Learning Objectives

- Describe the structure and properties of carboxylic acids and esters.
- Name common carboxylic acids and esters.

The odor of vinegar is caused by the presence of acetic acid, a carboxylic acid, in the vinegar. The odor of ripe bananas and many other fruits is due to the presence of esters, compounds that can be prepared by the reaction of a carboxylic acid with an alcohol. Because esters do not have hydrogen bonds between molecules, they have lower vapor pressures than the alcohols and carboxylic acids from which they are derived.

Both carboxylic acids and esters contain a carbonyl group with a second oxygen atom bonded to the carbon atom in the carbonyl group by a single bond. In a carboxylic acid, the second oxygen atom also bonds to a hydrogen atom. In an ester, the second oxygen atom bonds to another carbon atom. The names for carboxylic acids and esters include prefixes that denote the lengths of the carbon chains in the molecules and are derived following nomenclature rules similar to those for inorganic acids and salts (see these examples):

\[
\begin{align*}
\text{ethanoic acid} & \quad \text{methyl ethanoate} \\
(\text{acetic acid}) & \quad (\text{methyl acetate})
\end{align*}
\]

Figure 1 Two structures are shown. The first structure is labeled, “ethanoic acid,” and, “acetic acid.” This structure indicates a C atom to which H atoms are bonded above, below and to the left. To the right of this in red is a bonded group comprised of a C atom to which an O atom is double bonded above. To the right of the red C atom, an O atom is bonded which has an H atom bonded to its right. Both O atoms have two sets of electron dots. The second structure is labeled, “methyl ethanoate,” and, “methyl acetate.” This structure indicates a C atom to which H atoms are bonded above, below and to the left. In red, bonded to the right is a C atom with a double bonded O atom above and a single bonded O atom to the right. To the right of this last O atom in black is another C atom to which H atoms are bonded above, below and to the right. Both O atoms have two pairs of electron dots.

The functional groups for an acid and for an ester are shown in red in these formulas.

Carboxylic Acids

Carboxylic acids occur widely in nature, often combined with alcohols or other functional groups, as in fats, oils, and waxes. They are components of many foods, medicines, and household products (Figure 1). Not surprisingly, many of them are best known by common names based on Latin and Greek words that describe their source.
Carboxylic acids occur in many common household items. (a) Vinegar contains acetic acid, (b) aspirin is acetylsalicylic acid, (c) vitamin C is ascorbic acid, (d) lemons contain citric acid, and (e) spinach contains oxalic acid.

The carboxyl group contains the $\ce{C=O}$ of the carbonyl group, with the carbon atom also being bonded to a hydroxyl $\ce{-OH}$ group. A carboxylic acid is an organic compound that contains the carboxyl functional group. The general formula for a carboxylic acid can be abbreviated as $\ce{R-COOH}$. The carbon atom of the carboxyl group may be attached to a hydrogen atom or to a carbon chain. The naming of a carboxylic acid is as follows: Name the parent compound by finding the longest continuous chain that contains the carboxyl group. Change the $-e$ at the end of the name of the alkane to $-oic$ acid.

Carboxylic acids are weak acids, meaning they are not 100% ionized in water. Generally only about 1% of the molecules of a carboxylic acid dissolved in water are ionized at any given time. The remaining molecules are undissociated in solution.

We prepare carboxylic acids by the oxidation of aldehydes or alcohols whose $\ce{-OH}$ functional group is located on the...
carbon atom at the end of the chain of carbon atoms in the alcohol:

Figure \(\PageIndex{3}\) A chemical reaction with two arrows is shown. On the left, an alcohol, indicated with a C atom to which an R group is bonded to the left, H atoms are bonded above and below, and in red, a single bonded O atom with an H atom bonded to the right is shown. Following the first reaction arrow, an aldehyde is shown. This structure is represented with an R group bonded to a red C atom to which an H atom is bonded above and to the right, and an O atom is double bonded below and to the right. Appearing to the right of the second arrow, is a carboxylic acid comprised of an R group bonded to a C atom to which, in red, an O atom is single bonded with an H atom bonded to its right side. A red O is double bonded below and to the right. All O atoms have two pairs of electron dots.

The simplest carboxylic acid, formic acid (HCOOH, methanoic acid), was first obtained by the distillation of ants (Latin *formica*, meaning "ant"). The bites of some ants inject formic acid, and the stings of wasps and bees contain formic acid (as well as other poisonous materials).

The next higher homolog is acetic acid (CH\(_3\)COOH, ethanoic acid), which is made by fermenting cider and honey in the presence of oxygen. This fermentation produces vinegar, a solution containing 4%–10% acetic acid, plus a number of other compounds that add to its flavor. Acetic acid is probably the most familiar weak acid used in educational and industrial chemistry laboratories.

Pure acetic acid solidifies at 16.6°C, only slightly below normal room temperature. In the poorly heated laboratories of the late 19th and early 20th centuries in northern North America and Europe, acetic acid often "froze" on the storage shelf. For that reason, pure acetic acid (sometimes called concentrated acetic acid) came to be known as *glacial acetic acid*, a name that survives to this day.

The third homolog, propionic acid (CH\(_3\)CH\(_2\)COOH, propionic acid), is seldom encountered in everyday life. The fourth homolog, butyric acid (CH\(_3\)CH\(_2\)CH\(_2\)COOH), is one of the most foul-smelling substances imaginable. It is found in rancid
butter and is one of the ingredients of body odor. By recognizing extremely small amounts of this and other chemicals, bloodhounds are able to track fugitives.

Many carboxylic acids occur naturally in plants and animals. Citrus fruits such as oranges and lemons contain citric acid (Figure \(\PageIndex{4}\)). Ethanoic and citric acids are frequently added to foods to give them a tart flavor.

![Citric acid](image)

Figure \(\PageIndex{4}\): Citric acid is a large carboxylic acid with three ionizable hydrogen atoms. It is found in citrus fruits and gives them their sour or tart flavor.

Benzoic, propanoic, and sorbic acids are used as food preservatives because of their ability to kill microorganisms that can lead to spoilage. Methanoic and ethanoic acids are widely used in industry as starting points for the manufacture of paints, adhesives, and coatings.

![Benzoic acid](image)

**Esters: The Sweet Smell of RCOOR’**

An ester is an organic compound that is a derivative of a carboxylic acid in which the hydrogen atom of the hydroxyl group has been replaced with an alkyl group. The structure is the product of a carboxylic acid (the \(\ce{R}\)-portion) and an alcohol (the \(\ce{R’}\)-portion). The general formula for an ester is shown below.

\[
\text{R} - \text{C} - \text{O} - \text{R’}
\]

The \(\ce{R}\) group can either be a hydrogen or a carbon chain. The \(\ce{R’}\) group must be a carbon chain since a hydrogen atom would make the molecule a carboxylic acid.

Esters are produced by the reaction of acids with alcohols. For example, the ester ethyl acetate, \(\text{CH}_3\text{CO}_2\text{CH}_2\text{CH}_3\), is formed when acetic acid reacts with ethanol:
Once a flower or fruit has been chemically analyzed, flavor chemists can attempt to duplicate the natural odor or taste. Both natural and synthetic esters are used in perfumes and as flavoring agents. A chemical reaction is shown. On the left, a $\text{CH}_3$ group bonded to a red C atom. The C atom forms a double bond with an O atom which is also in red. The C atom is also bonded to an O atom which is bonded to an H atom, also in red. A plus sign is shown, which is followed by $\text{HOCH}_2\text{CH}_3$. The H O group is in red. Following a reaction arrow, a $\text{CH}_3$ group is shown which is bonded to a red C atom with a double bonded O atom and a single bonded O. To the right of this single bonded O atom, a $\text{CH}_2\text{CH}_3$ group is attached and shown in black. This structure is followed by a plus sign and $\text{H}_2\text{O}$. The O atoms in the first structure on the left and the structure following the reaction arrow have two pairs of electron dots.

Figure 6. Esters are responsible for the odors associated with various plants and their fruits. There are nine structures represented in this figure. The first is labeled, “raspberry,” and, “iso-butyl formate.” It shows an H atom with a line going up and to the right which then goes down and to the right. It goes up and to the right again and down and to the right and up and to the right. At the first peak is a double bond to an O atom. At the first trough is an O atom. The second is labeled, “apple,” and, “butyl acetate.” There is a line that goes up and to the right, down and to the right, up and to the right, and down and to the right. At the second peak is a double bond to an O atom. The third is labeled, “pineapple,” and, “ethyl butyrate.” It shows a line that goes down and to the right, up and to the right, down and to the right, up and to the right, and down and to the right. At the second peak is a double bond to an O atom and at the second trough is an O atom. The fourth is labeled, “rum,” and “propyl isobutyrate.” It shows a line that goes down and to the right, up and to the right, down and to the right, up and to the right, and down and to the right. The first complete peak has a double bond to an O atom and the second trough has an O atom. The fifth is labeled, “peach,” and “benzyl acetate.” It shows a line that goes up and to the right, down and to the right, up and to the right, and down and to the right. This line connects to a hexagon with a circle inside it. The first peak has a double bond to an O atom and the first trough has an O atom. The sixth is labeled, “orange,” and, “octyl acetate.” It shows a line that goes up and to the right and down and to the right and up and to the right and down and to the right and up and to the right and down and to the right and up and to the right and down and to the right and up and to the right.
down and to the right. The first peak has a double bond to an O atom and the first complete trough has an O atom. The seventh is labeled, “wintergreen,” and “methyl salicylate.” It shows a hexagon with a circle inside of it. On the right, is a bond down and to the right to an O H group. On the right is a bond to a line that goes up and to the right and down and two the right and up and to the right. At the first peak is a double bond to an O atom, the next trough shows an O atom and at the end of the line is a C H subscript 3 group. The eighth is labeled, “honey,” and “methyl phenylacetate.” It shows a hexagon with a circle inside of it. It shows it connecting to a line on the right that goes down and to the right then up and to the right and down and to the right and up and to the right. At the first peak that is not part of the hexagon is a double bond to an O atom. At the last trough is an O atom. The ninth is labeled, “strawberry,” and “ethyl methylphenylglycidate.” This shows a hexagon with a circle inside of it. On the right, it connects to a line that goes up and to the right and down and to the right and up and to the right and down and to the right and up and to the right. At the first peak is a line that extends above and below. Below, it connects to an O atom. At the next trough, the line extends down and to the left to the same O atom. At the next peak is a double bond to an O atom and at the next trough is an O atom.

**Chemistry Is Everywhere: Esters, Fragrances, and Flavorings**

Esters are very interesting compounds, in part because many have very pleasant odors and flavors. (Remember, never taste anything in the chemistry lab!) Many esters occur naturally and contribute to the odor of flowers and the taste of fruits. Other esters are synthesized industrially and are added to food products to improve their smell or taste; it is likely that if you eat a product whose ingredients include artificial flavorings, those flavorings are esters. Here are some esters and their uses, thanks to their odors, flavors, or both:

<table>
<thead>
<tr>
<th>Ester</th>
<th>Tastes/Smells Like</th>
<th>Ester</th>
<th>Tastes/Smells Like</th>
</tr>
</thead>
<tbody>
<tr>
<td>allyl hexanoate</td>
<td>pineapple</td>
<td>isobuty formate</td>
<td>raspberry</td>
</tr>
<tr>
<td>benzyl acetate</td>
<td>pear</td>
<td>isobutyl acetate</td>
<td>pear</td>
</tr>
<tr>
<td>butyl butanoate</td>
<td>pineapple</td>
<td>methyl phenylacetate</td>
<td>honey</td>
</tr>
<tr>
<td>ethyl butanoate</td>
<td>banana</td>
<td>nonyl caprylate</td>
<td>orange</td>
</tr>
<tr>
<td>ethyl hexanoate</td>
<td>pineapple</td>
<td>penty acetate</td>
<td>apple</td>
</tr>
<tr>
<td>ethyl heptanoate</td>
<td>apricot</td>
<td>propyl ethanoate</td>
<td>pear</td>
</tr>
<tr>
<td>ethyl pentanoate</td>
<td>apple</td>
<td>propyl isobutyrate</td>
<td>rum</td>
</tr>
</tbody>
</table>

Among the most important of the natural esters are fats (such as lard, tallow, and butter) and oils (such as linseed, cottonseed, and olive oils), which are esters of the trihydroxyl alcohol glycerine, \(C_3H_5(OH)_3\), with large carboxylic acids, such as palmitic acid, \(CH_3(CH_2)_{14}CO_2H\), stearic acid, \(CH_3(CH_2)_{16}CO_2H\), and oleic acid, \(\text{CH}_3\text{(CH}_2\text{)}_7\text{CH}=\text{CH(CH}_2\text{)}_7\text{CO}_2\text{H}\). Oleic acid is an unsaturated acid; it contains a \(\text{C=CO}\) double bond. Palmitic and stearic acids are saturated acids that contain no double or triple bonds.
Note

Fats and vegetable oils are esters of long-chain fatty acids and glycerol. Esters of phosphoric acid are of the utmost importance to life.

Esters are common solvents. Ethyl acetate is used to extract organic solutes from aqueous solutions—for example, to remove caffeine from coffee. It also is used to remove nail polish and paint. Cellulose nitrate is dissolved in ethyl acetate and butyl acetate to form lacquers. The solvent evaporates as the lacquer "dries," leaving a thin film on the surface. High boiling esters are used as softeners (plasticizers) for brittle plastics.

Summary

- A carboxylic acid is an organic compound that contains the carboxyl functional group.
- The general formula for a carboxylic acid can be abbreviated as \( R-COOH \).
- Many carboxylic acids are used in the food and beverage industry for flavoring and/or as preservatives.
- An ester has an OR group attached to the carbon atom of a carbonyl group.
- Fats and vegetable oils are esters of long-chain fatty acids and glycerol.
- Esters occur widely in nature and generally have pleasant odors and are often responsible for the characteristic fragrances of fruits and flowers.

Contributors and Attributions

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- TextMap: Beginning Chemistry (Ball et al.)
- OpenSTAX