4.3: Carboxylic Acids

Learning Objectives

- Name carboxylic acids with common names.
- Name carboxylic acids according to IUPAC nomenclature.

A common carbonyl-containing organic molecule is the **carboxylic acid.** A carboxylic acid contains a **carboxyl group**, which is formed when a hydroxyl group (–OH) is attached to the carbon of a carbonyl group.

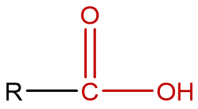


Figure 4.3.1: General structure of a carboxylic acid with the carboxyl group shown in red.

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 4.3.2). Not surprisingly, many of them are best known by common names based on Latin and Greek words that describe their source.

Figure 4.3.2: Carboxylic Acids in the Home. 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. © Thinkstock

Common Carboxylic Acids

The simplest carboxylic acid, formic acid (HCOOH), 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).

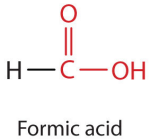
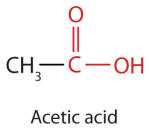


Figure 4.3.3: Structure of formic acid.

The next higher homolog is acetic 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.



Acetic acid

Figure 4.3.4: Structure of acetic acid.

> 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_3CH_2COOH), is seldom encountered in everyday life. The fourth homolog, butyric acid ($CH_3CH_2CH_2COOH$), 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.

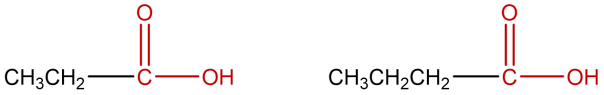
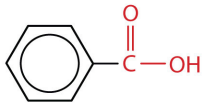


Figure 4.3.5: Structures of propionic acid (left) and butyric acid (right).

The acid with the carboxyl group attached directly to a benzene ring is called benzoic acid (C_6H_5COOH).

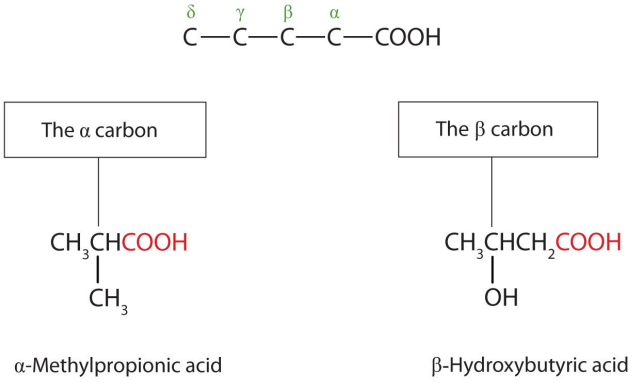


Benzoic acid

Figure 4.3.6: Structure of benzoic acid.

Naming Carboxylic Acids

Both common and International Union of Pure and Applied Chemistry (IUPAC) names are used for carboxylic acids. The common names of carboxylic acids use Greek letters (α, β, γ, δ, and so forth), not numbers, to designate the position of substituents in acids. These letters refer to the position of the carbon atom in relation to the carboxyl carbon atom.



α-Methylpropionic acid

β-Hydroxybutyric acid

Figure 4.3.7: Locator guidelines used in common names of carboxylic acids.

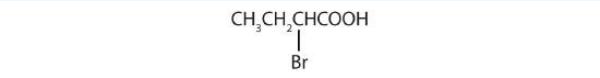
Here are some simple IUPAC rules for naming carboxylic acids:

1. The parent hydrocarbon is the one that corresponds to the **longest continuous chain (LCC) containing the carboxyl group**. The parent name is determining by replacing the *-e* ending of the parent alkane with the **suffix *-oic* and the word *acid* *(-oic acid)***.
2. **Number the parent chain** to determine the location of atoms present in the molecule. As with aldehydes, the **carboxyl carbon atom is always assigned to C1**. It is unnecessary to designate this group by number.
3. **Substituents are named and numbered** as in alkanes. These groups are listed in alphabetical order prior to the parent name. *According to these rules, the IUPAC name for the molecules shown above in* Figure 4.3.7 are 2-methylpropanoic acid (left) and 3-hydroxybutanoic acid (right).

Greek letters are used with common names; numbers are used with IUPAC names.

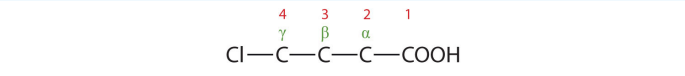
✔ Example 4.3.1

Give the common and IUPAC names for each compound.

1. $ClCH_2CH_2CH_2COOH$
2. 

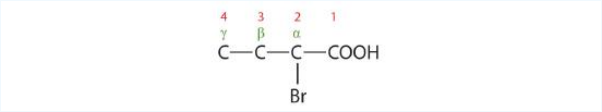
Solution

1. The LCC contains four carbon atoms; the compound is therefore named as a substituted butyric (or butanoic) acid.



The chlorine atom is attached to the γ-carbon in the common system or C4 in the IUPAC system. The compound is γ-chlorobutyric acid or 4-chlorobutanoic acid.

2. The LCC contains four carbon atoms; the compound is therefore named as a substituted butyric (or butanoic) acid.



The bromine (Br) atom is at the α-carbon in the common system or C2 in the IUPAC system. The compound is α-bromobutyric acid or 2-bromobutanoic acid.

? Exercise 4.3.1

Give the IUPAC name for each compound.

a. $ClCH_2CH_2CH_2CH_2COOH$
b. $(CH_3)_2CHCH_2CHBrCOOH$

✔ Example 4.3.2

Write the condensed structural formula for β-chloropropionic acid.

Solution

Propionic acid has three carbon atoms: C–C–COOH. Attach a chlorine (Cl) atom to the parent chain at the beta carbon atom, the second one from the carboxyl group: Cl–C–C–COOH. Then add enough hydrogen atoms to give each carbon atom four bonds: $ClCH_2CH_2COOH$.

? Exercise 4.3.2

Write the condensed structural formula for 4-bromo-5-methylhexanoic acid.

Key Takeaways

- Simple carboxylic acids are best known by common names based on Latin and Greek words that describe their source (e.g., formic acid, Latin *formica*, meaning “ant”).
- Greek letters, not numbers, designate the position of substituted acids in the common naming convention.
- IUPAC names are derived from the LCC of the parent hydrocarbon with the *-e* ending of the parent alkane replaced by the suffix *-oic* and the word *acid*.
