

Organic Chemistry

An organic molecule consists of two parts:

- the functional group which is the part of the molecule which reacts e.g. C=C in alkenes
- the alkyl group e.g.

CH₃- Methyl

CH₃CH₂- Ethyl

CH₃CH₂CH₂- Propyl

Alkyl groups usually remain unchanged during a chemical reaction.

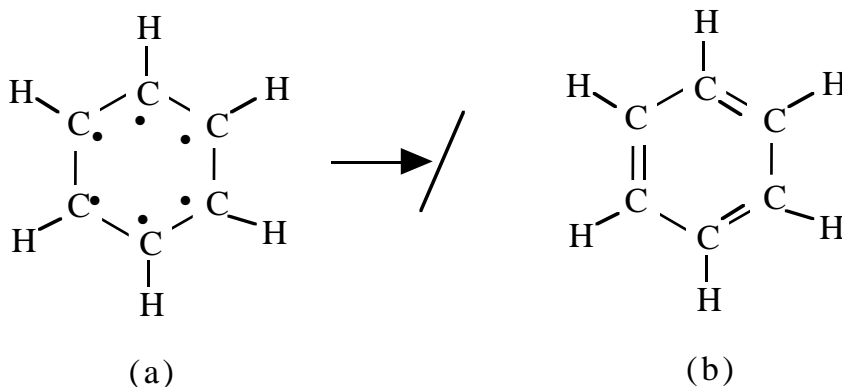
Some organic molecules contain the C₆H₅- (Phenyl) group derived from Benzene.

Benzene C₆H₆

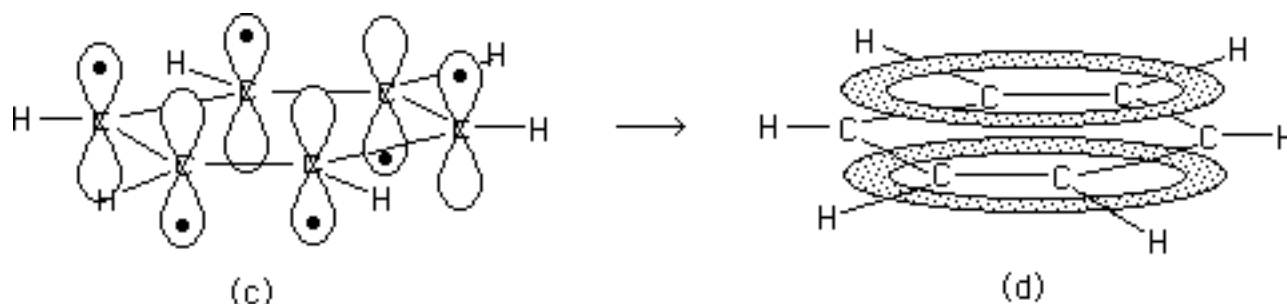
Benzene is obtained from coal tar.

Benzene is an unsaturated liquid which does **not** decolourise Bromine and therefore contains **no** double bonds.

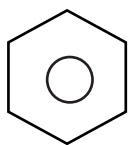
Each Carbon atom uses 3 of its 4 valence electrons to form 3 bonds (a). The 6 spare electrons **do not** form 3 double bonds (b) :



A more stable alternative is available : the ring is flat. The 6 electrons occupy clouds perpendicular to the ring (c). These clouds can coalesce forming one cloud above and below the plane of the ring (d) :



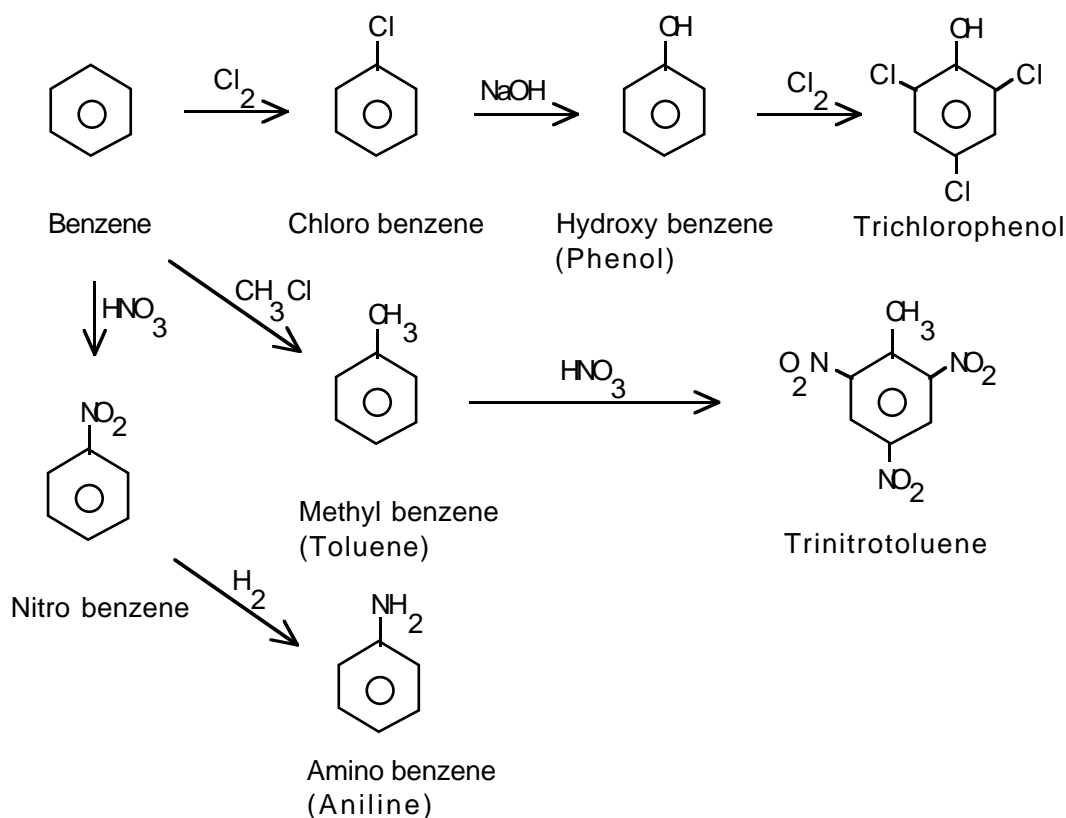
The electrons are shared by all 6 Carbon atoms (delocalised). Since each electron is attracted by 6 nuclei instead of 2, structure (d), usually written



is more stable than (b).

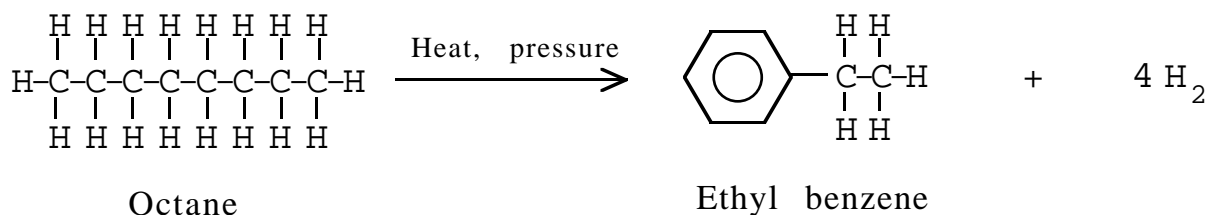
Ring compounds with delocalised electrons are said to be **aromatic**.

Since the delocalised electrons are so tightly bound, the benzene ring resists addition reactions ; reactions involve substitution of the Hydrogen atoms ; the Benzene ring remains unaffected.



The phenyl group is C_6H_5-

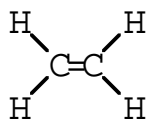
Like branched-chain hydrocarbons, aromatic hydrocarbons are used in petrol because they do not cause pre-ignition in the car engine. They are made by reforming e.g.



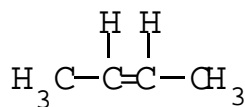
Alkenes

Functional Group: C=C

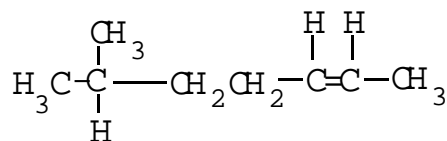
e.g.



Ethene



But-2-ene

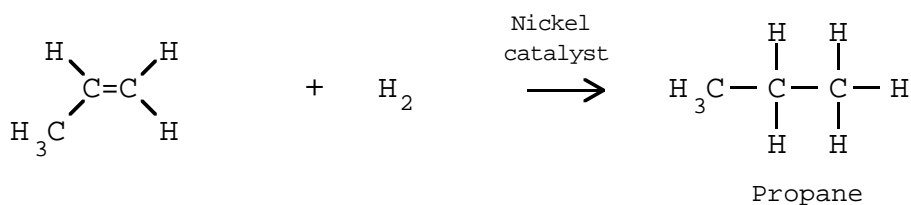


6-Methylhept-2-ene

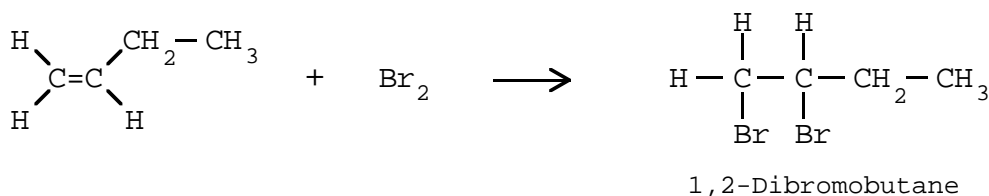
Naming : where a functional group is present, number from the end nearest the functional group.

Alkenes undergo **addition reactions**

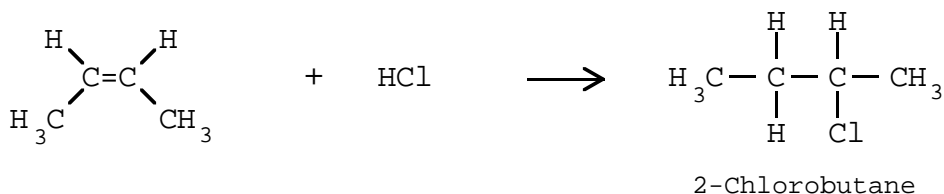
1. Reaction with Hydrogen
e.g. Propene



2. Reaction with Halogens
e.g. But-1-ene + Bromine

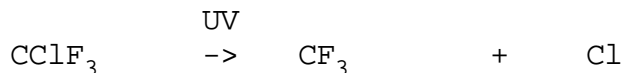


3. Reaction with Hydrogen halides
e.g. But-2-ene + Hydrogen chloride

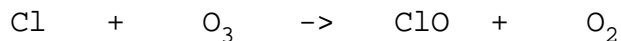


Reactions 2 and 3 produce haloalkanes of which Chlorofluorocarbons are one notorious example. The use of CFC's in aerosol propellants and fridges has led to an increase in the concentration of these substances in the upper atmosphere where they destroy the Ozone layer.

Ultra violet light breaks C-Cl bonds liberating free Chlorine atoms:

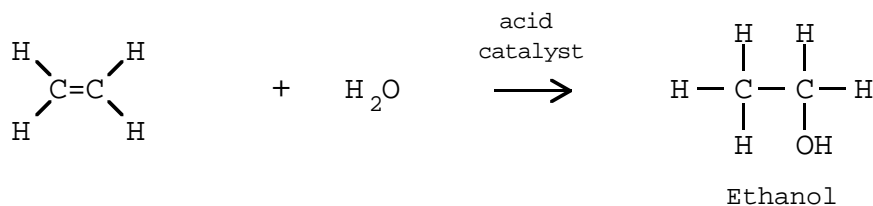


These Cl atoms then combine with Ozone:



Ozone screens out harmful UV radiation from the Earth. Its depletion will lead to an increase in skin cancer.

4. Reaction with Water (Hydration)
e.g. Ethene

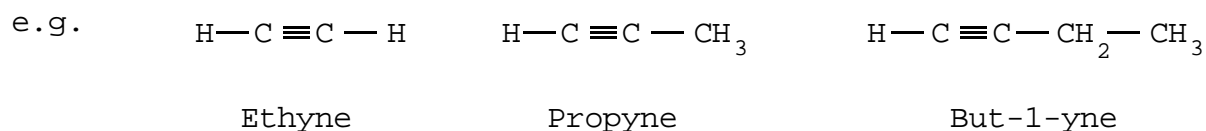


The reaction is carried out at 300 °C and 65 atm. in the presence of Phosphoric acid catalyst.

This method of making Ethanol provides a more convenient industrial alternative to fermentation.

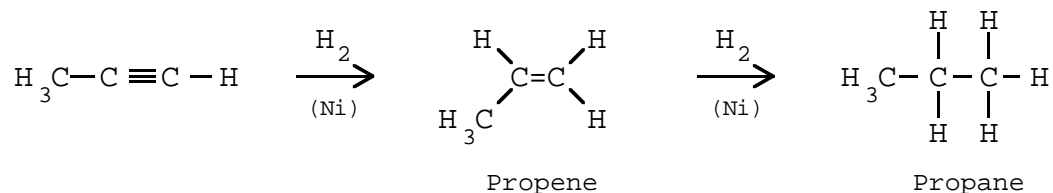
Alkynes

Functional Group: $-\text{C}\equiv\text{C}-$

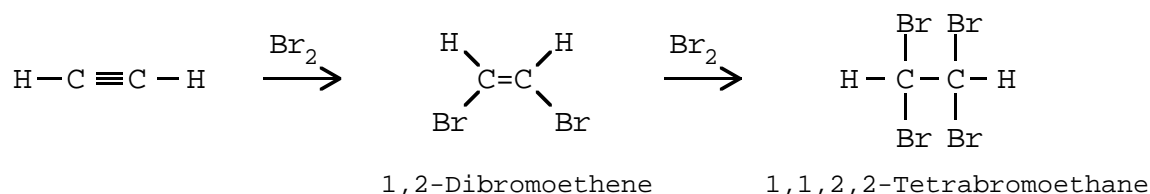


Like alkenes, alkynes undergo addition reactions

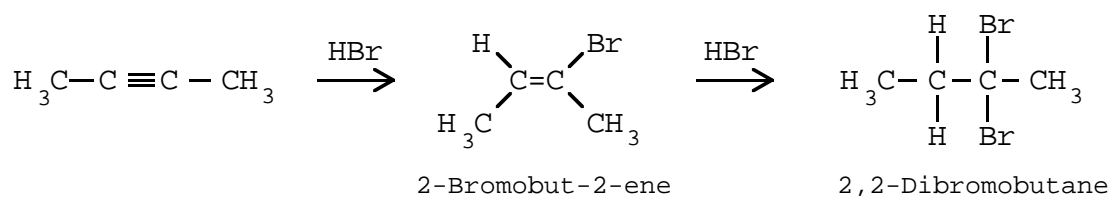
1. Reaction with Hydrogen
e.g. Propyne



2. Reaction with Halogens
e.g. Ethyne + Bromine



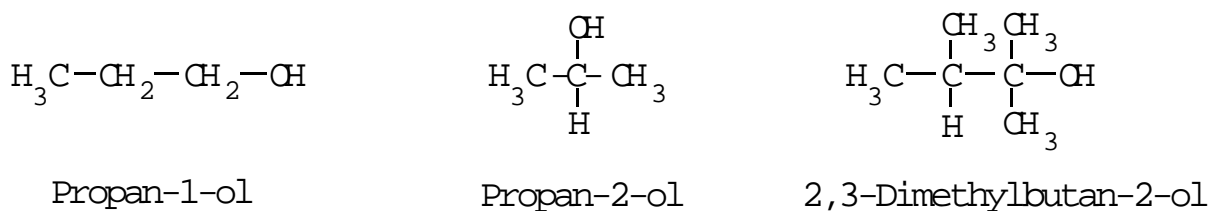
3. Reaction with Hydrogen halides
e.g. But-2-yne + Hydrogen bromide



Alcohols (or Alkanols)

Functional Group: OH

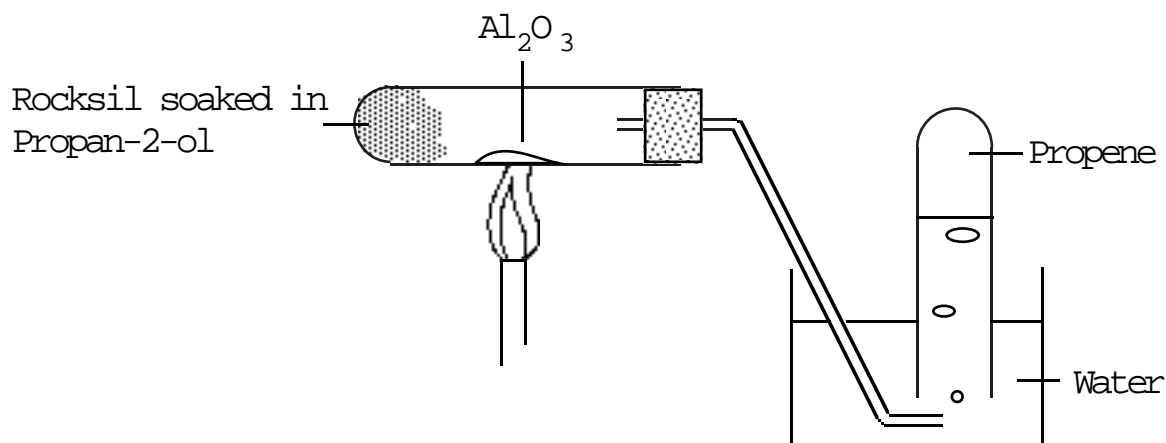
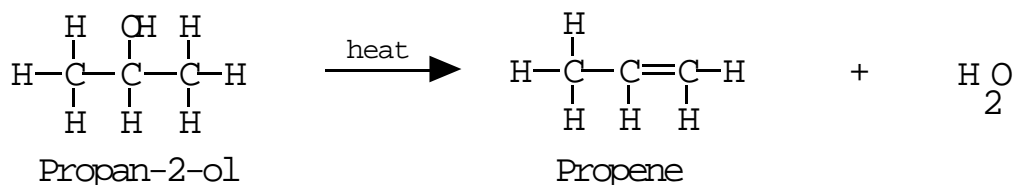
e.g.

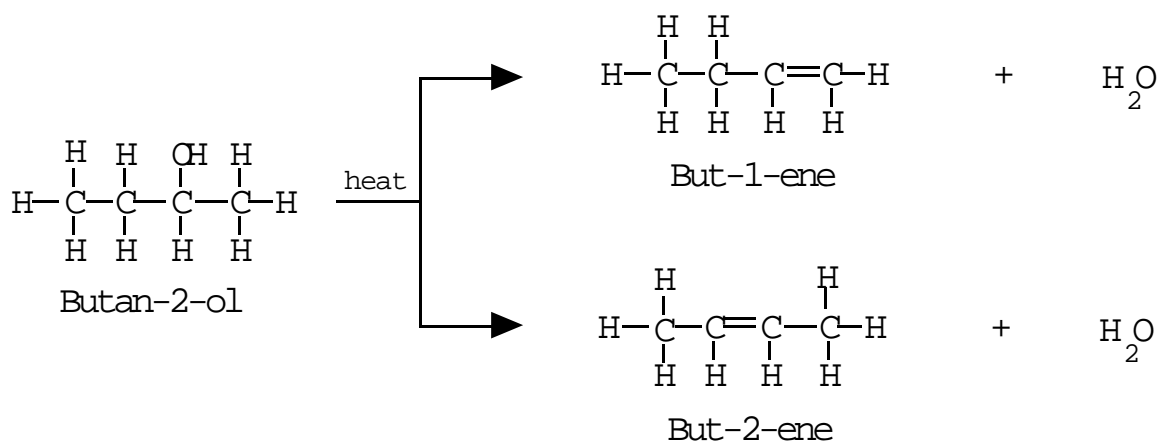


Dehydration of Alcohols

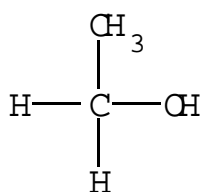
Alcohols can be converted to alkenes by passing the vapour over heated Aluminium oxide catalyst. The reaction is called 'dehydration' since loss of Water occurs.

Example 1

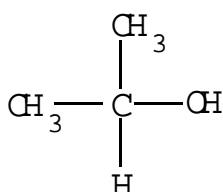


Example 2Classification of Alcohols

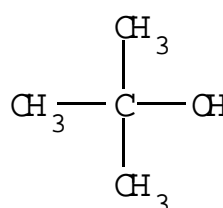
Alcohols can be classified as primary, secondary or tertiary according to the number of alkyl (or aromatic) groups attached to the Carbon bearing the hydroxyl group e.g.



Primary



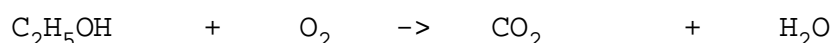
Secondary



Tertiary

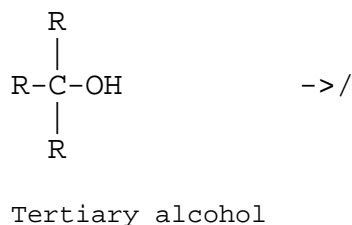
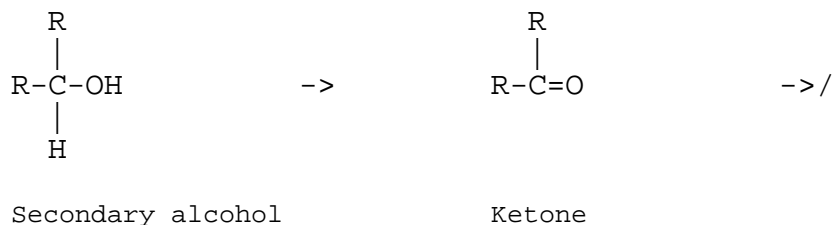
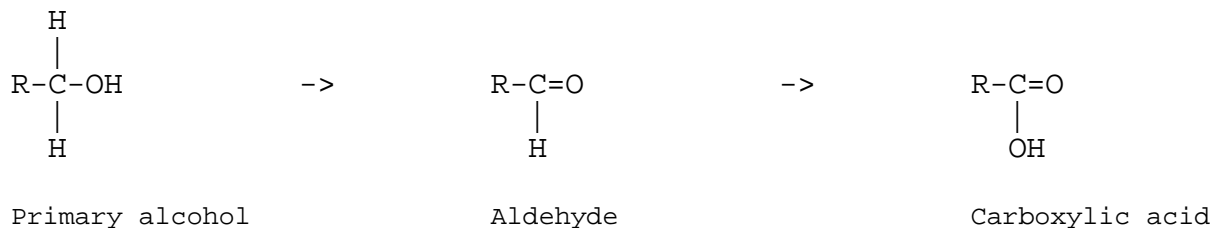
Reactions of Alcohols with Oxygen (Oxidation)

Alcohols burn in Oxygen to produce Carbon dioxide and Water e.g.

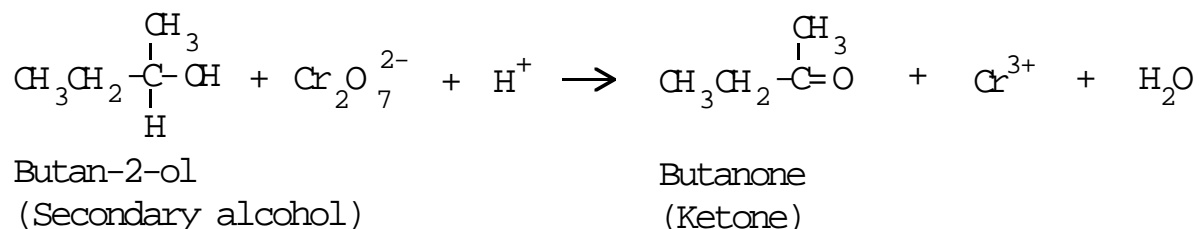
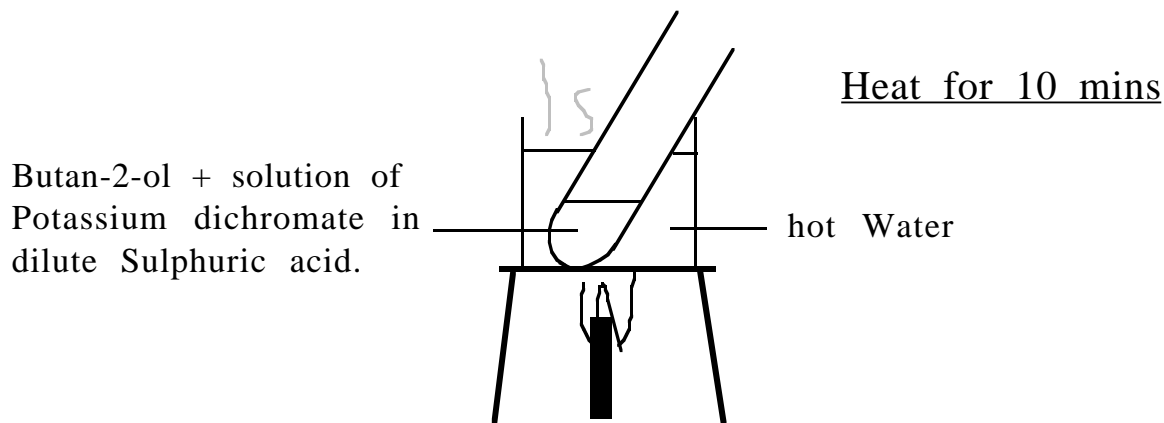


Under more carefully controlled conditions, using selected oxidising agents e.g. Copper(II) oxide $\text{Cu}^{2+}\text{O}^{2-}$ or acidified Potassium dichromate $(\text{K}^+)_2\text{Cr}_2\text{O}_7^{2-}$, alcohols can be oxidised to form more interesting products.

Products depend on the class of alcohol used (R = alkyl or aromatic group) :



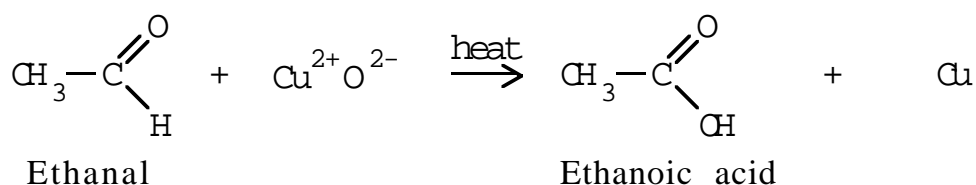
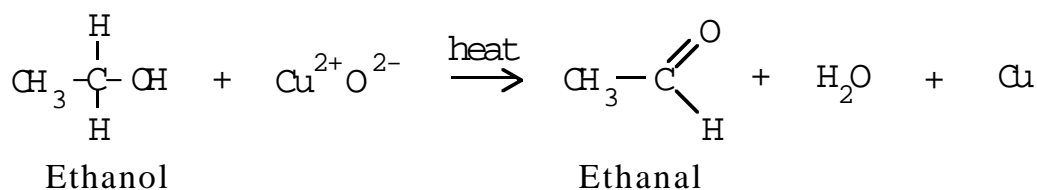
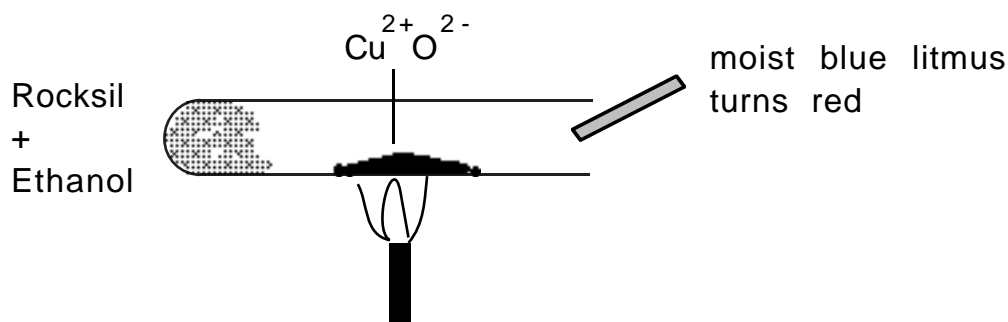
Example 1 : The oxidation of Butan-2-ol using acidified Potassium dichromate.



Since the dichromate ion $\text{Cr}_2\text{O}_7^{2-}$ is orange and the chromium(III) ion Cr^{3+} is green, there is a colour change from orange to green during this reaction.

Example 2 :The oxidation of Ethanol using Copper(II) oxide.

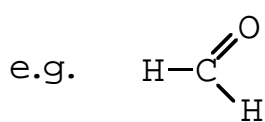
Since Ethanol is a primary alcohol oxidation takes place in two stages ; the product contains both Ethanal and Ethanoic acid (turns moist blue litmus red)



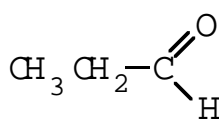
Note that oxidation results in an increase in the O:H ratio in the organic compound.

Aldehydes (or Alkanals)

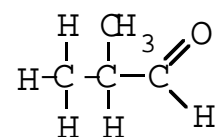
Functional Group: $\begin{array}{c} \text{O} \\ || \\ -\text{C} \\ | \\ \text{H} \end{array}$



Methanal

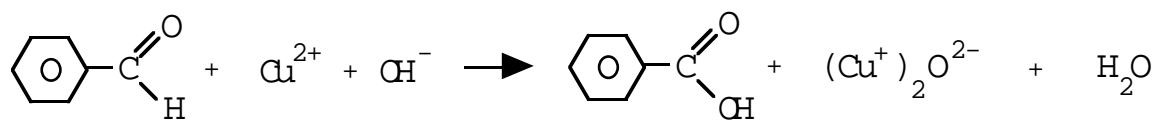


Propanal



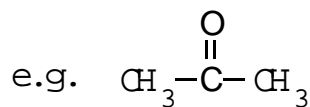
Methyl propanal

N.B. Since aldehydes can be oxidised to carboxylic acids, aldehydes are reducing agents. They will reduce Benedict's solution (a blue solution containing Cu^{2+} and OH^-), on heating, to form Copper(I) oxide - a brick-red precipitate e.g.

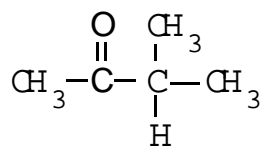


Benzaldehyde

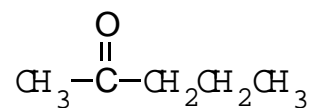
Benzoic acid

Ketones (or Alkanones)Functional Group: $\begin{array}{c} \text{O} \\ \parallel \\ -\text{C} \\ \diagdown \end{array}$ 

Propanone



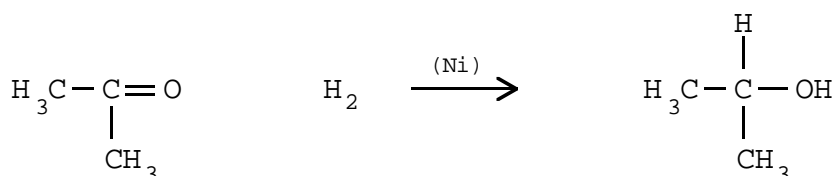
Methyl butanone



Pentan-2-one

Comparison of aldehydes and ketones**Similarities:**

- Both contain the carbonyl group C=O
- Both aldehydes and ketones may be reduced with Hydrogen using a Nickel catalyst e.g.

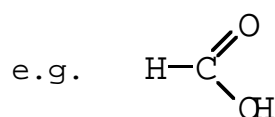


Reduction results in a decrease in the O:H ratio.

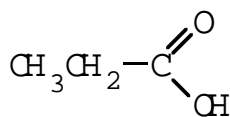
Differences:

Unlike aldehydes, ketones cannot be further oxidised. Ketones are not reducing agents.

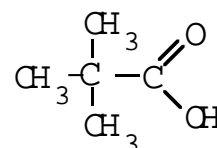
Aldehydes can be distinguished from ketones by their reaction with Benedict's solution: aldehydes react forming a brick-red precipitate; ketones do not react.

Carboxylic acids (or Alkanoic acids)Functional Group: $\begin{array}{c} \text{O} \\ \parallel \\ -\text{C} \\ \diagdown \\ \text{OH} \end{array}$ 

Methanoic acid

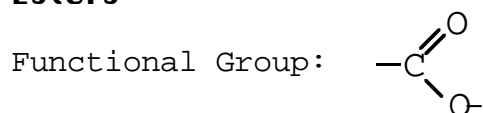


Propanoic acid

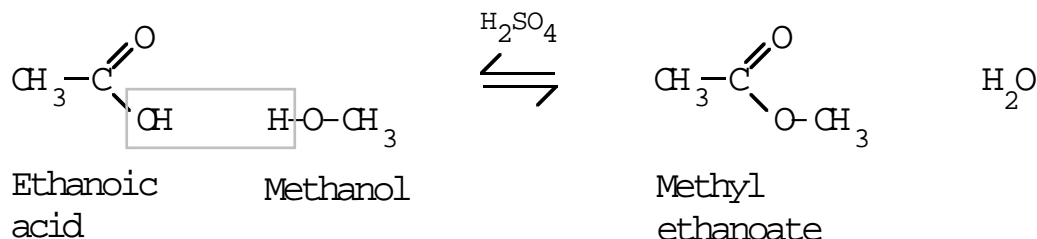


Dimethylpropanoic acid

Esters



Esters are formed by the condensation reaction between an alcohol and a carboxylic acid using concentrated Sulphuric acid catalyst e.g.

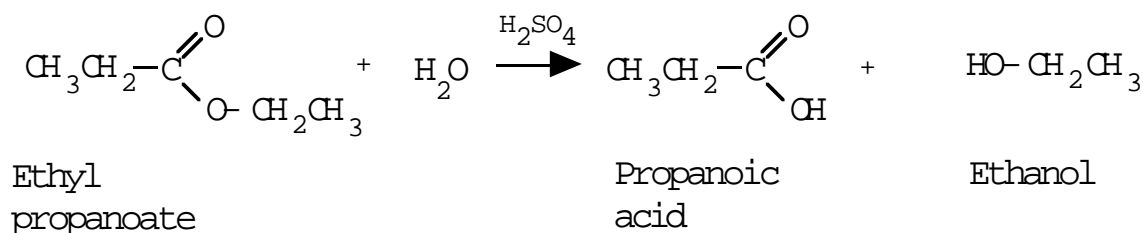


The reaction is known as **esterification**.

The formula of Methyl ethanoate may also be written: $\text{CH}_3\text{COOCH}_3$

Esters are used as flavourings, perfumes and solvents.

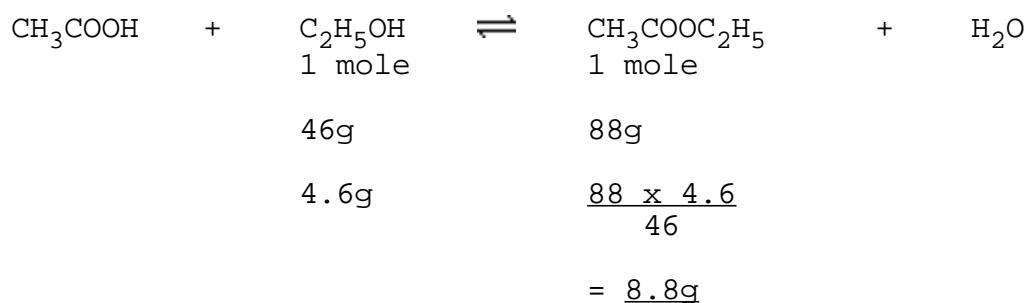
Esterification is reversible : esters can be hydrolysed e.g.



Due to this reversibility, yields of esters are usually low and can be calculated as in the following example:

- (a) Calculate the mass of Ethyl ethanoate which should be obtained by reaction of 4.6g of Ethanol with excess Ethanoic acid given the equation.

Answer :



- (b) Only 7.2 g of Ethyl ethanoate is actually obtained. Calculate the percentage yield of Ethyl ethanoate.

Answer :

$$\% \text{ yield} = \frac{7.2 \times 100}{8.8} = 81.8 \%$$