5.5: Carboxylic Acids and Esters

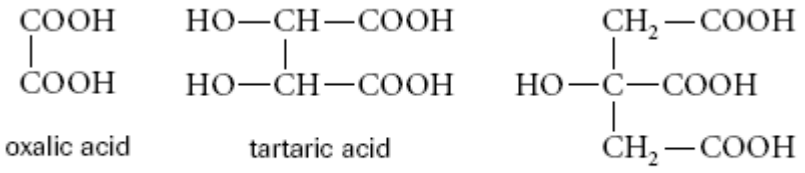
Naming Carboxylic Acids

The functional group of carboxylic acids is the **carboxyl group**, written in formulas as **-COOH**. This functional group combines two other functional groups already familiar to us: the hydroxyl (-OH) group in alcohols, and the carbonyl (-C=O) group in aldehydes and ketones.

The IUPAC name for a carboxylic acid is formed by taking the name of the alkane or alkene with the same number of carbon atoms as the longest chain in the acid. Remember to count the C atom in the carboxyl group in the total number of the parent chain. The ***-e*** ending of the alkane name is replaced with the suffix ***-oic***, followed by the word "**acid**."

The simplest carboxylic acid is methanoic acid,HCOOH, commonly called formic acid; the name is derived from the Latin word *formica* which means "ant," the first source of this acid. Methanoic acid is used in removing hair from hides and in coagulating and recycling rubber. Ethanoic acid, commonly called acetic acid, is the compound that makes vinegar taste sour. This acid is used extensively in the textile dyeing process and as a solvent for other organic compounds. The simplest aromatic acid is phenylmethanoic acid, better known by its common name, benzoic acid. Benzoic acid is largely used to produce sodium benzoate, a common preservative in foods and beverages.

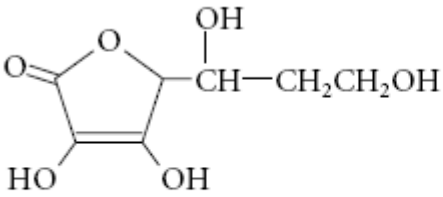
Some acids contain multiple carboxyl groups. When naming acids with multiple carboxyl groups, the suffix ***-dioic acid*** is used for acids with a carboxyl group at each end of the parent chain. The compound HOOC-CH2-COOH is named propanedioic acid; the carboxyl C atoms are counted in the parent chain. When more carboxyl groups are present, all COOH groups may be named as substituents on the parent chain; in this case, the parent chain does not include the carboxyl C atoms. An example is citric acid, shown below; it is named as a tricarboxylic acid of propane.



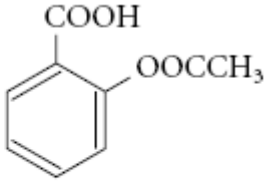
oxalic acid

tartaric acid

citric acid



ascorbic acid
(Vitamin C)



acetylsalicylic acid
(ASA)

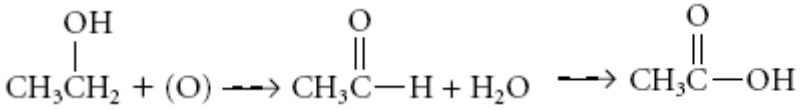
Properties of Carboxylic Acids

With the presence of both carbonyl (-C=O) and hydroxyl groups (-OH), the molecules of carboxylic acids are polar and form hydrogen bonds with each other and with water molecules. These acids exhibit similar solubility behaviour to that of alcohols; that is, the smaller members (one to four carbon atoms) of the acid series are soluble in water, whereas larger ones are relatively insoluble. Carboxylic acids have the properties of acids: a litmus test can distinguish these compounds from other hydrocarbon derivatives. They also react with organic "bases" in neutralization reactions to form organic "salts."

The melting points of carboxylic acids are higher than those of their corresponding hydrocarbons. We can explain this by the increased intermolecular attractions of the polar carboxyl functional groups.

Preparing Carboxylic Acids

When an *alcohol* is mildly oxidized, an *aldehyde* is produced. Further controlled oxidation of the aldehyde results in the formation of a *carboxylic acid*, containing a carboxyl group.



ethan*ol* ethan*al* (acetaldehyde) ethan*oic acid* (acetic acid)

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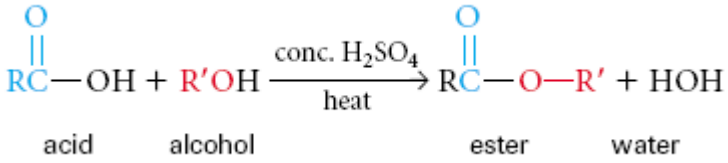
From Carboxylic Acids to Organic "Salts": Esterification

Carboxylic acids react as other acids do, in neutralization reactions, for example. A carboxylic acid can react with an alcohol, forming an ester and water. In this reaction, the alcohol acts as an organic base and the ester formed may be considered an organic salt. This condensation reaction is known as **esterification**.

The general reaction between a carboxylic acid and an alcohol is represented below. An acid catalyst, such as sulfuric acid, and heat are generally required. It is interesting to note that, by tracking the oxygen atoms using isotopes, it has been found that the acid contributes the -OH group to form the water molecule in the reaction.



Esters occur naturally in many plants and are responsible for the odours of fruits and flowers. Synthetic esters are often added as flavourings to processed foods, and as scents to cosmetics and perfumes.

Naming and Preparing Esters

Esters are organic "salts" formed from the reaction of a carboxylic acid and an alcohol. Consequently, the name of an ester has two parts. The first part is the **name of the alkyl group from the alcohol** used in the esterification reaction. The second part comes from the acid. The **ending of the acid name** is changed from ***-oic* acid to *-oate***. For example, in the reaction of ethanol and butanoic acid, the ester formed is ethyl butan*oate*, an ester with a banana odour.

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The functional group for an ester is a carboxyl group in which the H atom is substituted by an alkyl group:-COOR. The general structural formula for an ester is shown below.

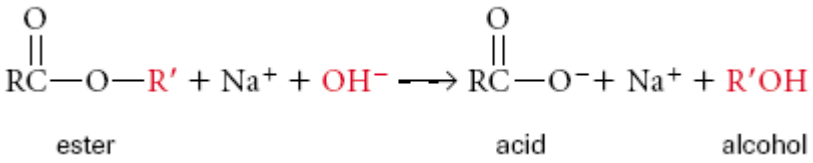
Properties of Esters

The functional group of an ester is similar to the carboxyl group of an acid. What it lacks in comparison to an acid is its -OH group; the hydroxyl group is replaced by an -OR group. With the loss of the polar -OH group, esters are less polar, and therefore are less soluble in water, and have lower melting and boiling points than their parent acids. Moreover, the acidity of the carboxylic acids is due to the H atom on their –OH group, and so esters, having no -OH groups, are not acidic.

It is the low-molecular-mass esters that we can detect by scent, because they are gases at room temperature. The larger, heavier esters more commonly occur as waxy solids.

Reactions of Esters: Hydrolysis

When esters are treated with an acid or a base, a reversal of esterification occurs; that is, the ester is split into its acid and alcohol components. This type of reaction is called **hydrolysis**. In the general example shown below, the reaction is carried out in a basic solution, and the products are the sodium salt of the carboxylic acid and the alcohol.



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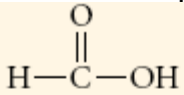
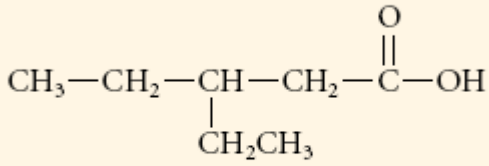
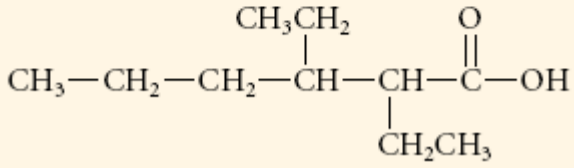
Worksheet 5.5: Carboxylic Acids and Esters

1. Draw a structural diagram for each of the following compounds:
   (a) octanoic acid
   (b) benzoic acid
   (c) 2-methylbutanoic acid

2. Give IUPAC and, if applicable, common names for these molecules:

(a)


(b)


(c)


3. Draw a structural diagram and write the IUPAC name of an alcohol that can be used in the synthesis of oxalic (ethanedioic) acid.

4. The labels have fallen off three bottles. Bottle A contains a gas, bottle B contains a liquid, and bottle C contains a solid. The labels indicate that the compounds have the same number of carbon atoms, one being an alkane, one an alcohol, and the other a carboxylic acid. Suggest the identity of the contents of each bottle, and give reasons for your answer.

5. Write a series of chemical equations to illustrate the synthesis of a carboxylic acid from the controlled oxidation of 1-propanol.

6. When a bottle of wine is left open to the air for a period of time, the wine often loses its alcoholic content and starts to taste sour. Write a series of equations to illustrate the reactions.

7. Write complete structural diagram equations and word equations for the formation of the following esters. Refer to Table 2 and identify the odour of each ester formed.
   (a) ethyl methanoate
   (b) ethyl benzoate
   (c) methyl butanoate
   (d) 3-methylbutyl ethanoate

8. Name the following esters, and the acids and alcohols from which they could be prepared.

(a) CH3CH2COOCH2CH3
(b) CH3CH2CH2COOCH3
(c) HCOOCH2CH2CH2CH3
(d) CH3COOCH2CH2CH3

9. In what way is the functional group of an ester different from that of a carboxylic acid? How does this difference account for any differences in properties?

10. Describe the experimental conditions in the hydrolysis of ethyl formate. Write a balanced equation for the reaction, and name the product(s).