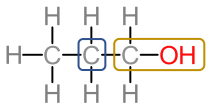
Alcohols, Esters, and Carboxylic Acids

A. Classification of alcohols

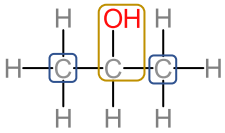
- Alcohols are organic molecules **containing the hydroxyl group, –OH**. The general formula is $C_nH_{2n+1}OH$

- Based on the position of carbon atom that bonded to the –OH group, there are three classifications of alcohol

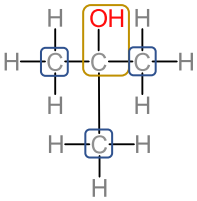
1. Primary Alcohols
   The carbon atom bonded to the –OH group is **attached to one other carbon atom**



2. Secondary Alcohols
   The carbon atom bonded to the –OH group is **attached to two other carbon atoms**



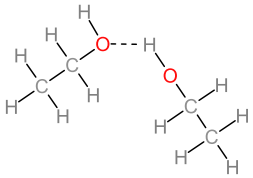
3. Tertiary Alcohols
   The carbon atom bonded to the –OH group is **attached to three other carbon atoms**



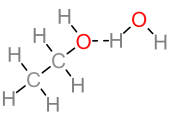
B. Properties of alcohols

- Alcohols have high boiling point compared to other organic molecules with similar relative molecular masses.

- This is occurred because of hydrogen bonding between alcohol molecules. This also explain why alcohol is soluble in water.



Hydrogen Bond between Molecules

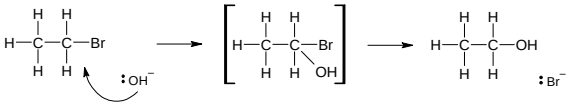


Hydrogen Bond with Water (H_2O)

C. Production of Alcohols

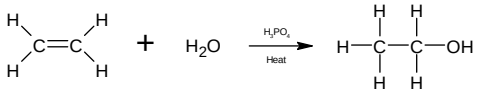
- Nucleophilic substitution of a halogenoalkane by heating aqueous NaOH

$$CH_3CH_2Br + NaOH_{(Aq)} \xrightarrow{Heat} CH_3CH_2OH + NaBr$$



Nucleophilic Substitution of Halogenoalkane Mechanism

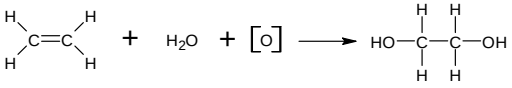
- Electrophilic addition of steam, $H_2O_{(g)}$ to an alkene



Electrophilic Addition of Ethene

Reagent : Steam
Catalyst : H_3PO_4
Condition : Heat 330°C, 6 MPa

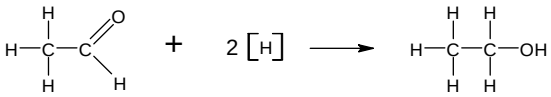
- Oxidation of alkenes



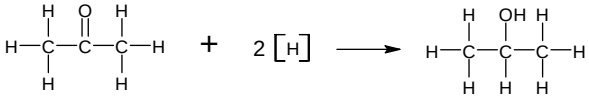
Oxidation of Ethene

Reagent : Acidified $KMnO_4$
Condition : Cold and Diluted

- Reduction of aldehyde (to form primary alcohol) or of ketone (to form secondary alcohol) using a reducing agent such as $NABH_4$ or $LiAlH_4$

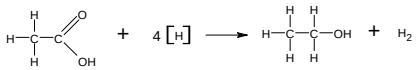


Reduction of Ethanal Forming a Primary Alcohol, Ethanol



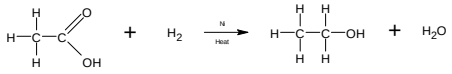
Reduction of Propanone Forming a Secondary Alcohol, Propan-2-Ol

- Reduction of carboxylic acid
  1. Reduced by $NaBH_4$ or $LiAlH_4$



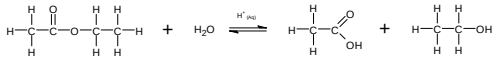
Reduction of Ethanoic Acid Forming Ethanol

  2. Reduced by H_2



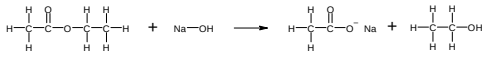
Reduction of Ethanoic Acid with H_2 Forming Ethanol

- Hydrolysis of ester
  1. With Acid



Hydrolysis of Ethylethanoate with Acid Forming Ethanoic Acid and Ethanol

  2. With Alkali



Hydrolysis of Ethylethanoate with Sodium Hydroxide Forming Sodium Ethanoate and Ethanol

Reaction Type	Reagents	Conditions	Product
Electrophilic Addition	Alkene Steam	Heat H_3PO_4 Catalyst	Alcohol
Oxidation	Alkenes Cold and Diluted $KMnO_4$	Shaking of Reagents	Diol
Nucleophilic Substitution	Halogenoalkanes Aqueous NaOH	Heat	Alcohol
Reduction	Aldehydes/Ketones	$NaBH_4$ or $LiAlH_4$	Primary/ Secondary Alcohol
Reduction	Carboxylic Acid	$NaBH_4$ or $LiAlH_4$ OR H_2, Ni catalyst and Heat	Primary Alcohol
Hydrolysis	Esters	Dilute Acid or Alkali Heat	Alcohol

Summarized Alcohol Production Table

D. Reaction of alcohols

- Combustion

  Alcohol + O_2 ⟶ $CO_2 + H_2O$

- Substitution to Form Halogenoalkane
  1. With PX_5

     ROH + PX_5 ⟶ RX + POX_3 + HX

     Condition: RTP
  2. With PX_3

     3ROH + PX_3 ⟶ 3RX + H_3PO_3

     Condition: Heat
  3. With SOX_2

     ROH + SOX_2 ⟶ RX + SO_2 + HX

     Condition: Heat
  4. With HX

     ROH + HX ⟶ RX + H_2O

     Reagent : NaX and Concentrated H_2SO_4

     Condition: Heat Under Reflux

Note: X = Any Halogen

- With Sodium Metal

  ROH $_{(l)}$ + Na $_{(s)}$ ⟶ RONa + ½ $H_{2\,(g)}$

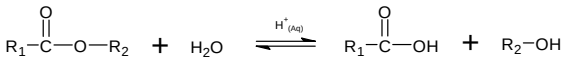
- Esterification

  Alcanoic Acid + Alcohol ⟶ Ester + Water

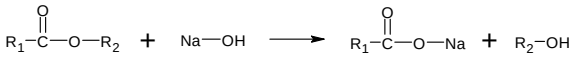
  Reagent : Concentrated H_2SO_4

  Condition : Heated Under Reflux

- Hydrolysis of Ester
  1. With Aqueous Acid

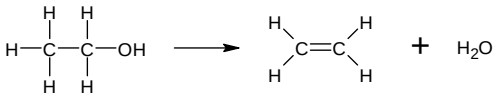


  2. With Aqueous Base / NaOH



  Condition: Heated Under Reflux

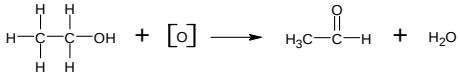
- Dehydration



  Reagent : Concentrated H_2SO_4 or Catalyst such as Heated zeolite/ceramic/pumice/ Al_2O_3

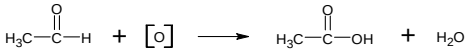
  Condition : Heat 170°C

- Oxidation
  1. Primary Alcohols



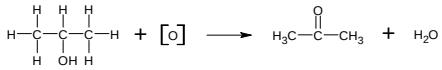
  Condition: Heat by Distillation

  The formed aldehyde can be further oxidised to form ethanoic acid by heating under reflux



  Condition: Heated Under Reflux

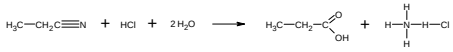
2. Secondary Alcohols



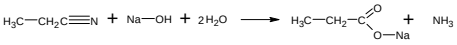
Reagent : Acidified $KMnO_4$ or $K_2Cr_2O_7$
Condition : Heated by Distillation or Under Reflux

e. Carboxylic Acids and the production

- Carboxylic acids are compounds with **–COOH functional group**
- Hydrolysis of Nitriles
  1. With Diluted Acid



  2. With Diluted Alkali

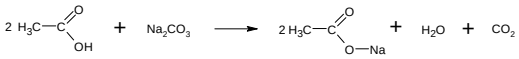


F. Reaction of Carboxylic Acids

- Redox with Reactive Metals

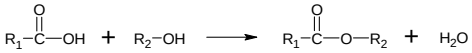
- Neutralisation with Alkali

- Acid-Base with Carbonates



G. Ester and the production

- Esters are compounds with **–COOH functional group**
- They are **characterised by their sweet and fruity smells** which used for the complex mixture of substance blended in perfume, artificial flavour, and as solvents for example in nail varnish remover
- Esters are produced from condensation reaction between carboxylic acid and alcohol with concentrated H_2SO_4. Alternately, the reaction is called **esterification**
- The general reaction is
  Alcanoic Acid + Alcohol ⟶ Ester + Water



Reagent : Concentrated H_2SO_4
Condition : Heated Under Reflux