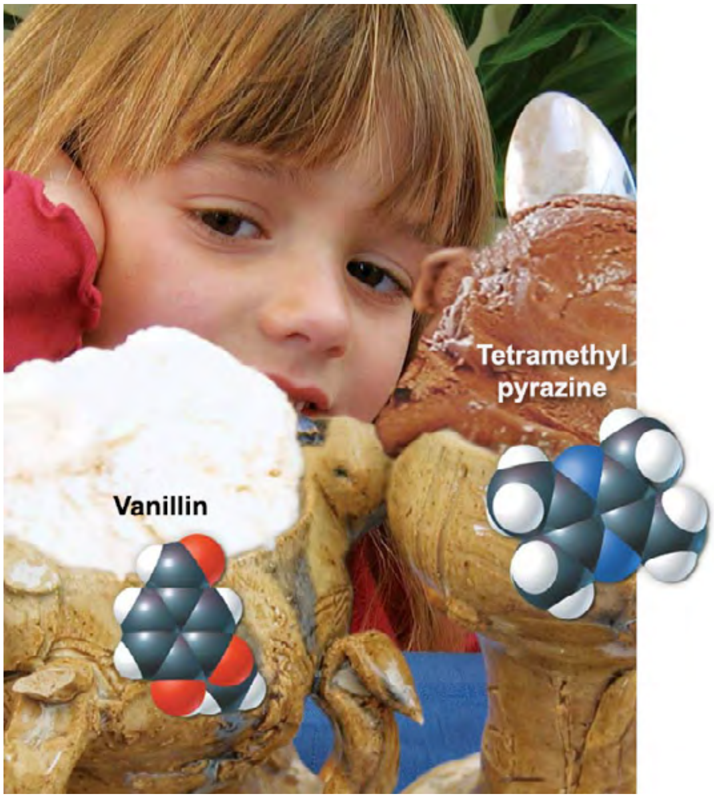


Chapter 12

Organic Compounds

THE MAIN IDEA

Carbon can form a limitless number of chemical structures.

12.6 Carbonyl Compounds

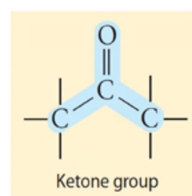
The **carbonyl group** consists of a carbon atom double-bonded to an oxygen atom. It occurs in the organic compounds known as *ketones*, *aldehydes*, *amides*, *carboxylic acids*, and *esters*.

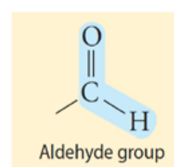
A **ketone** is a carbonyl-containing organic molecule in which the carbonyl carbon is bonded to two carbon atoms. A familiar example of a ketone is *acetone*, which is often used in fingernail-polish remover and is shown in **Figure 12.22a**. In an **aldehyde**, the carbonyl carbon is bonded either to one carbon atom and one hydrogen atom, as in **Figure 12.22b**, or, in the case of formaldehyde, the simplest aldehyde, to two hydrogen atoms.

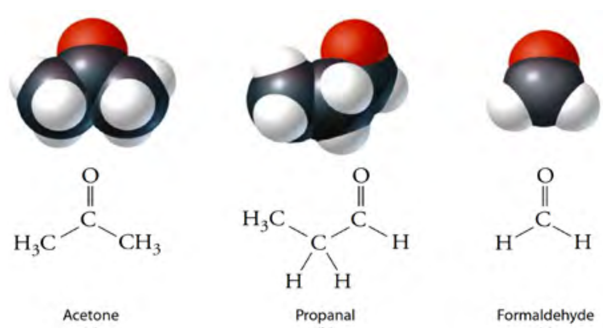
Many aldehydes are particularly fragrant. A number of flowers, for example, owe their pleasant odor to the presence of simple aldehydes. The smells of lemons, cinnamon, and almonds are due to the aldehydes citral, cinnamaldehyde, and benzaldehyde, respectively. The structures of these three aldehydes are shown in **Figure 12.23**. Another aldehyde, vanillin, which was introduced at the beginning of this chapter, is the key flavoring molecule derived from seed pods of the vanilla orchid. You may have

READING CHECK

What type of bond is found between the carbon and the oxygen of a carbonly group?



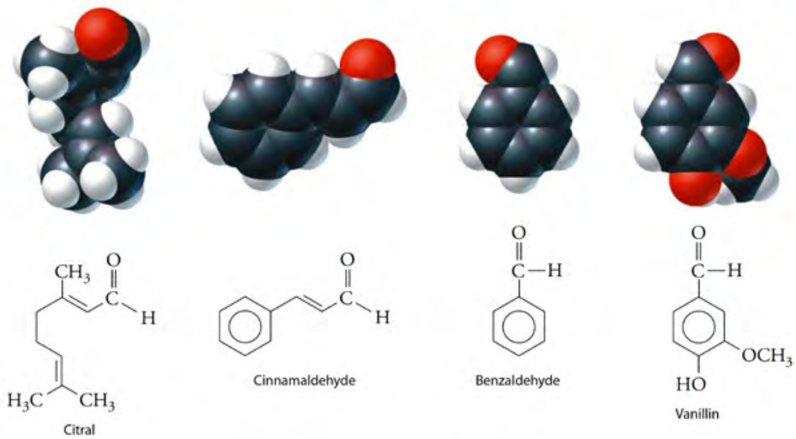


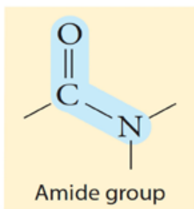


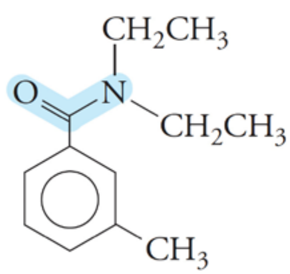
< Figure 12.22

(a) When the carbon of a carbonyl group is bonded to two carbon atoms, the result is a ketone. An example is acetone. (b) When the carbon of a carbonyl group is bonded to at least one hydrogen atom, the result is an aldehyde. An example is propanal. The simplest aldehyde is formaldehyde, which has two hydrogens bonded to the carbon of the carbonyl.

Figure 12.23 >
Aldehydes are responsible for many familiar fragrances.







N,N-Diethyl-*m*-toluamide
(DEET)

Λ Figure 12.24
N,N-diethyl-*m*-toluamide is an example of an amide. Amides contain the amide group, shown highlighted in blue.

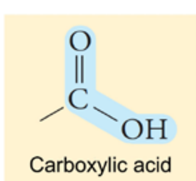


Figure 12.25 >

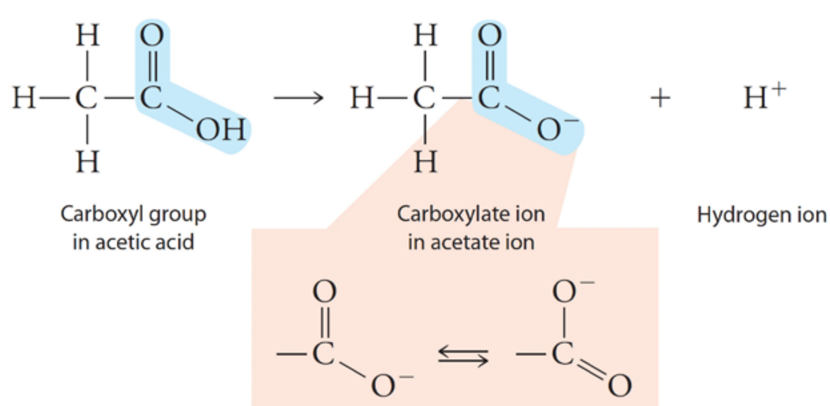
The negative charge of the carboxylate ion is spread across the two oxygen atoms of the carboxyl group. This stabilizes the negative charge, which makes it easier for the carboxylic acid group to donate a hydrogen ion.

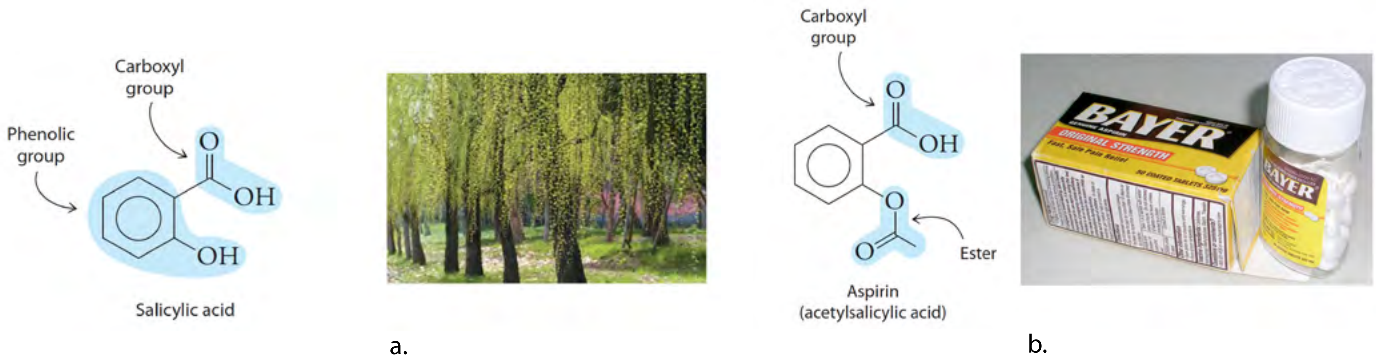
noticed that vanilla seed pods and vanilla extract are fairly expensive. Imitation vanilla flavoring is less expensive because it is merely a solution of the compound vanillin, which is economically synthesized from waste chemicals from the wood pulp industry. Imitation vanilla does not taste the same as natural vanilla extract, however, because in addition to vanillin, many other flavorful molecules contribute to the complex taste of natural vanilla. Many books manufactured in the days before acid-free paper smell of vanilla because of the vanillin formed and released as the paper ages, a process accelerated by the acids the paper contains.

An **amide** is a carbonyl-containing organic molecule in which the carbonyl carbon is bonded to a nitrogen atom. The active ingredient of most mosquito repellents is an amide whose chemical name is N, N-diethyl-*m*-toluamide but is commercially known as DEET, shown in **Figure 12.24**. This compound is actually not an insecticide. Rather, it causes certain insects, especially mosquitoes, to lose their sense of direction, which effectively protects DEET wearers from being bitten.

In a **carboxylic acid** the carbonyl carbon is bonded to a hydroxyl group. As its name implies, this functional group is able to donate hydrogen ions. Organic molecules that contain it are therefore weakly acidic. An example is acetic acid, $C_2H_4O_2$, which, after water, is the main ingredient of vinegar—when you smell vinegar, you are smelling acetic acid. You may recall that this organic compound was used as an example of a weak acid back in Chapter 10.

As with phenols, the acidity of a carboxylic acid results in part from the ability of the functional group to accommodate the negative charge of the ion that forms after the hydrogen ion has been donated. As shown in **Figure 12.25**, a carboxylic acid transforms to a carboxylate ion as it loses the hydrogen ion.





Λ Figure 12.26

(a) Salicylic acid, which is found in the bark of willow trees, is an example of a molecule containing both a carboxyl group and a phenolic group. (b) Aspirin, acetylsalicylic acid, is less acidic than salicylic acid because it no longer contains the acidic phenolic group, which has been converted to an ester.

The negative charge of the carboxylate ion is then distributed between the two oxygens. This spreading out helps to accommodate the negative charge. An interesting example of an organic compound that contains both a carboxylic acid and a phenol is salicylic acid, found in the bark of willow trees and illustrated in **Figure 12.26a**. At one time brewed for its antipyretic (fever-reducing) effect, salicylic acid is an important analgesic (painkiller), but it causes nausea and stomach upset due to its relatively high acidity, a result of the presence of two acidic functional groups. In 1899, Friedrich Bayer and Company, in Germany, introduced a chemically modified version of this compound in which the acidic phenolic group was transformed into an *ester* functional group. The result was the less acidic and more tolerable drug called acetylsalicylic acid, the chemical name for aspirin, shown in **Figure 12.26b**.

An **ester** is an organic molecule similar to a carboxylic acid except that in the ester, the hydroxyl hydrogen is replaced by a carbon. Unlike carboxylic acids, esters are not acidic because they lack the hydrogen of the hydroxyl group. Like aldehydes, many simple esters have notable fragrances and are often used as flavorings. Some familiar ones are listed in **Table 12.5.**

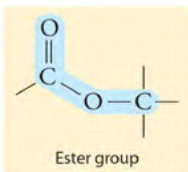
FOR YOUR INFORMATION

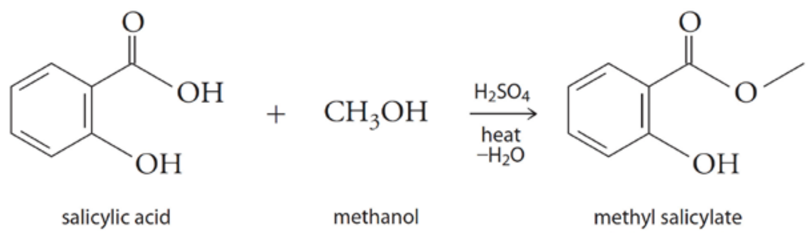
Felix Hoffmann was the chemist working at Bayer & Co, who in 1897, added the acetyl group to the phenol group of salicylic acid. According to Bayer, Hoffmann was inspired by his father, who had been complaining about the side effects of salicylic acid. To market the new drug, Bayer invented the name aspirin, where *a-* is for acetyl, *-spir-* is for the spirea flower, another natural source of salicylic acid, and *-in* is a common suffix for medications. After World War I, Bayer, a German company, lost the rights to use the name aspirin. Bayer didn't regain these rights until 1994, for a steep price of $1 billion.

TABLE 12.5 Some Esters and Their Flavors and Odors

STRUCTURE	NAME	FLAVOR/ODOR
$H-C(=O)-O-CH_2CH_3$	Ethyl formate	Rum
$H_3C-C(=O)-O-CH_2CH_2-CH(CH_3)-CH_3$	Isopentyl acetate	Banana
$H_3C-C(=O)-O-CH_2(CH_2)_6CH_3$	Octyl acetate	Orange
$CH_3CH_2CH_2-C(=O)-O-CH_2CH_3$	Ethyl butyrate	Pineapple

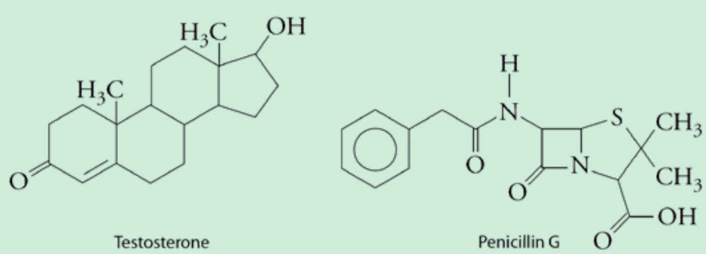
Esters are fairly easy to synthesize by dissolving a carboxylic acid in an alcohol and then bringing the mixture to a boil in the presence of a strong acid, such as sulfuric acid, H_2SO_4. Shown below is the synthesis of methyl salicylate from salicylic acid and methanol. Methyl salicylate is responsible for the smell of wintergreen and is a common ingredient of hard candies.





CONCEPT **CHECK**

Identify all the functional groups in these two molecules (ignore the sulfur group in penicillin G).



CHECK YOUR ANSWER

Testosterone: alcohol and ketone. Penicillin G: amide (two amide groups) and carboxylic acid.