

# WJEC Chemistry A-level

## 4.3: Alcohols and Phenols

Detailed Notes

Welsh Specification

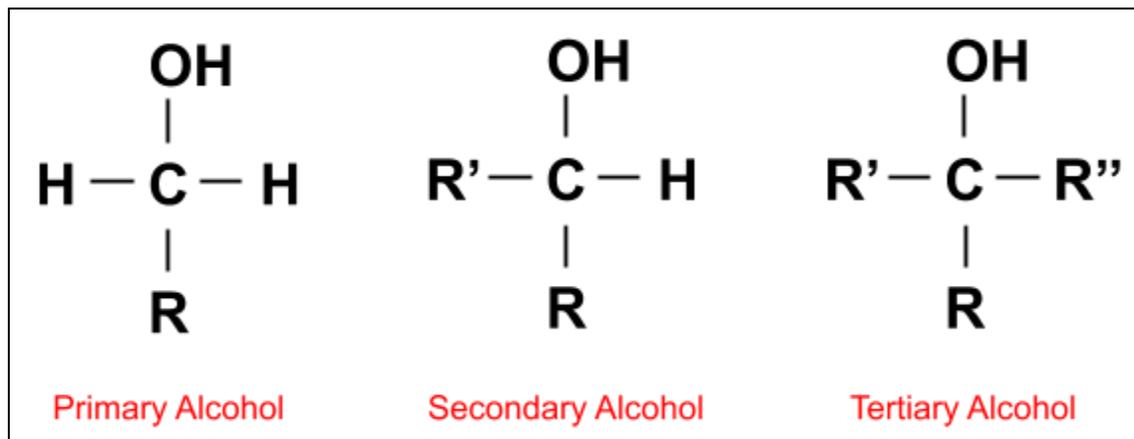
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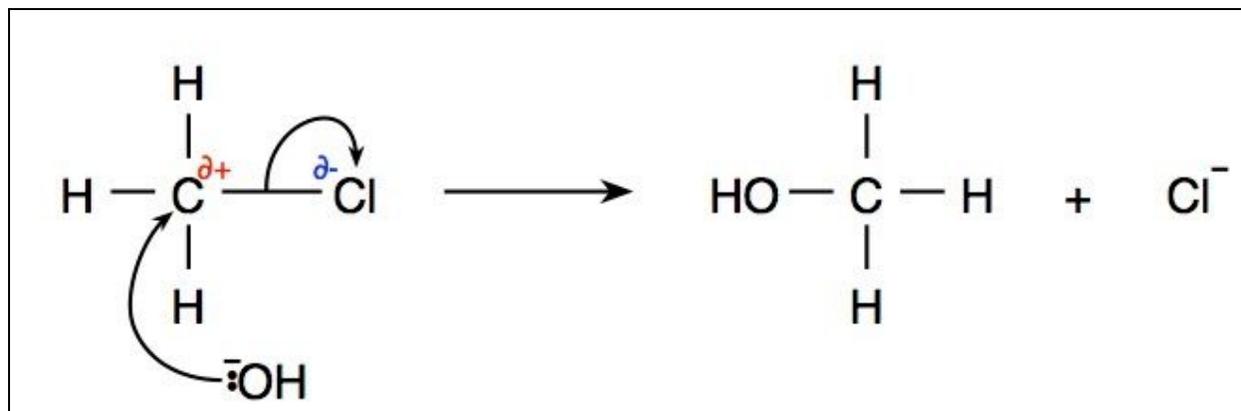
## Primary and Secondary Alcohols

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



**Primary and secondary** alcohols can be formed by **nucleophilic substitution** reactions by reacting halogenoalkanes with an aqueous hydroxide. They can also be produced from carbonyl compounds by **nucleophilic addition** reactions.

### Mechanism - Nucleophilic Substitution

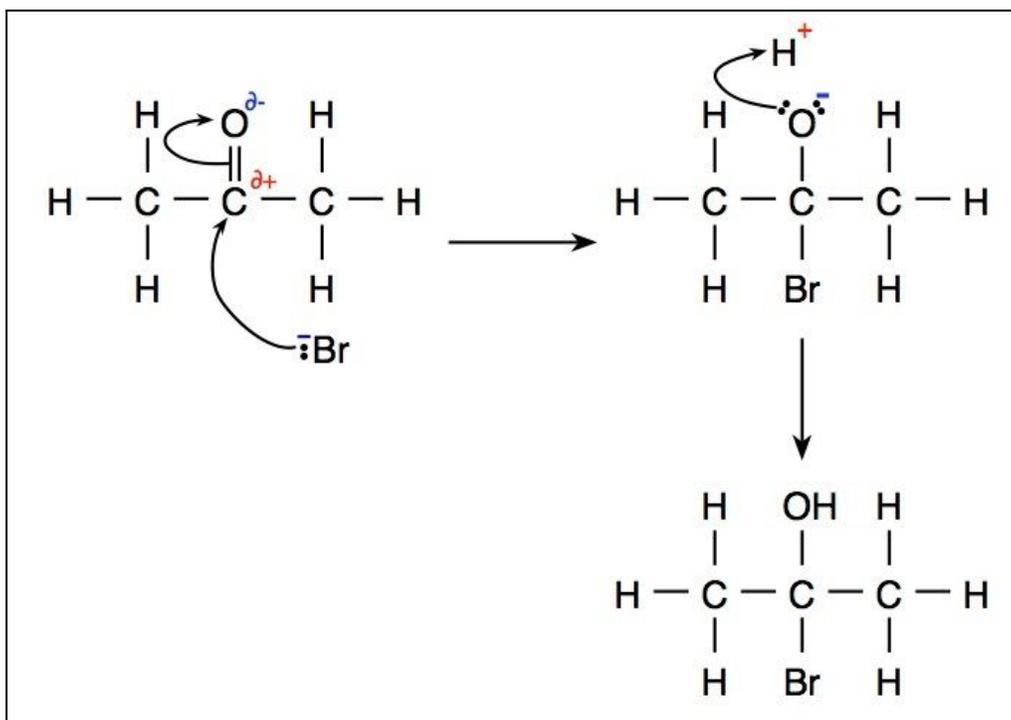


*In this example, a primary alcohol (methanol) is produced.*





## Mechanism - Nucleophilic Addition

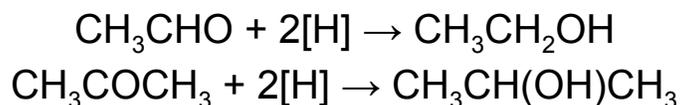


*In this example, a secondary alcohol (2-bromopropan-2-ol) is produced.*

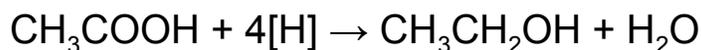
## Reduction of Carbonyl Compounds

Primary and secondary alcohols can also be formed by the **reduction of carbonyl compounds**.

**Aldehydes** and **ketones** can both be reduced by  $\text{NaBH}_4$  dissolved in water with methanol. This is the **reducing agent** which provides the  $\text{H}^-$  ion for the reaction. Aldehydes are reduced to primary alcohols whereas ketones are reduced to secondary alcohols:



**Carboxylic acids** can also be reduced to primary alcohols, but they require a **stronger reducing agent**.  $\text{LiAlH}_4$  is the reducing agent used for the reduction of carboxylic acids:



The mechanism for these reactions is **nucleophilic addition**. This is the same as the mechanism above - except that the bromide ion is a  $\text{H}^-$  ion.



## Reactions of Alcohols

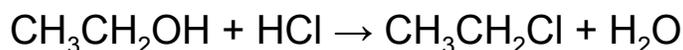
In primary and secondary alcohols, the **-OH** functional group is available to react with various different compounds, making it useful for **organic synthesis** reactions.

### Reactions with Hydrogen Halides

Alcohols can undergo a **nucleophilic substitution** reaction with **hydrogen halides** to produce a **halogenoalkane**. This is due to the **high polarity** of the H-Halide bond that results in the halide being able to act as a nucleophile.

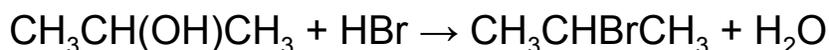
#### Hydrogen chloride

The reaction of primary and secondary alcohols with hydrogen chloride requires an **anhydrous zinc chloride catalyst**.



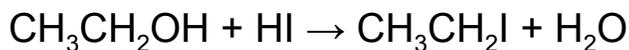
#### Hydrogen bromide

To react hydrogen bromide with an alcohol, **potassium bromide** is first added to the alcohol, followed by **concentrated sulfuric acid**. This produces the **hydrogen bromide in-situ**. This then reacts with the alcohol to produce a bromoalkane.



#### Hydrogen iodide

To react hydrogen iodide with an alcohol, **potassium iodide** is first added to the alcohol, followed by **concentrated phosphoric(V) acid**,  $\text{H}_3\text{PO}_4$ . This produces the hydrogen iodide in-situ which reacts with the alcohol to produce an iodoalkane. Phosphoric acid is used instead of sulfuric acid because the **sulfuric acid would oxidise the iodide ions** to iodine, reducing the **yield of hydrogen iodide**.



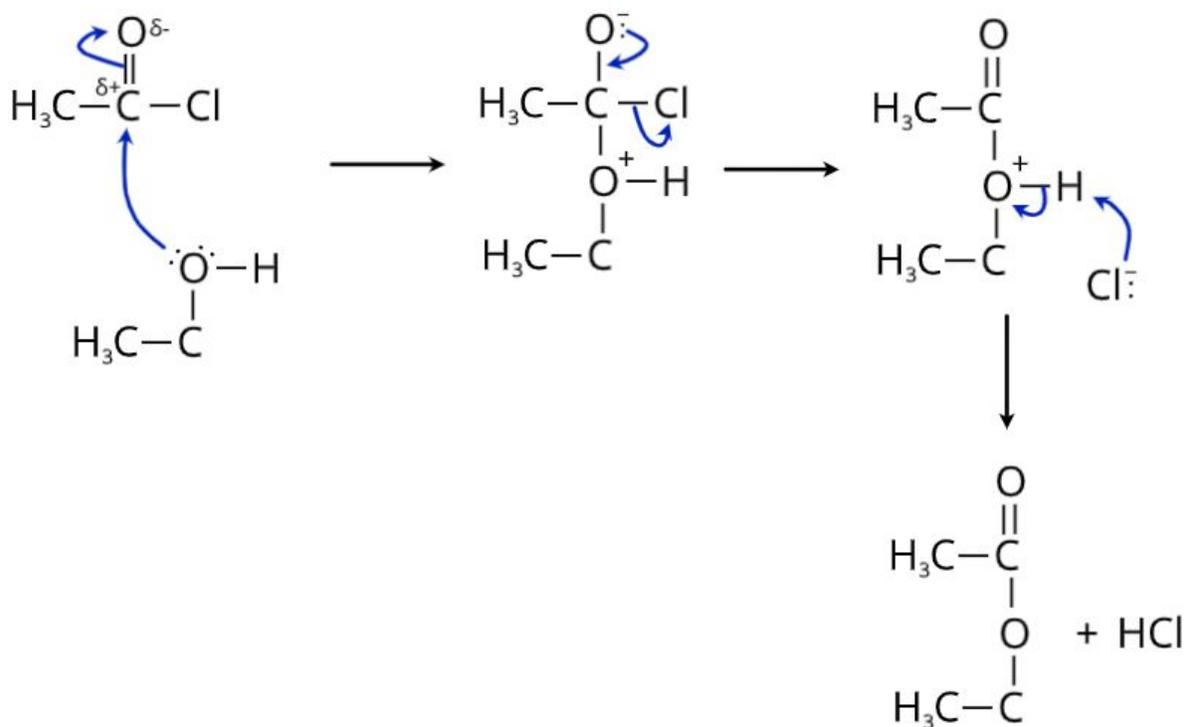
### Reactions with Ethanoyl Chloride

Ethanoyl chloride is a type of **acyl chloride**. These are derivatives of carboxylic acids, where the **-OH** group has been replaced with a **chlorine atom**. This makes for a **very polar** functional group that can react violently with **alcohols** to produce **esters**. Acyl chlorides react with alcohols in **nucleophilic addition elimination** reactions.





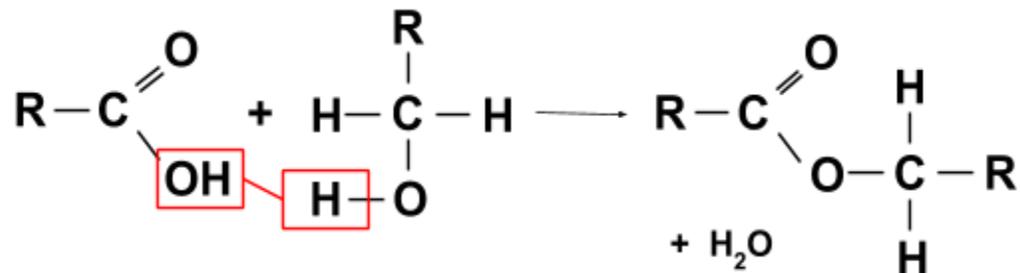
Example - Nucleophilic addition elimination of ethanoyl chloride with ethanol to produce ethyl ethanoate:



### Reactions with Carboxylic Acids

Carboxylic acids can react with **alcohols** in the presence of a **strong acid catalyst** to form **esters**. **Concentrated sulfuric acid** is commonly used as the acid catalyst. This process is called **esterification** and is carried out under **reflux**.

Example:



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





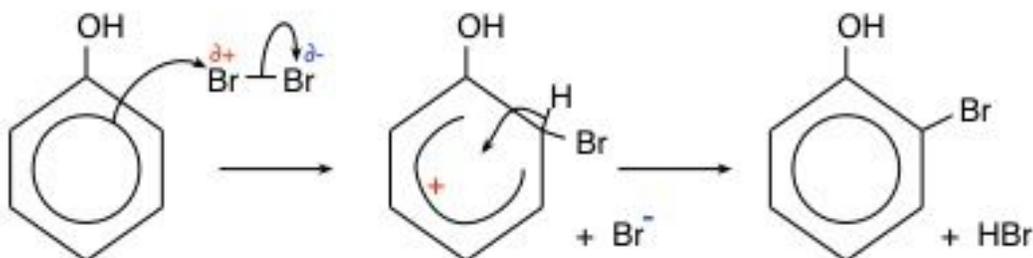
## Phenol

Phenol is an **aromatic alcohol** consisting of a benzene ring and an -OH alcohol group. It is **weakly acidic** with a pH between 5 and 6. When phenol loses a hydrogen ion, the **lone pair** on the oxygen atom overlaps with the **delocalised electron system** of benzene. This spreads the charge out, **stabilising the phenoxide ion**. This makes phenol acidic since the more stable the ion is, the more likely it is to form.

Phenol can undergo reactions with **halides** to produce **aromatic halogenoalkanes** and reacts with **acyl chlorides** to produce **aromatic esters**.

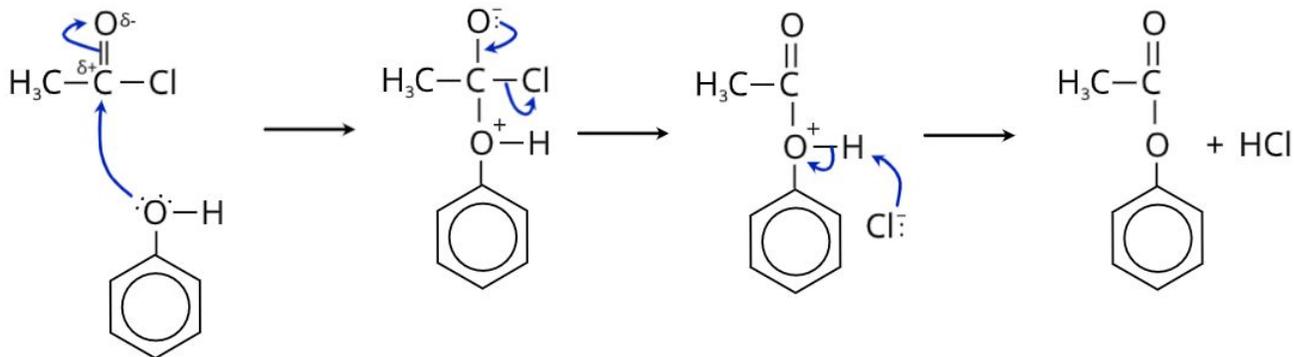
### Electrophilic Substitution

The **electron rich** delocalised ring in phenol causes the **polarisation** of the bromine molecule. This makes it susceptible to **electrophilic attack**. Electrophilic substitution can then occur, producing an **aromatic halogeno-alcohol**.



### Reaction with ethanoyl chloride

**Phenol** reacts with ethanoyl chloride in a very similar way to how aliphatic alcohols react with ethanoyl chloride. Due to the **stability** of the **benzene ring**, phenol does not react as readily with ethanoyl chloride, since the **lone pair** of electrons on the oxygen are overlapping with the electron system, making them **less available**. The product of this **nucleophilic addition-elimination** reaction is an **aromatic ester**:





## Test for Phenol

**Aqueous ferric chloride** ( $\text{FeCl}_3$ ) can be used to **test for phenols**. Compounds containing phenols will cause the solution to turn a vivid purple, blue, green or red colour - depending on the **nature of the phenols**. In particular, if **phenol** itself is present, the solution will turn a vivid **violet-purple** colour on the addition of ferric chloride solution.

