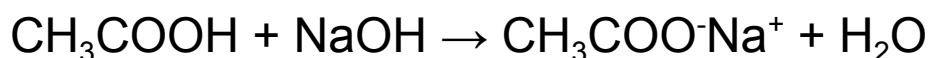


Carboxylic acids react with **hydrogen carbonates** in a similar way:



### Reactions with Bases

Carboxylic acids react with bases to produce a **carboxylate salt and water**.

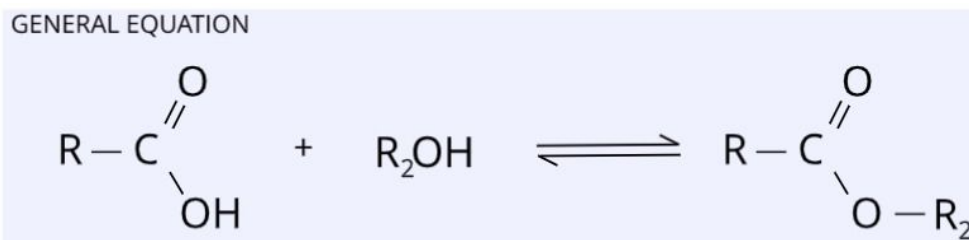




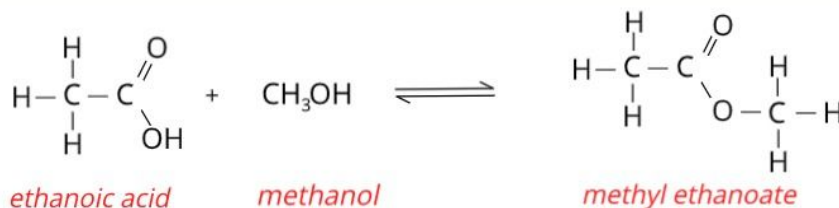
## Esterification

Carboxylic acids can react with alcohols in the presence of a **strong acid catalyst**, under **reflux**, to form esters. **Concentrated sulfuric acid** is often used as the acid catalyst. These are carbon compounds with a **C=O** carbonyl group and a **C-O-C** bond which joins together the two reactants.

Example:



E.g.

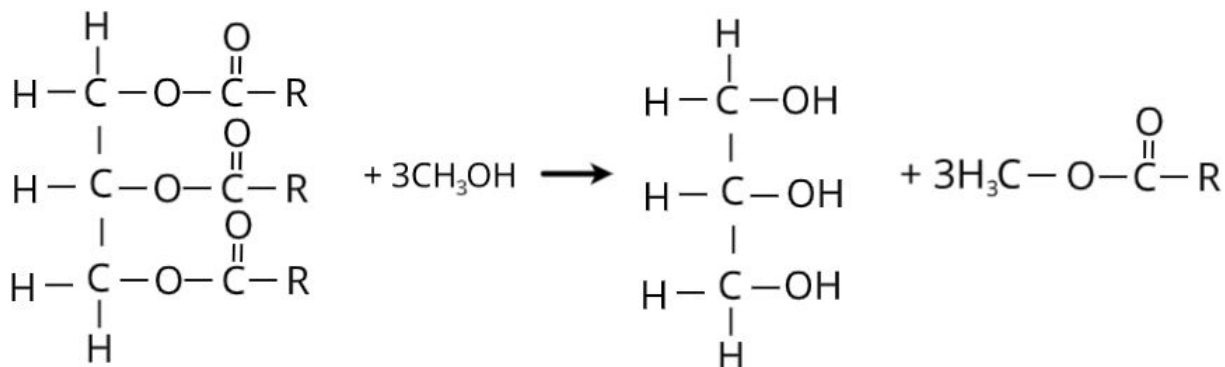


Esters are **sweet smelling** compounds used in **food flavourings** and **perfumes**. They have **low boiling points** and also make good **solvents** for other polar molecules.

## Triglyceride Esters

Vegetable oils and fats are esters of naturally occurring **glycerol (propane-1,2,3-triol)**. This alcohol undergoes **esterification** to form **triglyceride esters**.

Example:



**Biodiesel** is an ester produced from vegetable oils and methanol in the presence of a **strong acid catalyst**.





## Separating Productions

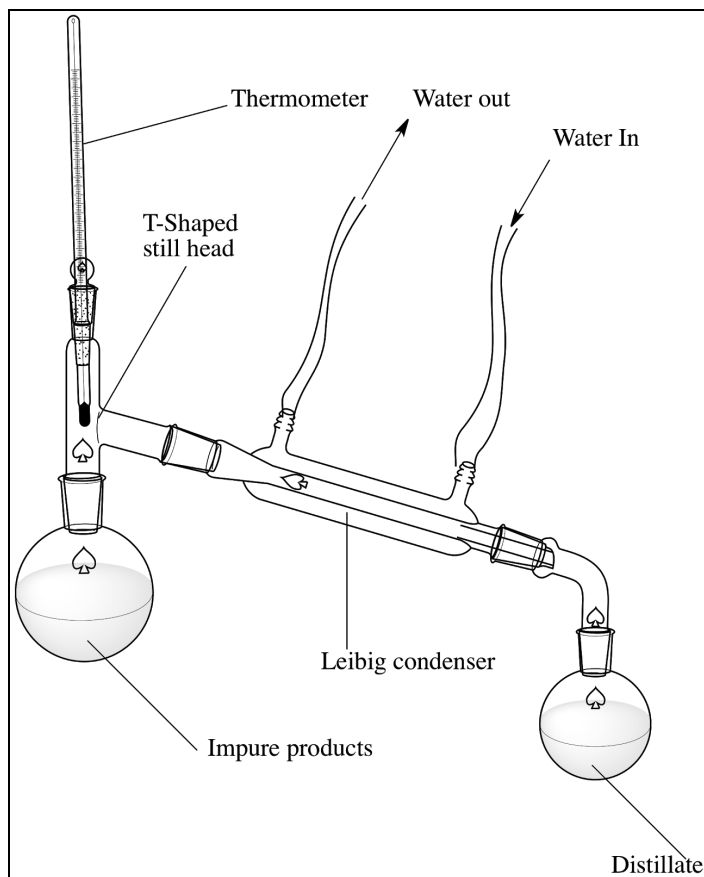
Different carbon compounds have **different boiling points** depending on the **length** of the carbon chain and the **functional groups** present. This is very useful when there is a mixture of compounds as it means they can be easily separated by **distillation**.

### Distillation

In distillation, the mixture is **gradually warmed** and held at the boiling point of the lowest compound (this value can be found in a data book). This compound will **evaporate** and **condense** away from the original mixture so that the **isolated product** can be collected.

The temperature of the mixture can then be raised to the boiling point of the next compound and the process repeated until all components of the mixture have been separated.

A special arrangement of equipment, including a **Liebig condenser** must be used to carry out this distillation process.





The distillation process is especially useful for the **separation of alcohols** and their **oxidised forms** as they have quite differing boiling points due to the type of **intermolecular forces** present.

*Example:*

Compound	Family	Mr	IMF Type	Boiling Point (°C)
$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$	alkane	58	Van der Waals	-1
$\text{CH}_3\text{CH}_2\text{CHO}$	aldehyde	58	Strong dipole	49
$(\text{CH}_3)_2\text{CO}$	ketone	58	Strong dipole	56
$\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$	alcohol	60	Hydrogen bonding	97

