19.13
Reactions of Carboxylic Acids:
A Review and a Preview
Reactions of Carboxylic Acids

Reactions already discussed

Acidity (Sections 19.4-19.9)

Reduction with LiAlH$_4$ (Section 15.3)

Esterification (Section 15.8)

Reaction with Thionyl Chloride (Section 12.7)
Reactions of Carboxylic Acids

New reactions in this chapter

\( \alpha \)-Halogenation

Decarboxylation

But first we revisit acid-catalyzed esterification to examine its mechanism.
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Mechanism of Acid-Catalyzed Esterification
Acid-catalyzed Esterification

(also called Fischer esterification)

$$\text{Ph-COOH} + \text{CH}_3\text{OH} \overset{\text{H}^+}{\rightleftharpoons} \text{Ph-COCH}_3 + \text{H}_2\text{O}$$

Important fact: the \textit{oxygen} of the alcohol is incorporated into the ester as shown.
The mechanism involves two stages:

1) formation of tetrahedral intermediate (3 steps)
2) dissociation of tetrahedral intermediate (3 steps)
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1) formation of tetrahedral intermediate (3 steps)

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Mechanism of Fischer Esterification

tetrahedral intermediate in esterification of benzoic acid with methanol
First stage: formation of tetrahedral intermediate

\[
\text{COH} + \text{CH}_3\text{OH} \xrightleftharpoons{H^+} \text{OCH}_3
\]

methanol adds to the carbonyl group of the carboxylic acid

the tetrahedral intermediate is analogous to a hemiacetal
**Second stage: conversion of tetrahedral intermediate to ester**

\[
\text{C}_6\text{H}_5\text{C} = \text{OCH}_3 + \text{H}_2\text{O} \xrightarrow{\text{H}^+} \text{C}_6\text{H}_5\text{C} = \text{OCH}_3
\]

This stage corresponds to an acid-catalyzed dehydration.
Mechanism of formation of tetrahedral intermediate
Step 1
Step 1
Step 1

The carbonyl oxygen is protonated because the cation produced is stabilized by electron delocalization (resonance).
Step 2
Step 2
Step 3
Tetrahedral intermediate to ester stage
Step 4

Chemical reaction diagram involving molecules and atoms.
Step 4

![Chemical Reaction Diagram]
Step 5

The molecule shown is an aromatic compound with a hydroxyl group (-OH) on one end and a methoxy group (-OCH₃) on the other. Additionally, there is a quaternary ammonium group (N⁺) on the same carbon atom as the methoxy group. This structure is likely part of a larger reaction or molecule, possibly involved in a chemical transformation or reaction sequence.
Step 5

Chemical reaction diagram showing the transformation of a compound involving the steps of hydration and dehydration.
Step 6
Key Features of Mechanism

Activation of carbonyl group by protonation of carbonyl oxygen

Nucleophilic addition of alcohol to carbonyl group forms tetrahedral intermediate

Elimination of water from tetrahedral intermediate restores carbonyl group
Intramolecular Ester Formation: Lactones
Lactones are cyclic esters

Formed by intramolecular esterification in a compound that contains a hydroxyl group and a carboxylic acid function
Examples

4-hydroxybutanoic acid $\rightarrow$ 4-butanolide

IUPAC nomenclature: replace the -oic acid ending of the carboxylic acid by -olide. Identify the oxygenated carbon by number.
Examples

4-hydroxybutanoic acid → 4-butanolide

5-hydroxypentanoic acid → 5-pentanolide
Common names

γ- butyrolactone  δ-valerolactone

Ring size is designated by Greek letter corresponding to oxygenated carbon
A γ lactone has a five-membered ring
A δ lactone has a six-membered ring
Reactions designed to give hydroxy acids often yield the corresponding lactone, especially if the resulting ring is 5- or 6-membered.
Example

\[
\text{CH}_3\text{CCH}_2\text{CH}_2\text{CH}_2\text{COH}
\]

1. NaBH\textsubscript{4}
2. H\textsubscript{2}O, H\textsuperscript{+}

5-hexanolide (78%)
Example

\[ \text{CH}_3\text{CCH}_2\text{CH}_2\text{CH}_2\text{COH} \]

1. \( \text{NaBH}_4 \)
2. \( \text{H}_2\text{O}, \text{H}^+ \)

\[ \text{H}_3\text{C} \]

5-hexanolide (78%)

via:

\[ \text{OH} \]

\[ \text{CH}_3\text{CHCH}_2\text{CH}_2\text{CH}_2\text{COH} \]