

Carboxylic Acids

Reading: Wade chapter 20, sections 20-1- 20-15

Study Problems: 20-32- 20-33, 20-35, 20-36, 20-37, 20-39, 20-42, 20-43.

Key Concepts and Skills:

- Show how the acidity of carboxylic acids varies with their substitution
- Show how to synthesize carboxylic acids from oxidation of alcohols and aldehydes, carboxylations of Grignard reagents, hydrolysis of nitriles, and oxidation of alkyl benzenes.
- Propose mechanisms for nucleophilic substitution reactions, showing how esters and amides can be formed from acids using acid chlorides as intermediates
- Give the mechanism of the Fischer esterification, and illustrate how the equilibrium can be driven toward reactants or products.
- Predict the products of the reactions of carboxylic acids with diazomethane, LiAlH_4 , amines + heating, excess alkyllithium reagents.

Lecture Topics:

I. Carboxylic acids: Structure and Common Names

A carboxyl group consists of a carbonyl ($\text{C}=\text{O}$) bound to a hydroxyl group (OH). Carboxylic acids have the overall form $\text{RC}(=\text{O})\text{OH}$, or more commonly written: RCOOH .

II. Structure of carboxylic acids

The carboxylic acid has two important resonance forms:

Protonation of the carboxylic acid occurs preferentially on the carbonyl oxygen atom, since more resonance forms are possible for the positively charged molecule:

III. Properties

The trend in boiling points are rationalized by formation of hydrogen-bonded dimers, which doubles the weight of the molecules entering the gas phase.

Solubility- low M.W. acids are fully water soluble; most acids are soluble in alcohols because of the possibility of hydrogen bonding. Carboxylic acids are also generally soluble in non-polar solvents like chloroform (CHCl_3) and ether, because the structure of the hydrogen-bonded dimer is not disrupted.

IV. Acidity Measurement

The stability of the conjugate base of an acid determines the acidity of HA; very stable conjugate bases arise from stronger acids.

Compare the acidity of alcohols and acids by considering the stability of their conjugate base forms:

Diacids have two dissociation constants; the second dissociation constant is considerably less in magnitude than the first because of the creation of two negative charges in close proximity on the same molecule:

Substituent effect on acidity: electron-withdrawing groups stabilize the negative charge of the conjugate base, thus increasing the acidity of the acid. Electron-donating groups destabilize the negative charge, lowering the acidity of the acid. Distancing of the electron donating/withdrawing group from the site of the acid weakens the effect.

Groups ortho and para on a ring influence acidity to a greater extent than meta substituents.

V. Carboxylate Salts

Strong bases quantitatively deprotonate carboxylate salts. The weak base NaHCO_3 can also be used because the production of CO_2 gas upon dissociation of H_2CO_3 drives equilibrium toward production of carboxylate ion.

The carboxylate ion can be converted to the carboxylic acid by treatment with a strong acid.

Acids can be purified by extraction; base wash of an organic layer brings the carboxylate salt into the aqueous layer; the organic layer can be separated, removing organic impurities from the acid. Acidifying the aqueous solution regenerates the acid, which can be extracted into the organic layer and evaporated to recover the pure acid.

VI. Spectroscopy

VII. Synthesis of Acids

1. Oxidation of 1° alcohols : chromic acid (Collins' reagent: $\text{Na}_2\text{Cr}_2\text{O}_4/\text{H}_2\text{SO}_4$) or KMnO_4 are used. See chapter 18.
2. Oxidative cleavage of alkenes

3. Oxidation of aromatic side chains: Requires groups on aromatic ring be strongly resistant to acid/oxidation:

4. Grignard Carboxylation involves the reaction of a Grignard reagent with CO_2 :

5. Nitrile hydrolysis: acidic or basic hydrolysis of nitriles leads to carboxylic acids: