Carboxylic Acid

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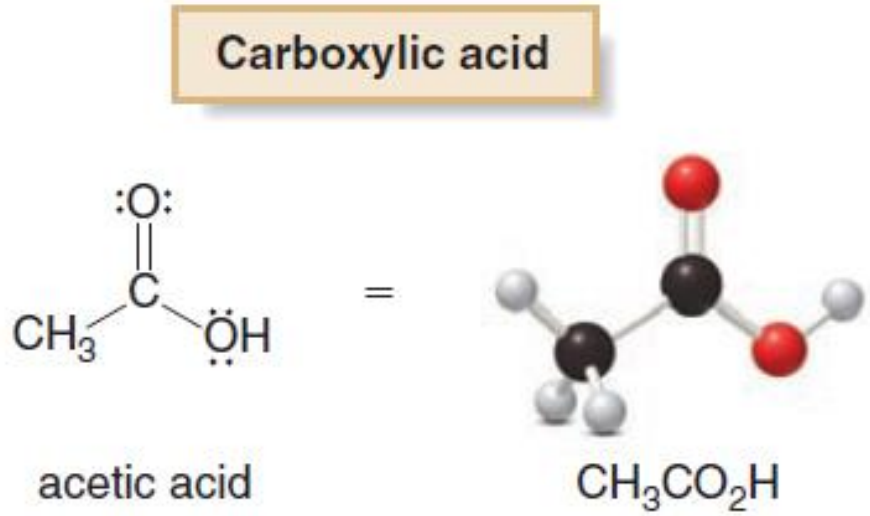
Lecture 13

3. Carboxylic Acid

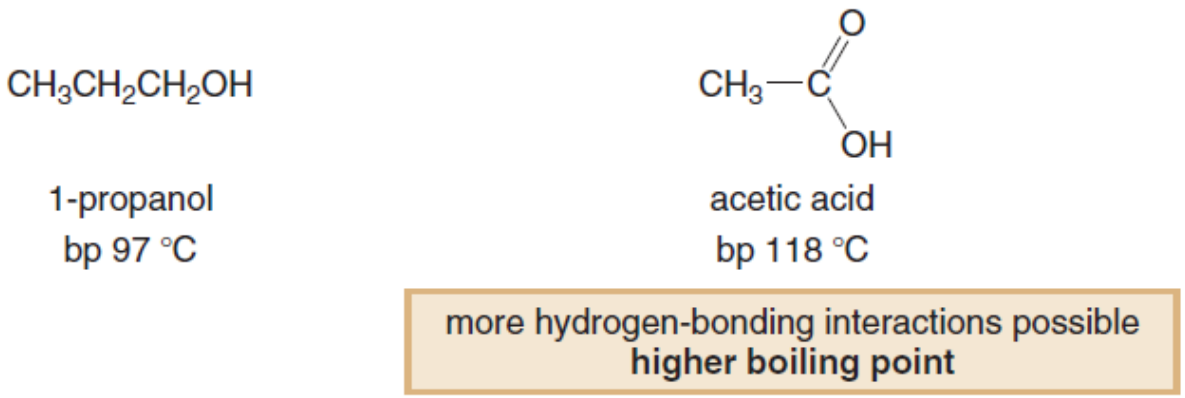
- Carboxylic acids of organic molecules that contain a carbonyl group (C=O) singly bonded to an oxygen atom.
- The structure of a carboxylic acid is often abbreviated as **RCOOH** or **RCO_2H**. Keep in mind that the central carbon in both functional groups has a **double bond to one oxygen and a single bond to another**.

✓ A carboxylic acid contains a carboxyl group (COOH).



3.1. Physical Properties of Carboxylic Acid

1. Carboxylic acids are polar compounds because they possess a polar carbonyl group.
2. Carboxylic acids also exhibit intermolecular hydrogen bonding.
3. Carboxylic acids have stronger intermolecular forces than alcohols, giving them higher boiling points and melting points, when comparing compounds of similar size.
4. Like other oxygen-containing compounds, carboxylic acids having **fewer than six carbons are soluble in water**. **Higher molecular weight compounds are insoluble in water** because the nonpolar part of the molecule, the C-C and C-H bonds, gets larger than the polar carbonyl group.

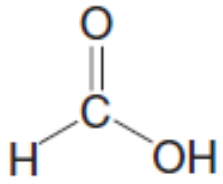


3.2. Nomenclature of Carboxylic Acid

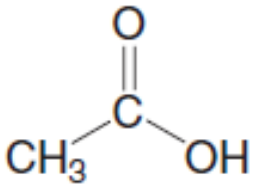
- •In the IUPAC system, carboxylic acids are identified by the suffix ***-oic acid***.

➢ To name a carboxylic acid using the IUPAC system:

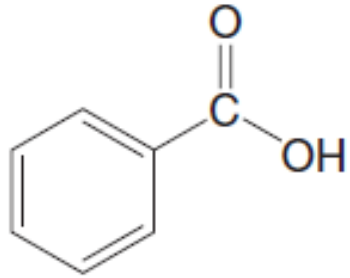
1. Find the longest chain containing the COOH group, and change the -e ending of the parent alkane to the suffix ***-oic acid***.
2. Number the carbon chain to put the COOH group at C1, but omit this number from the name. Apply all of the other usual rules of nomenclature.



formic acid
(methanoic acid)



acetic acid
(ethanoic acid)



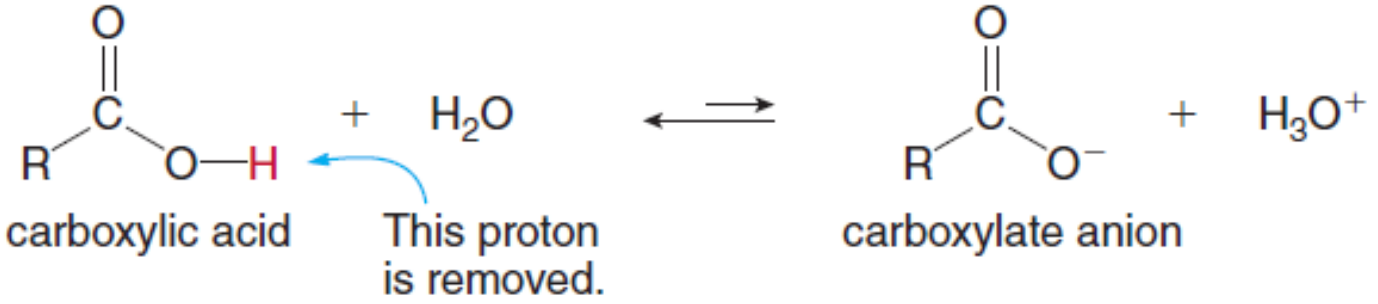
benzoic acid
(benzenecarboxylic acid)

[IUPAC names are given in parentheses, and are rarely used.]

3.3. Reactions of Carboxylic Acids

3.3A. Reaction with water:

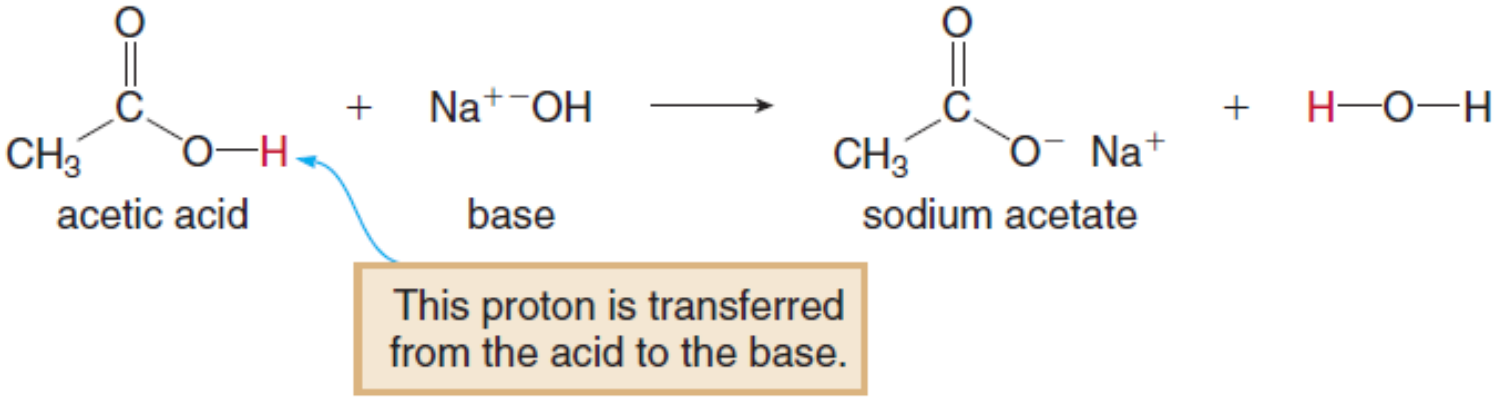
- ***Carboxylic acids are acids; that is, they are proton donors.***
- When a carboxylic acid is dissolved in water, **an acid–base reaction occurs**: the carboxylic acid donates a proton to H_2O, forming its **conjugate base**, a carboxylate anion, and water gains a proton, forming its conjugate acid, H_3O^+.



While carboxylic acids are more acidic than other families of organic compounds, they are weak acids compared to inorganic acids like HCl or H_2SO_4.

3.3B. Reaction with Bases:

- ***Carboxylic acids*** react with bases such as NaOH to form **water-soluble salts**. In this reaction, essentially all of the carboxylic acid is converted to its carboxylate anion.



- ✓ A proton is removed from acetic acid (CH_3COOH) to form its conjugate base, the acetate anion (CH_3COO^-), which is present in solution as its sodium salt, sodium acetate (CH_3COONa) .
- ✓ Hydroxide (^-OH) gains a proton to form neutral H_2O.

PROBLEM

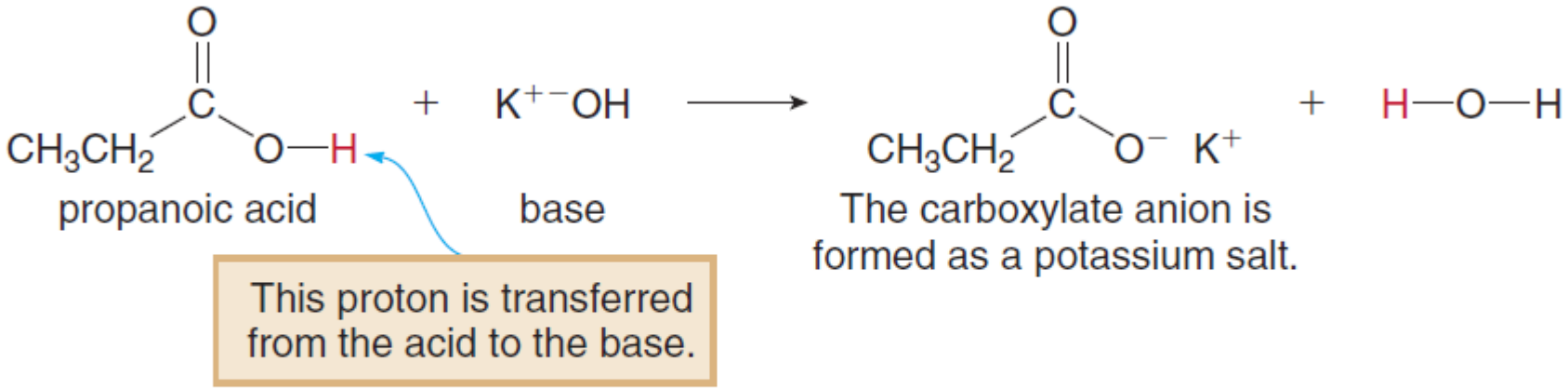
What products are formed when propanoic acid (CH_3CH_2COOH) reacts with potassium hydroxide (KOH)?

Analysis

In any acid–base reaction with a carboxylic acid:

- Remove a proton from the carboxyl group (COOH) and form the carboxylate anion ($RCOO^-$).
- Add a proton to the base.
- Balance the charge of the carboxylate anion by drawing it as a salt with a metal cation.

Solution

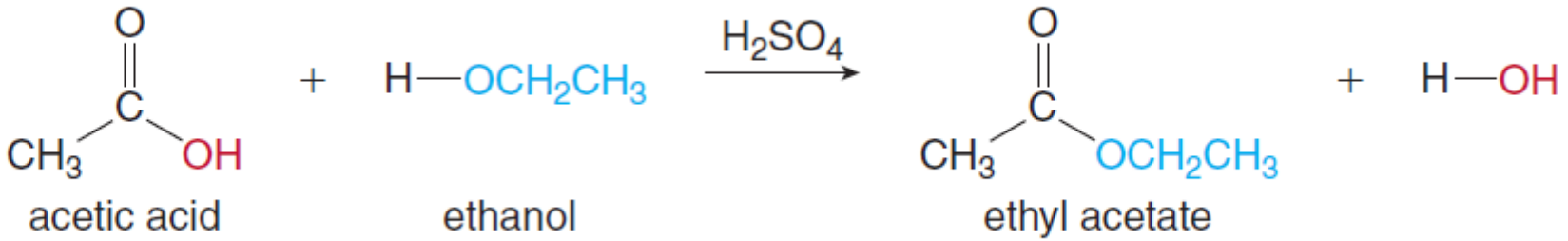


Thus, CH_3CH_2COOH loses a proton to form $CH_3CH_2COO^-$, which is present in solution as its potassium salt, $CH_3CH_2COO^-\,K^+$. Hydroxide (^-OH) gains a proton to form H_2O.

3.3C. Reaction with Alcohols:

- Treatment of a **carboxylic acid (RCOOH)** with an **alcohol (R'OH)** in the presence of an acid catalyst forms an **ester (RCOOR')**. This reaction is called a **Fischer esterification**. Esterification is a substitution because the **OR' group** of an alcohol replaces the **OH group** of the starting carboxylic acid.

Fischer esterification

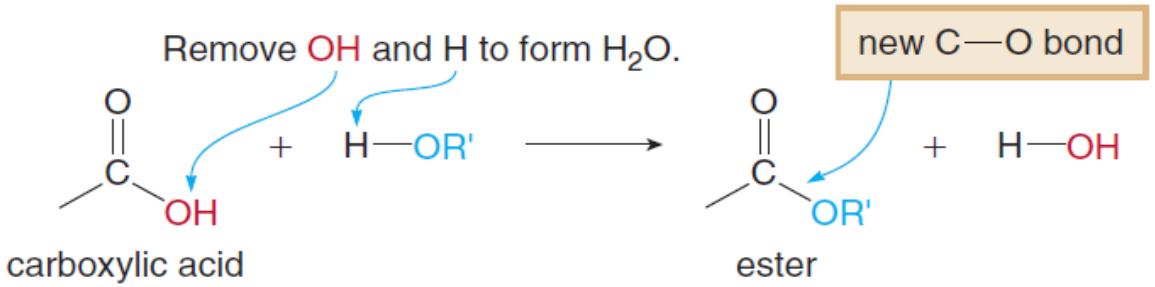


PROBLEM

What ester is formed when propanoic acid (CH_3CH_2COOH) is treated with methanol (CH_3OH) in the presence of H_2SO_4?

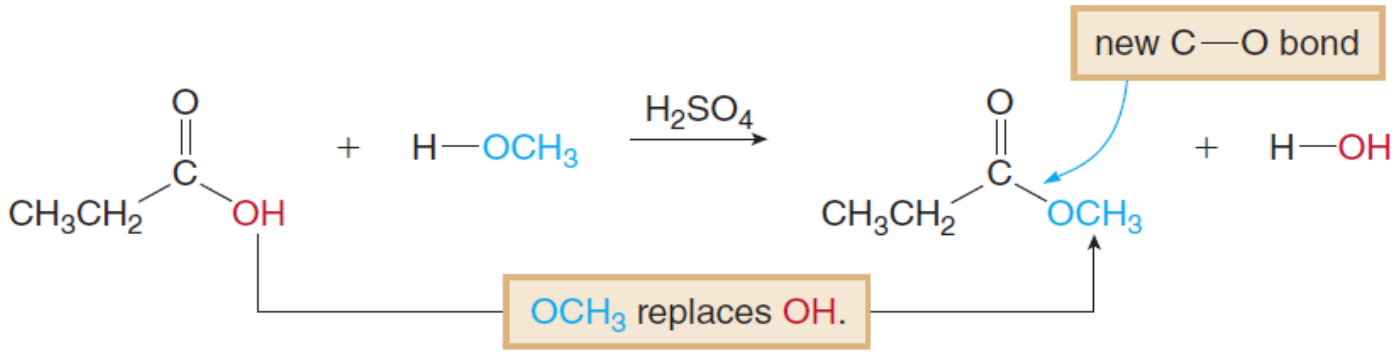
Analysis

To draw the products of esterification, replace the OH group of the carboxylic acid by the OR' group of the alcohol, forming a new C—O bond at the carbonyl carbon.



Solution

Replace the OH group of propanoic acid by the OCH_3 group of methanol to form the ester.

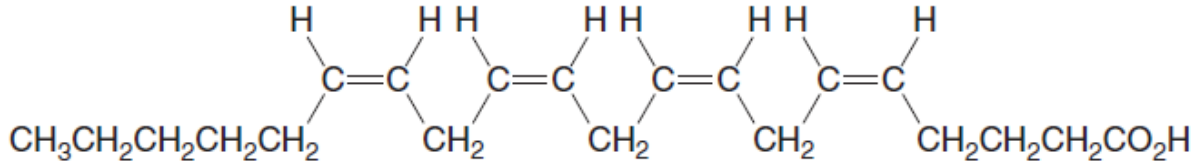


3.4. Aspirin and Anti-Inflammatory Agents

(FOCUS ON HEALTH & MEDICINE)

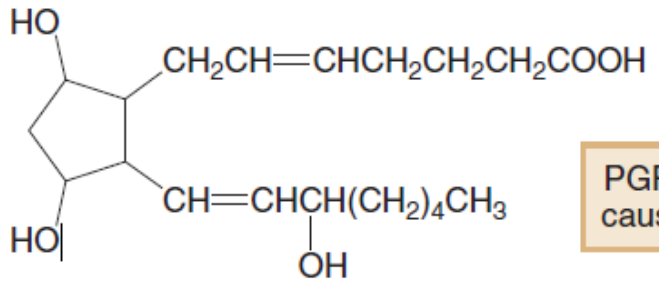
- **Aspirin** and **ibuprofen** are common **pain relievers** and **anti-inflammatory agents** that contain a carboxyl group.
- ***Aspirin relieves*** *pain and decreases inflammation because it prevents the synthesis of* ***prostaglandins****, the compounds responsible for both of these physiological responses, from* ***arachidonic acid****.*

- ***Aspirin*** was first used in medicine for its analgesic (pain-relieving), antipyretic (fever-reducing), and anti-inflammatory properties. Today it is also commonly used to prevent blood clots from forming in arteries.



arachidonic acid

Aspirin blocks this process.



$PGF_{2\alpha}$
a prostaglandin

$PGF_{2\alpha}$ and compounds like it cause pain and inflammation.