20.1 Give the structure of each of the following compounds.
(a) γ-hydroxybutyric acid  (b) β,β-dichloropropionic acid  
(c) (Z)-3-hexenoic acid  (d) 4-methylhexanoic acid  
(e) 1,4-cyclohexanedicarboxylic acid  (f) p-methoxybenzoic acid  
(g) α,α-dichloroadipic acid  (h) oxalic acid

20.2 Name each of the following compounds. Use a common name for at least one compound.
(a) \( \text{CH}_3\text{CH}_2\text{CO}_2\text{H} \)  
(b) \( \text{HO}_2\text{C(CH}_2\text{)}_2\text{CH(CH}_3\text{)}_2 \)  
(c) \( \text{OH} \)  
(d) \( \text{CH}_2\text{Cl}_2\text{CO}_2\text{H} \)  
(e) \( \text{HO}_2\text{C}-\text{CH}-\text{CO}_2\text{H} \)  
(f) \( \text{CH}_3\text{CO}_2\text{H} \)

---

20.2 STRUCTURE AND PHYSICAL PROPERTIES OF CARBOXYLIC ACIDS

The structure of a simple carboxylic acid, acetic acid, is compared with the structures of other oxygen-containing compounds in Fig. 20.1. Carboxylic acids, like aldehydes and ketones, have trigonal geometry at their carbonyl carbons. Notice, moreover, that the two oxygens of a carboxylic acid are quite different. One, the carbonyl oxygen, is the oxygen involved in the \( \text{C}=\text{O} \) double bond. Figure 20.1 demonstrates that the \( \text{C}=\text{O} \) bonds of aldehydes, ketones, and carboxylic acids have the same length. The other oxygen, called the carboxylate oxygen, is the oxygen involved in the \( \text{C}−\text{O} \) single bond. Notice in Fig. 20.1 that the \( \text{C}−\text{O} \) bond in a carboxylic acid is considerably shorter than the \( \text{C}−\text{O} \) bond in an alcohol or ether (about 1.36 Å).

---

Figure 20.1 Comparison of the structures of acetic acid and other oxygen-containing compounds. The carbonyl compounds have identical \( \text{C}=\text{O} \) bond lengths, and the \( \text{C}−\text{O} \) single bond in a carboxylic acid is shorter than that in an ether or alcohol.
versus about 1.42 Å). The reason for this difference is that the C—O bond in an acid is an $sp^2$–$sp^3$ single bond, whereas the C—O bond in an alcohol or ether is an $sp^3$–$sp^3$ single bond.

\[
\begin{align*}
\text{C—O} & \quad \text{versus} \quad \text{C—O} \\
\text{sp}^2 & \quad \text{sp}^3 \\
\text{(more } s \text{ character, therefore shorter)} & \quad \text{(longer)}
\end{align*}
\]

(20.2)

The carboxylic acids of lower molecular mass are high-boiling liquids with acrid, piercing odors. They have considerably higher boiling points than many other organic compounds of about the same molecular mass and shape:

- Acetic acid: 117.9 °C
- Isopropyl alcohol: 82.3 °C
- Acetone: 56.5 °C
- Isobutylene: −6.9 °C

The high boiling points of carboxylic acids can be attributed not only to their polarity, but also to the fact that they form very strong hydrogen bonds. In the solid state, and under some conditions in both the gas phase and solution, carboxylic acids exist as hydrogen-bonded dimers. (A dimer is any structure derived from two identical smaller units.)

The equilibrium constants for the formation of such dimers in solution are very large—on the order of $10^6$ to $10^7 \text{ M}^{-1}$. (The equilibrium constant for hydrogen-bond dimerization of ethanol, in contrast, is $11 \text{ M}^{-1}$.)

Many aromatic and dicarboxylic acids are solids. For example, the melting points of benzoic acid and succinic acid are 122 °C and 188 °C, respectively.

The simpler carboxylic acids are very soluble in water, as expected from their hydrogen-bonding capabilities; the unbranched carboxylic acids below pentanoic acid are miscible with water. Many dicarboxylic acids also have significant water solubilities.

**PROBLEM** 20.3 At a given concentration of acetic acid, in which solvent would you expect the amount of acetic acid dimer to be greater: CCl₄ or water? Explain.