This page explains what carboxylic acids are, and looks at the ions that they form in their salts. It also considers their simple physical properties such as solubility and boiling points.

**Carboxylic acids contain a -COOH group**

Carboxylic acids are compounds which contain a -COOH group. For the purposes of this page we shall just look at compounds where the -COOH group is attached either to a hydrogen atom or to an alkyl group.

Example

\[
\begin{align*}
\text{methanoic acid} & \quad \text{ethanoic acid} & \quad \text{propanoic acid} & \quad \text{2-methylpropanoic acid} \\
\text{CH}_3\text{C}^\prime\text{H}_2\text{O}^\prime & \quad \text{CH}_3\text{C}^\prime & \quad \text{CH}_3\text{C}^\prime\text{H}_2\text{O}^\prime & \quad \text{CH}_3\text{C}^\prime\text{H}_2\text{C}^\prime\text{H}_2\text{C}^\prime\text{H}_2\text{O}^\prime
\end{align*}
\]

The name counts the total number of carbon atoms in the longest chain - including the one in the -COOH group. If you have side groups attached to the chain, notice that you always count from the carbon atom in the -COOH group as being number 1.

**Salts of carboxylic acids**

Carboxylic acids are acidic because of the hydrogen in the -COOH group. When the acids form salts, this is lost and replaced by a metal. Sodium ethanoate, for example, has the structure:

\[
\begin{align*}
\text{sodium ethanoate} & \\
\text{CH}_3\text{C}^\prime & \quad \text{O}^\prime & \quad \text{Na}^+ \\
\text{O}^\prime & \quad \text{CH}_3\text{C}^\prime
\end{align*}
\]

Depending on whether or not you wanted to stress the ionic nature of the compound, this would be simplified to CH\text{\textsubscript{3}}\text{COO}^\prime\text{Na}^+ or just CH\text{\textsubscript{3}}\text{COONa}. Notice:

- The bond between the sodium and the ethanoate is ionic. Do not draw a line between the two (implying a covalent bond). That is absolutely wrong!
- Although the name is written with the sodium first, the formula is always written in one of the ways shown. This is something you just have to get used to.

**Physical properties of carboxylic acids**

The physical properties (for example, boiling point and solubility) of the carboxylic acids are governed by their ability to form hydrogen bonds.
Boiling points

Before we look at carboxylic acids, a reminder about alcohols: The boiling points of alcohols are higher than those of alkanes of similar size because the alcohols can form hydrogen bonds with each other as well as van der Waals dispersion forces and dipole-dipole interactions. The boiling points of carboxylic acids of similar size are higher still. For example:

<table>
<thead>
<tr>
<th></th>
<th>CH₃CH₂CH₂OH</th>
<th>97.2°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>propan-1-ol</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ethanoic acid</td>
<td>CH₃COOH</td>
<td>118°C</td>
</tr>
</tbody>
</table>

These are chosen for comparison because they have identical relative molecular masses and almost the same number of electrons (which affects van der Waals dispersion forces). The higher boiling points of the carboxylic acids are still caused by hydrogen bonding, but operating in a different way. In a pure carboxylic acid, hydrogen bonding can occur between two molecules of acid to produce a dimer.

\[
\text{CH}_3\overset{\delta+}{\text{C}}\overset{\delta-}{\text{O}}\overset{\delta+}{\text{H}}\overset{\delta-}{\text{O}}\overset{\delta+}{\text{C}}\overset{\delta-}{\text{CH}_3}
\]

Hydrogen bond between the fairly positive hydrogen atom and a lone pair on the fairly negative oxygen atom.

This immediately doubles the size of the molecule and so increases the van der Waals dispersion forces between one of these dimers and its neighbors - resulting in a high boiling point.

Solubility in water

In the presence of water, the carboxylic acids do not dimerize. Instead, hydrogen bonds are formed between water molecules and individual molecules of acid. The carboxylic acids with up to four carbon atoms will mix with water in any proportion. When you mix the two together, the energy released when the new hydrogen bonds form is much the same as is needed to break the hydrogen bonds in the pure liquids.

The solubility of the bigger acids decreases very rapidly with size. This is because the longer hydrocarbon "tails" of the molecules get between water molecules and break hydrogen bonds. In this case, these broken hydrogen bonds are only replaced by much weaker van der Waals dispersion forces. The energetics of dissolving carboxylic acids in water is made more complicated because some of the acid molecules actually react with the water rather than just dissolving in it.

Contributors

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