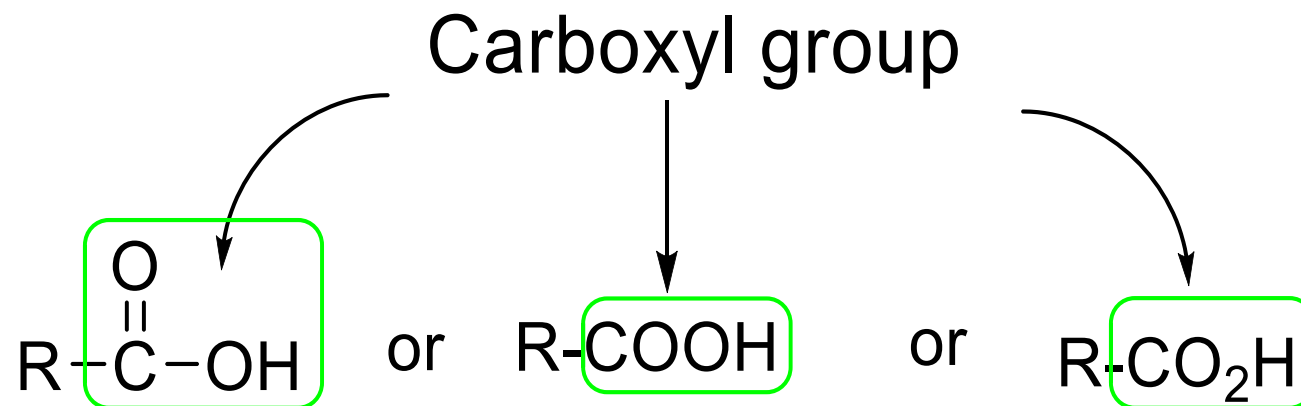


CARBOXYLIC ACIDS

Carboxylic Acids

Introduction

Carboxylic acids are organic compounds containing the carboxyl group (-COOH), wherein the hydroxyl group (-OH) is directly attached to the carbonyl (C=O) group.

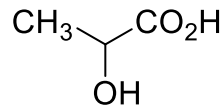


Three representations of a carboxylic acid

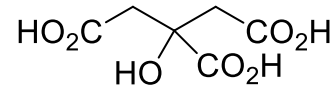
Carboxylic acids constitute one of the most frequently encountered classes of organic compounds in nature.

Natural Carboxylic Acids

A great many carboxylic acids are encountered in nature, mostly, in fruits. Indeed carboxylic acids were among the first class of organic compounds to ever be isolated from nature.



Lactic acid
(Sour milk)



Citric acid
(Lemons)



Edible carboxylic acids found in citrus fruits and fermented milk generally have sharp flavours.

Nomenclature of Carboxylic Acids

The common names of some basic carboxylic acids are derived from Latin names that indicate the first original natural source of the carboxylic acid.

Structure of Acid	Natural Source	Common Name
$\text{H}-\overset{\text{O}}{\parallel}{\text{C}}-\text{OH}$	Ants (Formica)	Formic acid
$\text{CH}_3-\overset{\text{O}}{\parallel}{\text{C}}-\text{OH}$	Vinegar (Acetum)	Acetic acid
$\text{CH}_3\text{CH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{OH}$	Basic Fat (Propio)	Propionic acid
$\text{CH}_3\text{CH}_2\text{CH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{OH}$	Rancid butter (Butyrum)	Butyric acid
$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{OH}$	Present in a Valerian herb	Valeric acid
$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{OH}$	Goat (Caper)	Caproic acid

Common Names of Carboxylic Acids

The common name of a carboxylic acid (R-COOH) is derived by adding the suffix **-ic acid** to a prefix representing the chain length of the carboxylic acid.

# of Carbons	Prefix	Common Name of Acid
1	Form-	Formic acid
2	Acet-	Acetic acid
3	Propion-	Propionic acid
4	Butyr-	Butyric acid
5	Valer-	Valeric acid
6	Capro-	Caproic acid
Aromatic acid	Benzo-	Benzoic acid

IUPAC Nomenclature of Aliphatic Carboxylic Acids

IUPAC names of straight chain aliphatic carboxylic acids are derived by adding the suffix **–oic acid** to the systematic name of the parent hydrocarbon. They are named as alkanolic acids.

# of Carbons	Structure & IUPAC Name of Alkane	Structure & IUPAC Name of Acid
1	$\begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\text{H} \\ \\ \text{H} \end{array}$ Methane	$\begin{array}{c} \text{O} \\ \\ \text{H}-\text{C}-\text{OH} \end{array}$ Methanoic acid
2	CH_3-CH_3 Ethane	$\begin{array}{c} \text{O} \\ \\ \text{CH}_3-\text{C}-\text{OH} \end{array}$ Ethanoic acid
3	$\text{CH}_3\text{CH}_2-\text{CH}_3$ Propane	$\begin{array}{c} \text{O} \\ \\ \text{CH}_3\text{CH}_2-\text{C}-\text{OH} \end{array}$ Propanoic acid

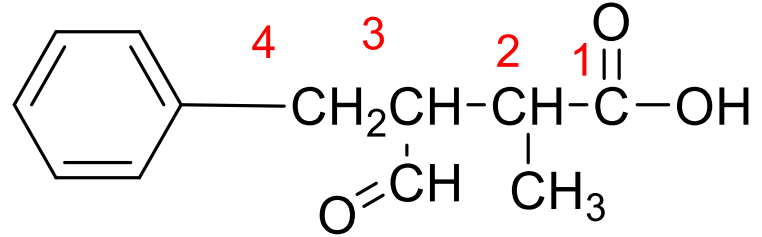
Systematic Nomenclature of Substituted Carboxylic Acids

The systematic names of substituted aliphatic carboxylic acids are derived by:

- (i) First identifying the parent chain that contains most, if not all, the carboxyl groups.
- (ii) Number the parent chain from the carbon of the carboxyl group i.e the carboxyl carbon is C-1.
- (iii) Identify the substituents and assign each substituent a locator/address number (2,3,4...etc.) consistent with the numbering in the parent chain.
- (iv) Arrange the names of the substituents in alphabetical order in the systematic name of the poly-substituted carboxylic acid.

Systematic Nomenclature of Substituted Carboxylic Acids

Example



Parent Name: Butanoic Acid

Substituents

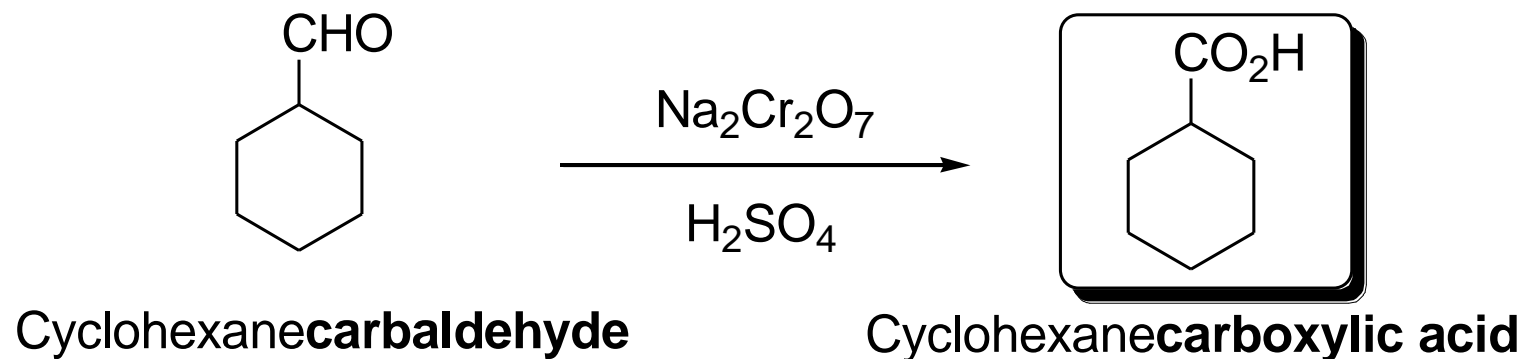
- 2-Methyl
- 3-Formyl
- 4-Phenyl

Complete Name: **3-Formyl-2-methyl-4-phenylbutanoic acid**

All other substituted aliphatic monocarboxylic acids are named using the same sequence.

Systematic Nomenclature of Cyclic Carboxylic Acids

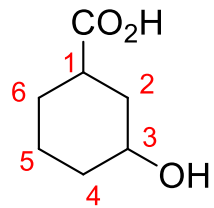
The systematic name of a carboxylic acid in which the COOH group is attached directly to a ring is derived by adding a suffix – **carboxylic acid** to the name of the attached cycloalkane or cycloalkene or arene.



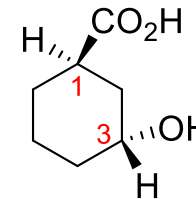
When such carboxylic acids are substituted, the carbon of the COOH group is itself not numbered, but it is, by convention, taken to be attached to C-1 of the ring.

Systematic Nomenclature of Substituted Cyclic Carboxylic Acids

For substituted carboxylic acids with the carboxyl group attached directly to a ring, the carbon of the COOH group is itself not numbered, but it is, by convention, taken to be attached to C-1 of the ring.

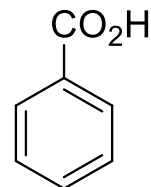


3-Hydroxycyclohexanecarboxylic acid



(1R,3R)-3-Hydroxycyclohexanecarboxylic acid

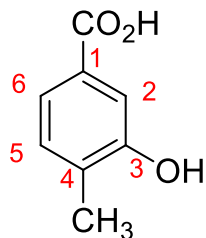
Under this system of nomenclature, benzoic acid would be named as benzenecarboxylic acid.



Benzenecarboxylic acid
(Benzoic acid)

IUPAC Nomenclature of Substituted Aromatic Carboxylic Acids

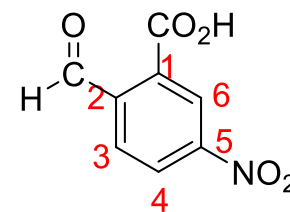
Substituted aromatic acids with one carboxyl group are named as derivatives of benzoic acid, with the position of substituents being cited using the locators (2,3 etc) according to their position on the benzene ring relative to the carboxyl group. The carbon on which the carboxyl group is attached is by convention C-1.



Parent Name: Benzoic Acid

Substituents ↓
3-Hydroxy-
4-Methyl

3-Hydroxy-4-methylbenzoic acid or
3-Hydroxy-4-methylbenzenecarboxylic acid



Parent Name: Benzoic Acid

Substituents ↓
2-Formyl-
5-Nitro-

2-Formyl-5-nitrobenzoic acid
2-Formyl-5-nitrobenzenecarboxylic acid

Systematic Nomenclature of Dicarboxylic Acids

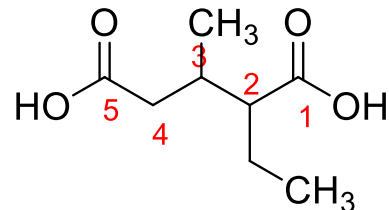
The systematic name of an open chain aliphatic dicarboxylic acid is derived by adding a suffix **-dioic acid** to the name of the parent hydrocarbon i.e. **alkanedioic acid**.

Systematic Name	Common Name	Structure
Ethanedioic acid	Oxalic acid	$\text{HO}_2\text{C}-\text{CO}_2\text{H}$
Propanedioic acid	Malonic acid	$\text{HO}_2\text{CCH}_2\text{CO}_2\text{H}$
Butanedioic acid	Succinic acid	$\text{HO}_2\text{C}(\text{CH}_2)_2\text{CO}_2\text{H}$
Pentanedioic acid	Glutaric acid	$\text{HO}_2\text{C}(\text{CH}_2)_3\text{CO}_2\text{H}$
Hexanedioic acid	Adipic acid	$\text{HO}_2\text{C}(\text{CH}_2)_4\text{CO}_2\text{H}$
Heptanedioic acid	Pimelic acid	$\text{HO}_2\text{C}(\text{CH}_2)_5\text{CO}_2\text{H}$

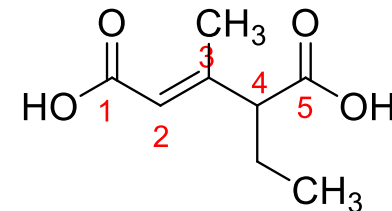
Systematic Nomenclature of Substituted Dicarboxylic Acids

The systematic name of an aliphatic dicarboxylic acid is derived by:

- (i) First identifying the parent chain that contains the two carboxylic acid groups and then adding a suffix **-dioic acid** to the name of the parent hydrocarbon.
- (ii) The parent chain is numbered from the end that gives the substituents in the chain the lowest possible address number.
- (iii) The substituents are arranged in alphabetical order in the full name of the dicarboxylic acid.



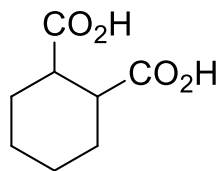
2-Ethyl-3-methylpentanedioic acid



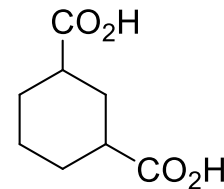
(*E*)-4-Ethyl-3-methylpent-2-enedioic acid

Systematic Nomenclature of Cyclic Dicarboxylic Acids

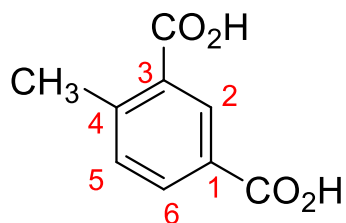
The systematic name of a cyclic aliphatic or aromatic dicarboxylic acid is derived by adding a suffix **-dicarboxylic acid** to the name of the parent cycloalkane or arene i.e. **cycloalkanedicarboxylic acid** or **arenedicarboxylic acid**.



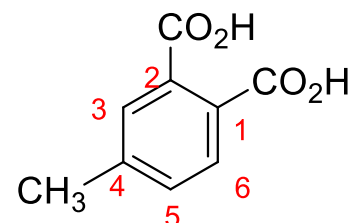
Cyclohexane-1,2-dicarboxylic acid



Cyclohexane-1,3-dicarboxylic acid



4-Methylbenzene-1,3-dicarboxylic acid

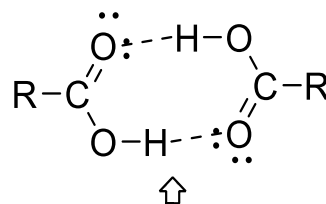
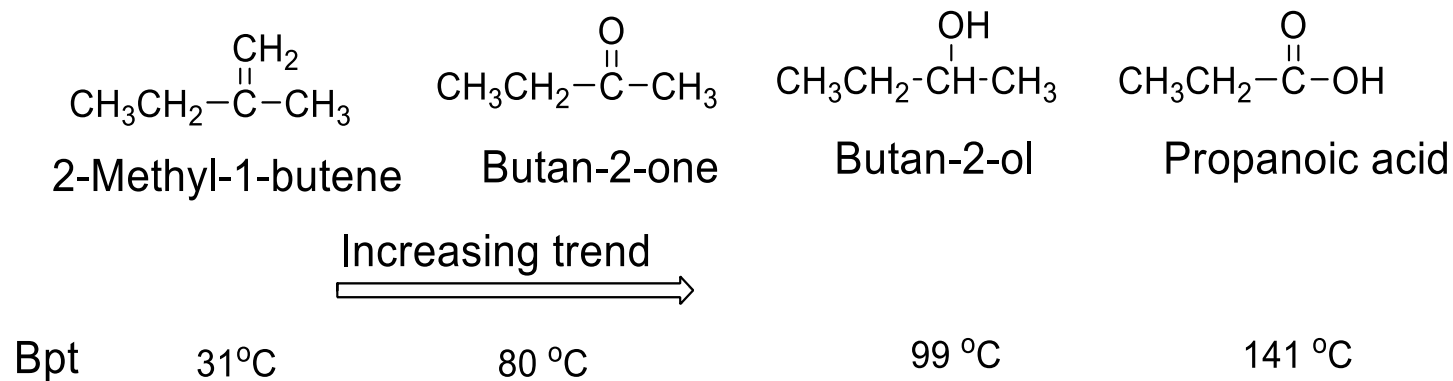


4-Methylbenzene-1,2-dicarboxylic acid

The positions of the two carboxyl groups are cited with the lowest possible address numbers to differentiate between isomers.

Properties of Carboxylic Acids

The physical properties of carboxylic acids can be explained from the perspective of the bond polarization in the carboxyl group and its capacity to engage in hydrogen-bonding. Carboxylic acids boil at considerably higher temperatures than alcohols, ketones, or aldehydes of similar molecular weight

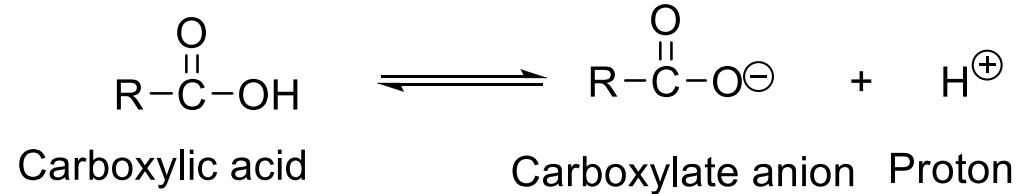


Strong intermolecular attractive forces hold the acid molecules together

The high boiling point of carboxylic acids is attributed to their capacity to readily form stable, hydrogen-bonded dimers.

Acidity of Carboxylic Acids

Carboxylic acids may dissociate to a carboxylate anion and a hydrogen ion (proton).



K_a = Acid dissociation constant

$$K_a = \frac{[\text{RCO}_2^-][\text{H}^+]}{[\text{RCO}_2\text{H}]}$$

High K_a \implies Strong acid

Low K_a \implies Weak acid

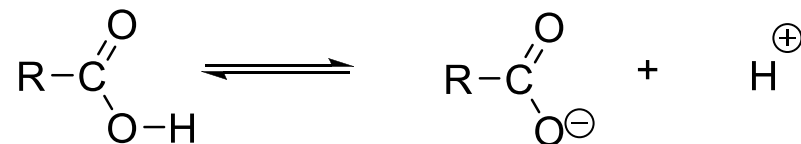
$$\text{p}K_a = -\log K_a$$

High $\text{p}K_a$ \implies Weakening acidity

Low $\text{p}K_a$ \implies Increasing acidity

Substituent Effects on the Acidity of Aliphatic Carboxylic Acids

Carboxylic acids dissociate to a carboxylate anion and a proton.

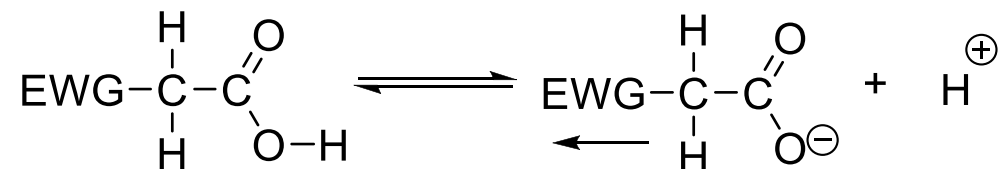


Any factors that stabilize the excess charge on the carboxylate anion will enhance the acid dissociation constant and hence the acidity of the carboxylic acid.

ALKYL GROUPS: EFFECTS OF ELECTRON-DONATING GROUPS			
Name of Acid	Structure	pK_a	Effect
Methanoic acid	HCO ₂ H	3.8	
Ethanoic acid	CH ₃ CO ₂ H	4.7	Weakening acidity
Propanoic acid	CH ₃ CH ₂ CO ₂ H	4.9	Negligible effect
Heptanoic acid	CH ₃ (CH ₂) ₅ CO ₂ H	4.9	

Substituent Effects on the Acidity of Aliphatic Carboxylic Acids

ELECTRON WITHDRAWING GROUPS			
Name of Acid	Structure	pK _a	Effect
Ethanoic acid	CH ₃ CO ₂ H	4.7	
Methoxyethanoic acid	CH ₃ OCH ₂ CO ₂ H	3.6	EWG's increase acidity
Cyanoethanoic acid	N≡C-CH ₂ CO ₂ H	2.5	
Nitroethanoic acid	O ₂ N-CH ₂ CO ₂ H	1.7	



The electron withdrawing groups disperse the negative charge of the carboxylate anion thus stabilizing it and promoting its formation. Note the enhanced acidity in substrates with electron-withdrawing groups.

Substituent Effects on the Acidity of Aliphatic Carboxylic Acids

α-HALOGENS: EFFECT OF ELECTRONEGATIVITY ON ACIDITY			
Name of Acid	Structure	pK_a	Effect
Ethanoic acid	CH ₃ CO ₂ H	4.7	
Fluoroethanoic acid	FCH ₂ CO ₂ H	2.6	α -Halogen groups increase acidity with increasing electronegativity
Chloroethanoic acid	ClCH ₂ CO ₂ H	2.9	
Bromoethanoic acid	BrCH ₂ CO ₂ H	2.9	

The increase in acidity with increasing electronegativity of the halogen is another manifestation of the effectiveness of charge dispersal in the stabilization of the negative charge of the carboxylate anion.

Substituent Effects on the Acidity of Aliphatic Carboxylic Acids

CUMMULATIVE EFFECT OF SUBSTITUENTS ON ACIDITY			
Name of Acid	Structure	pK_a	Effect
Chloroethanic acid	$\text{ClCH}_2\text{CO}_2\text{H}$	2.9	Substituent effects are additive
Dichloroethanoic acid	$\text{Cl}_2\text{CHCO}_2\text{H}$	1.3	
Trichloroethanoic acid	$\text{Cl}_3\text{CCO}_2\text{H}$	0.9	

The substituent effect is cumulative. The more the electron-withdrawing groups the better the stabilization of the carboxylate anion and the higher their acidities.

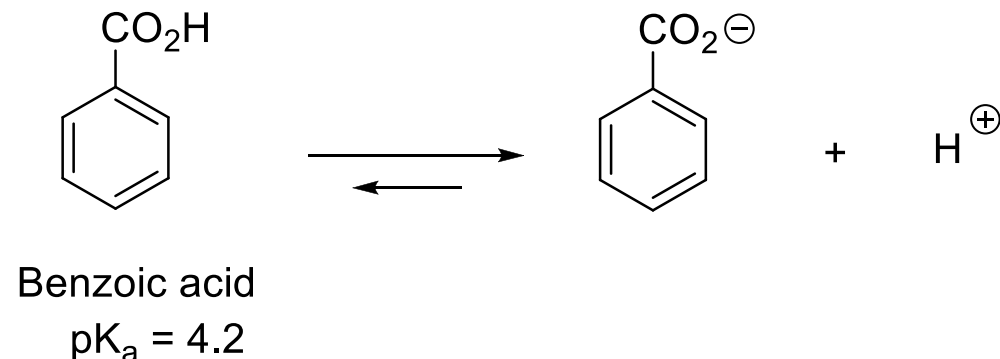
Substituent Effects on the Acidity of Aliphatic Carboxylic Acids

EFFECT OF BOND DISTANCE ON ACIDITY			
Name of Acid	Structure	pK _a	Effect
Chloroethanoic acid	$\text{ClCH}_2\text{CO}_2\text{H}$	2.9	The stabilizing effect due to the inductive effect decreases rapidly with distance.
3-Chloropropanoic acid	$\text{ClCH}_2\text{CH}_2\text{CO}_2\text{H}$	4.0	
4-Chlorobutanoic acid	$\text{ClCH}_2\text{CH}_2\text{CH}_2\text{CO}_2\text{H}$	4.5	

Substituents mainly exert their influence on the acidity of aliphatic carboxylic acid through the inductive effect. Since the inductive effect operates through sigma bonds, it diminishes rapidly with increasing distance from the carboxyl group (number of σ -bonds).

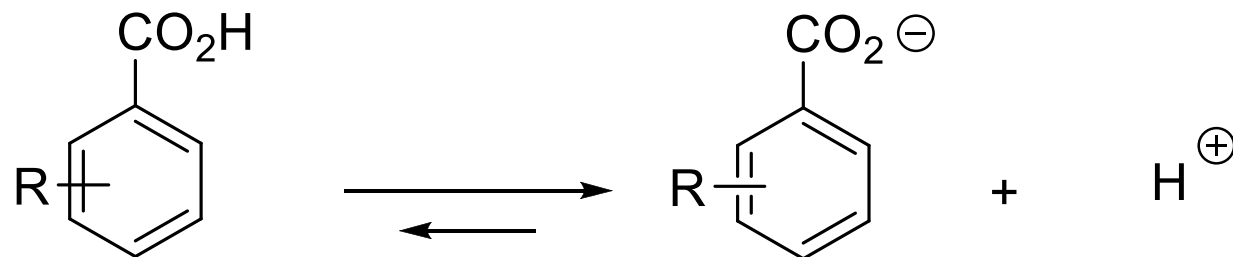
Acidity of Aromatic Carboxylic Acids

Benzoic acid is the simplest of aromatic carboxylic acids.



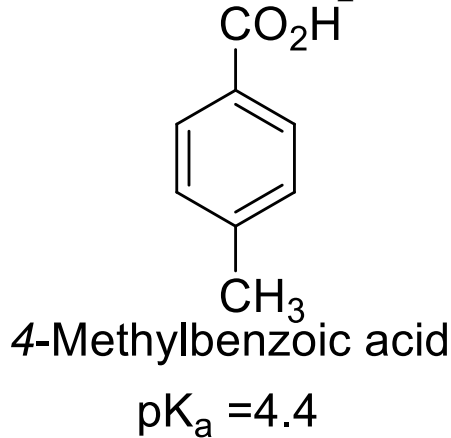
Two factors influence the acidity of substituted aromatic carboxylic acids: The **resonance effect** and the **inductive effect**.

Whereas the inductive effect only operates through σ -bonds, the resonance effect operates by electron or charge delocalization through π -bonds.

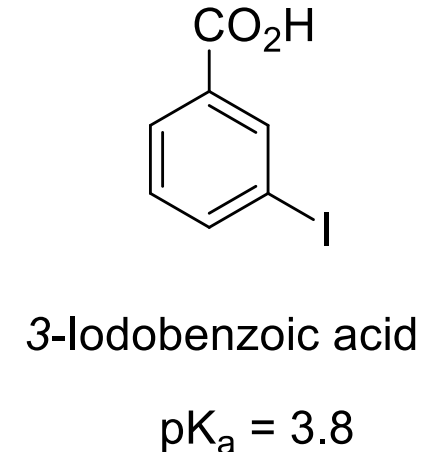
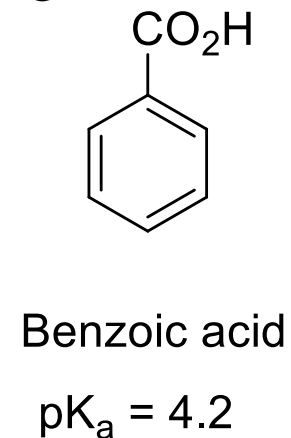


Acidity of Aromatic Carboxylic Acids: Inductive Effect

When an aromatic carboxylic acid has a substituent that does not have lone pairs of electrons or charge that can be delocalized in the aromatic nucleus, then, only the inductive effect can be invoked in explaining its degree of acidity.



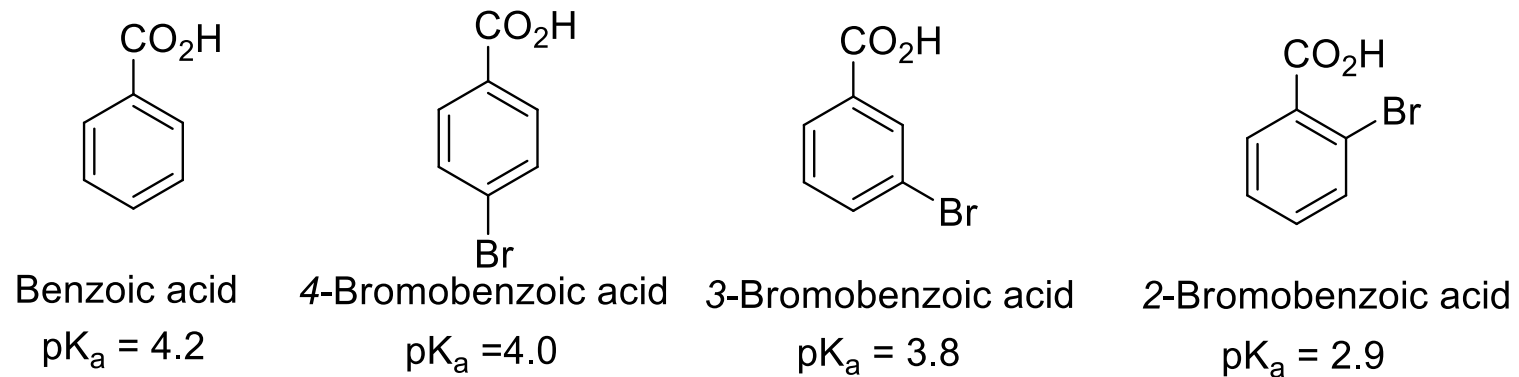
Electron donation
via inductive effect



Electron-withdrawal
via inductive effect

Whereas electron donating groups suppress the acidity of benzoic acids, electron-withdrawing groups enhance the acidity.

Acidity of Aromatic Carboxylic Acids: Inductive Effect



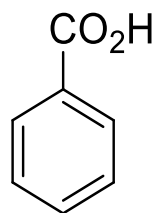
Electron-withdrawal via the inductive effect

Halides (F, Cl, Br and I) are usually considered as weakly ring deactivating through the inductive effect. The halobenzoate anions are more stabilized than benzoate anions, hence the higher acidity of all isomeric halobenzoic acids relative to unsubstituted benzoic acid.

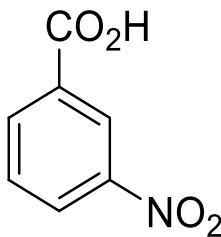
The 2-halobenzoic acids are more acidic than 3-halobenzoic acid, which are more acidic than the 4-halobenzoic acid derivatives.

Acidity of Aromatic Carboxylic Acids: the Resonance Effect

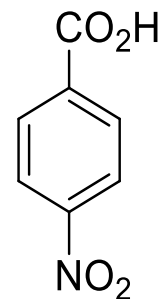
When both resonance and inductive effects apply in a specified substrate, the resonance effect dominates the inductive effect and thus determines the order of acidity among isomeric carboxylic acids.



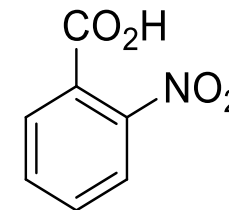
Benzoic acid
 $\text{pK}_a = 4.2$



m-Nitrobenzoic acid
 $\text{pK}_a = 3.5$



p-Nitrobenzoic acid
 $\text{pK}_a = 3.4$



o-Nitrobenzoic acid
 $\text{pK}_a = 2.2$

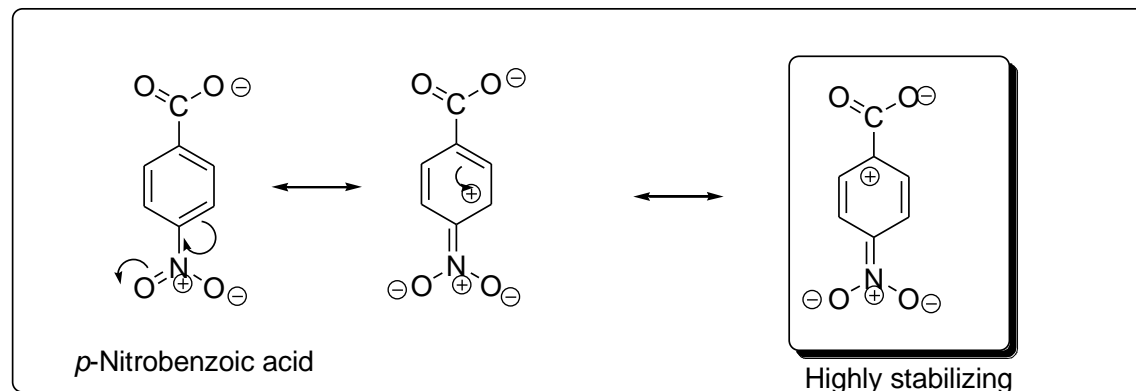
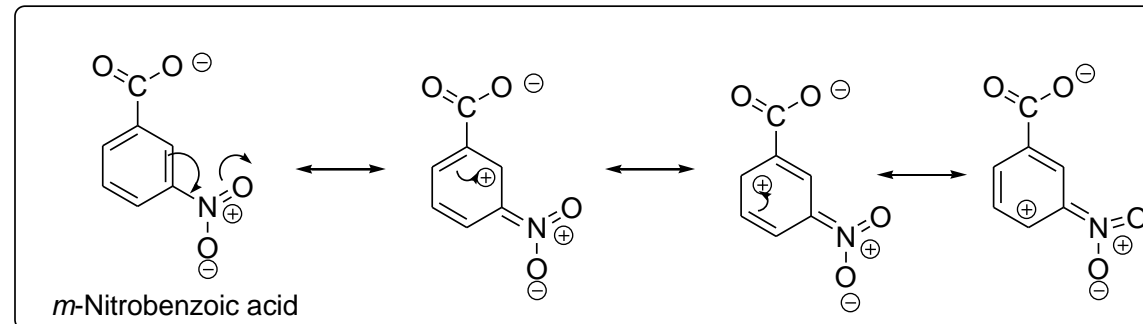
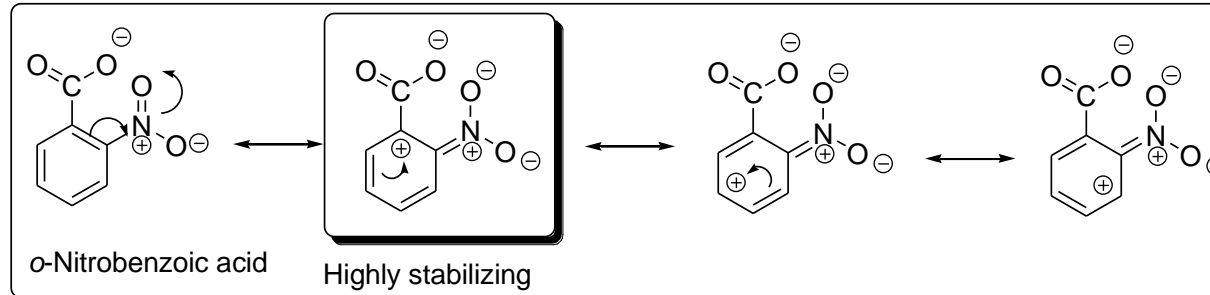
Electron-withdrawal via the resonance effect

The carboxylate anion obtained in the ionization of aromatic carboxylic acids is best stabilized when there are electron-withdrawing substituents attached to the aromatic nucleus.

It is for this reason that the nitrobenzoic acid derivatives, with the highly electron-withdrawing nitro group, are stronger acids than benzoic acid.

Resonance Structures of Isomeric Nitrobenzoates

Resonance Structures of carboxylate anions derived from ionization of isomeric nitrobenzoic acids



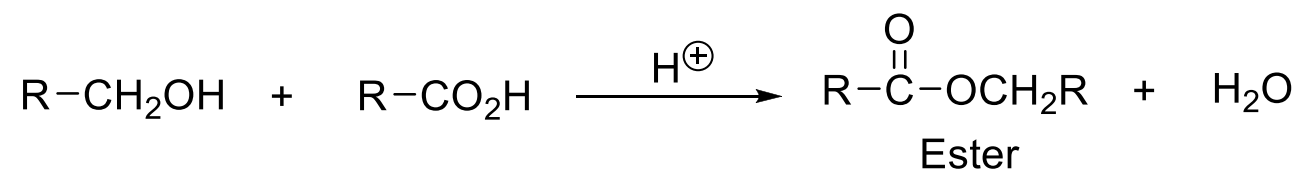
Synthesis of Carboxylic Acids

Oxidation of Primary Alcohols to Carboxylic Acids

The synthesis of carboxylic acids requires the generation or incorporation of the carboxyl group in a substrate.



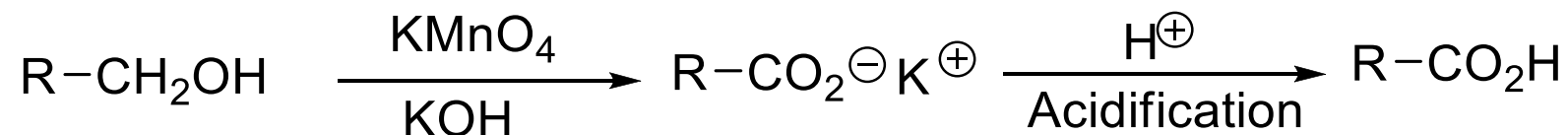
Although, primary alcohols can be oxidized to carboxylic acids using strong oxidizing agents such as CrO_3 , $\text{Na}_2\text{Cr}_2\text{O}_7$, $\text{K}_2\text{Cr}_2\text{O}_7$ or KMnO_4 , in practice, however, the oxidation of primary alcohols with acidic chromic acid solutions usually forms esters (acid-catalysed esterification between the carboxylic acid and the unreacted primary alcohol takes place) making this strategy synthetically inefficient.



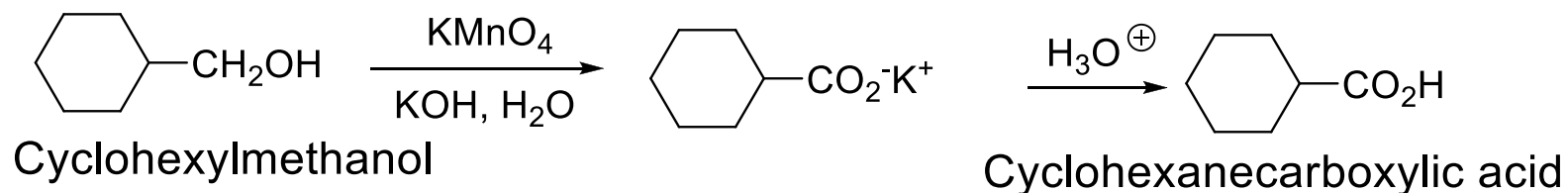
Synthesis of Carboxylic Acids

Oxidation of Primary Alcohols to Carboxylic Acids

The best conditions for the oxidation of primary alcohols to carboxylic acids is under the basic conditions employing potassium permanganate.

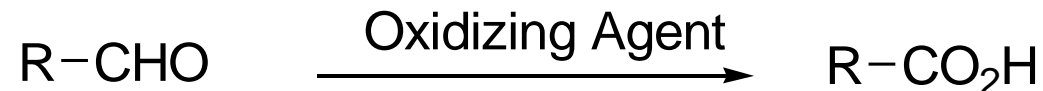


Example



Synthesis of Carboxylic Acids

Oxidation of Aldehydes to Carboxylic Acids



Aldehydes can be oxidised to carboxylic acids by a variety of oxidizing agents. Both strong and mild oxidizing agents may be employed successfully.

Strong Oxidizing Agents

- (a) CrO_3
Oxidations in water or dilute mineral acid
- (b) $\text{Na}_2\text{Cr}_2\text{O}_7$ or $\text{K}_2\text{Cr}_2\text{O}_7$
Oxidation in dilute mineral acid
- (c) KMnO_4
Oxidations in basic media in the presence of KOH

Mild Oxidizing Agents

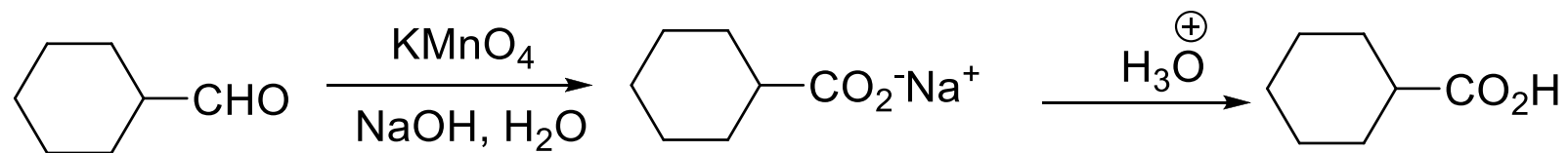
- (a) Ag_2O

Note that Ag_2O does not oxidize alcohols

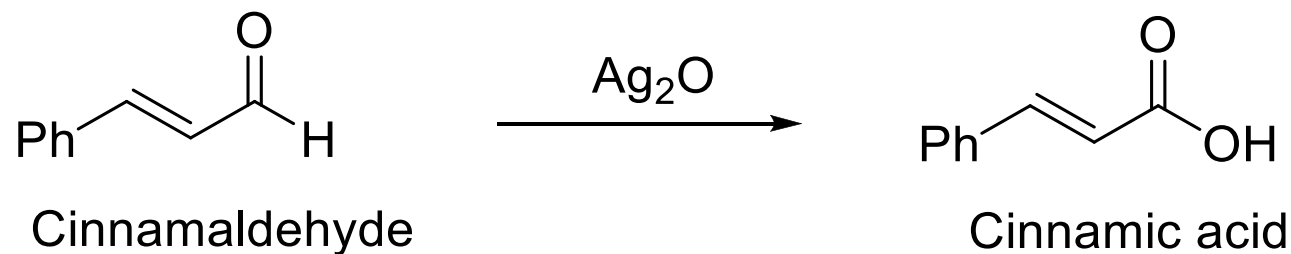
Synthesis of Carboxylic Acids

Oxidation of Aldehydes to Carboxylic Acids

Oxidations of aldehydes with KMnO_4 in basic media yields a carboxylate salt that must be acidified to provide the free carboxylic acid.

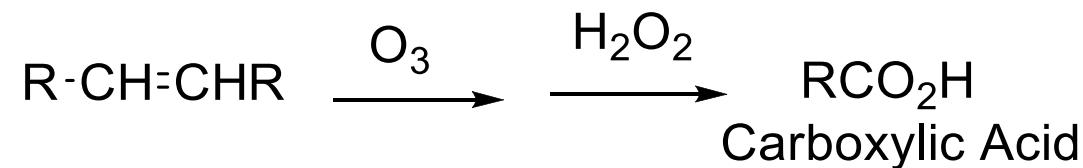


Some aldehydes may contain other functional groups that are sensitive to oxidation. The selective oxidation of such aldehydes requires the use of mild and selective oxidizing agents for aldehydes such as silver(I)oxide.

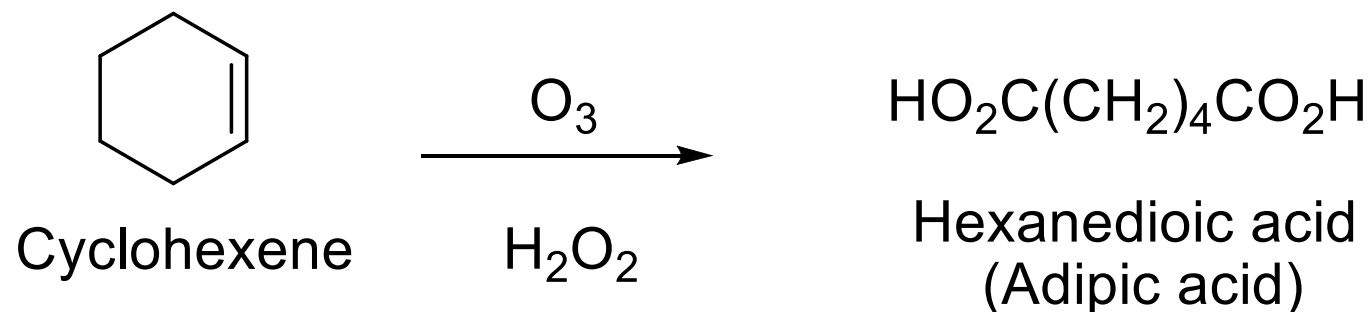


Synthesis of Carboxylic Acids

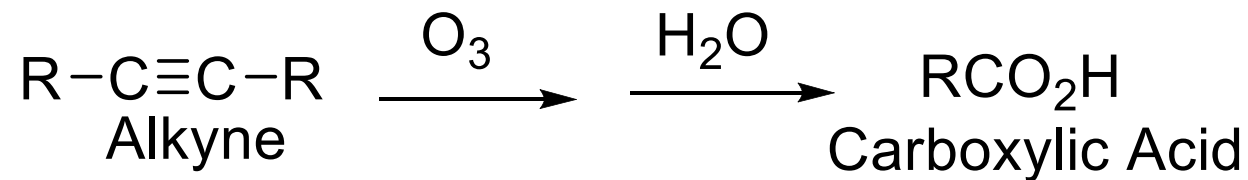
Ozonolysis of Alkenes to Carboxylic Acids



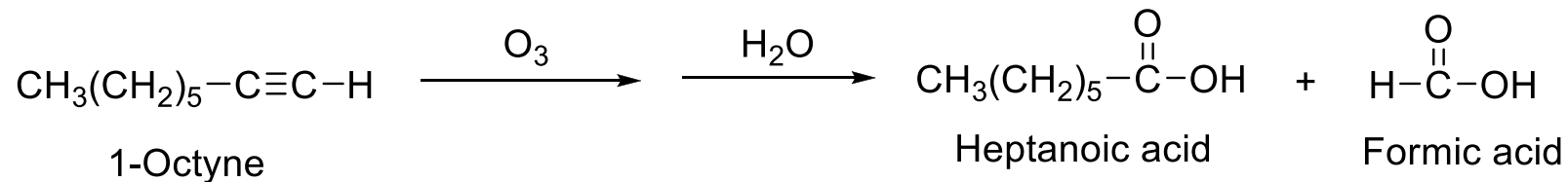
Ozonolysis of appropriately substituted alkenes under oxidative cleavage (H_2O_2) conditions provides carboxylic acids.



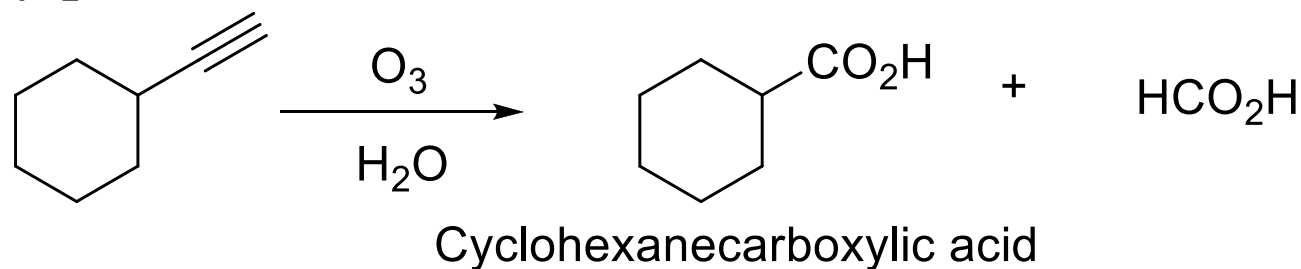
Ozonolysis of Alkynes to Carboxylic Acids



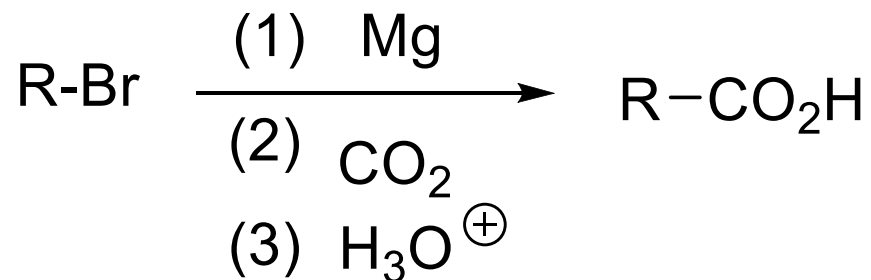
Ozonolysis of alkynes under hydrolytic conditions lends access to carboxylic acids.



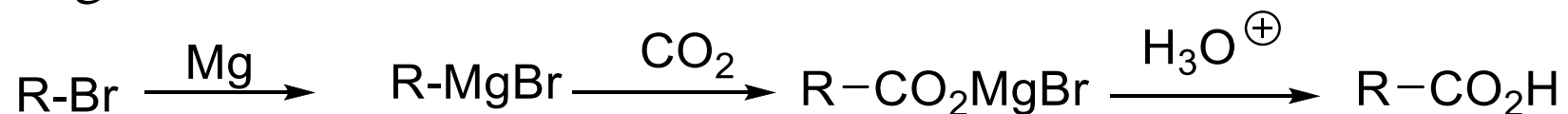
Terminal alkynes are strategic substrates in the synthesis of carboxylic acids because the methanoic acid formed can be readily washed with water leaving the other carboxylic acid relatively pure.



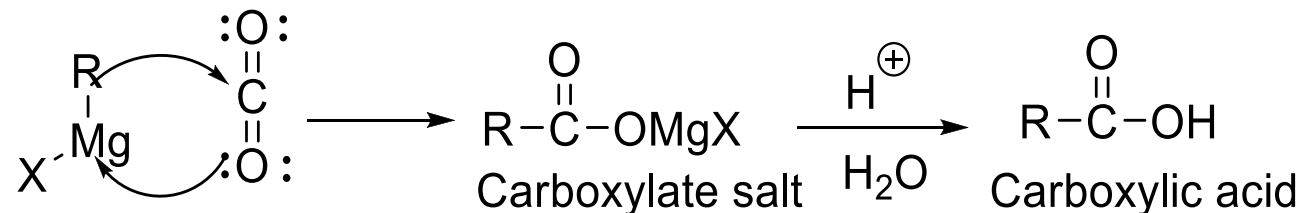
Carboxylation of Grignard Reagents



The reaction of Grignard reagents with carbon dioxide can be used to prepare carboxylic acids containing one more carbon atom than the parent alkyl/aryl halide of the organomagnesium reagent.



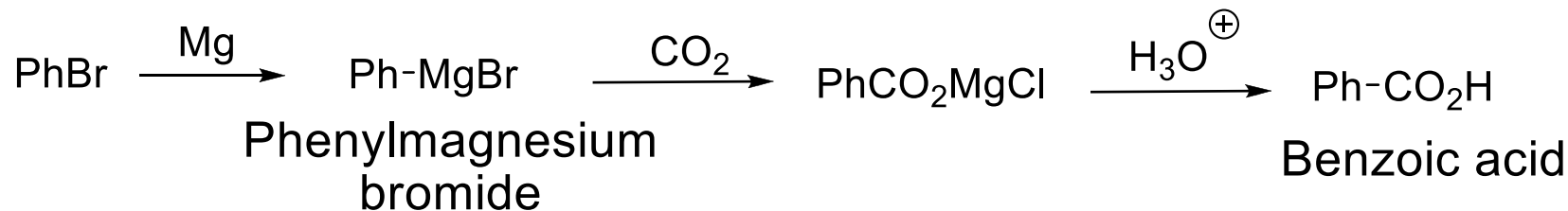
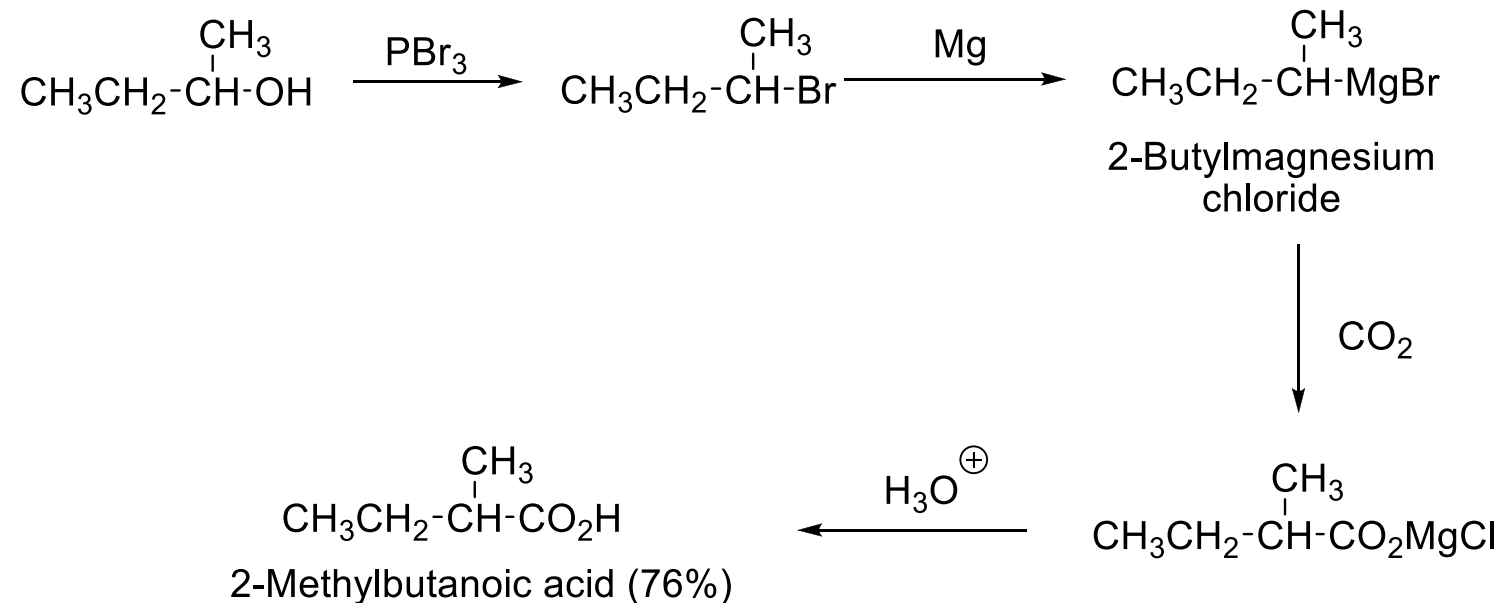
The nucleophilic carbon atom of the organometallic reagent attacks the carbon of the carbonyl group, while the magnesium atom complexes with the oxygen atom.



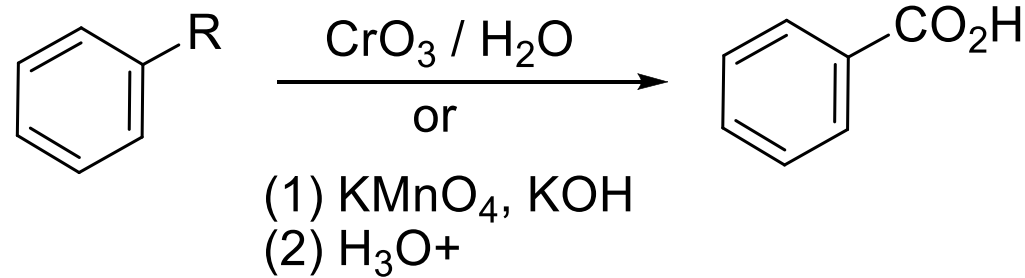
Carboxylation of Grignard Reagents

Both aliphatic and aromatic carboxylic acids can be prepared by carboxylation of Grignard reagents.

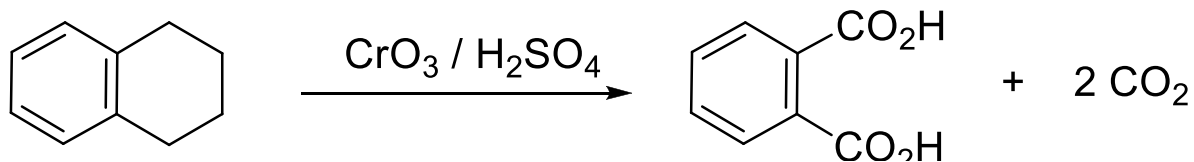
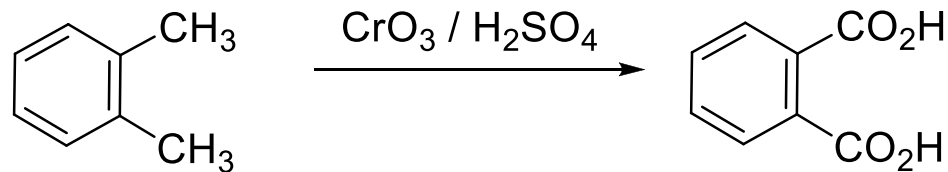
Examples



Side-Chain Oxidation of Alkylbenzenes to Benzoic Acids



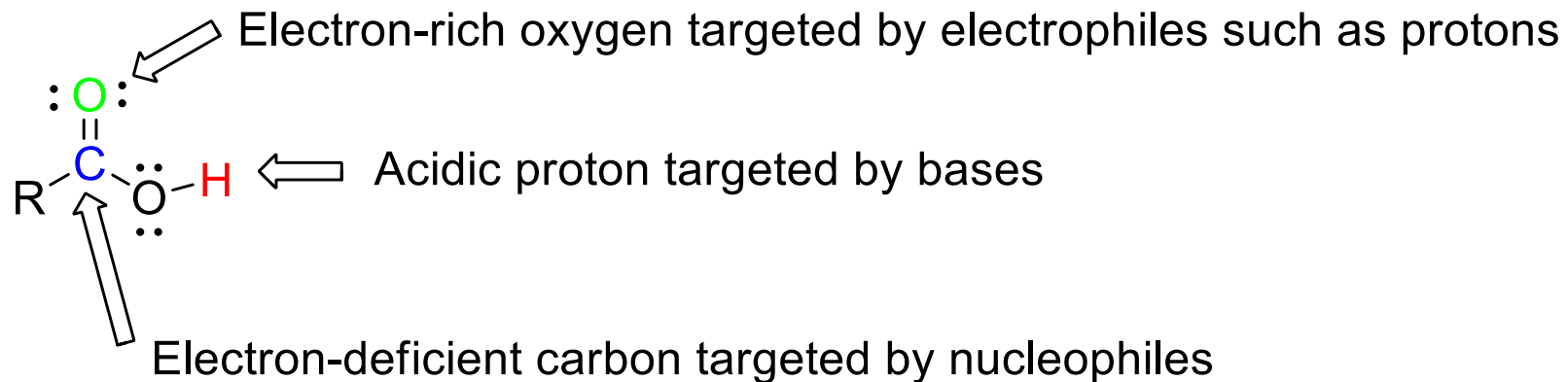
Oxidation of alkylbenzenes using strong oxidizing agents provides benzoic acids. The entire alkyl chain, regardless of its length, is oxidised to a carboxyl (-COOH) group.



Reactions of Carboxylic Acids

The reactions of carboxylic acids can be directed to various sites on the carboxyl group.

Reaction sites on the carboxyl group of Carboxylic Acids

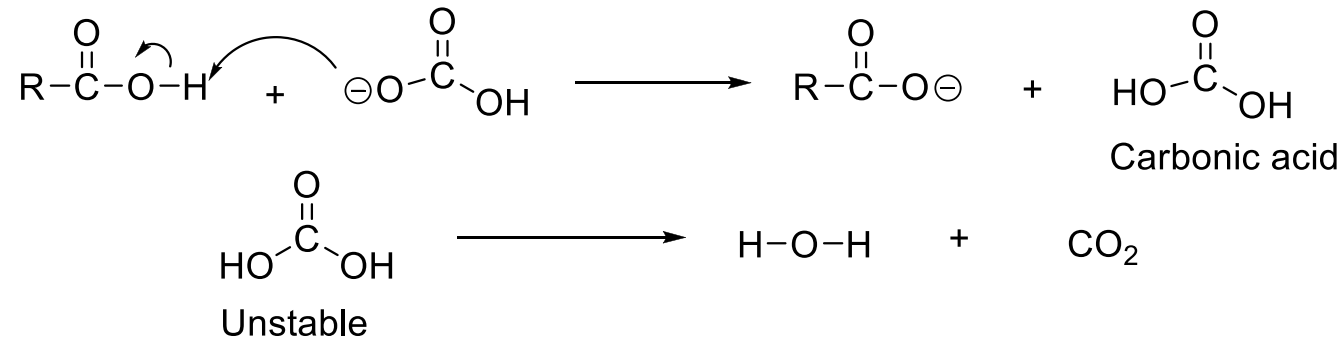


Reactions of carboxylic acids can be placed into four categories:

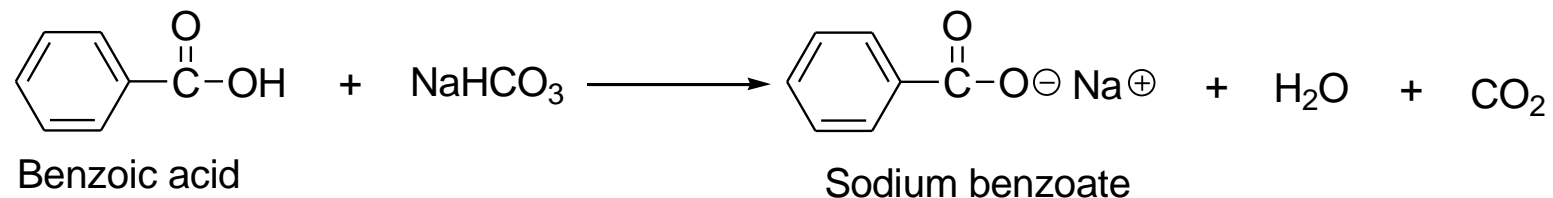
- (1) Reactions at the acidic hydrogen on the carboxyl group.
- (2) Reactions at the carbonyl group
- (3) Reactions at the carboxylate oxygen
- (4) Reactions that lead to loss of the carboxyl group as CO_2

Reaction of Carboxylic Acids with Sodium Bicarbonate

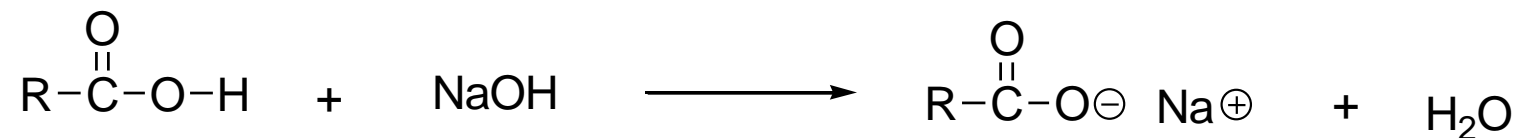
Most carboxylic acids ($pK_a \approx 5$) are stronger acids than carbonic acid (H_2CO_3) (pK_a 6.4). Consequently they displace carbonic acid from its salts (hydrogen carbonates). The most reliable test for carboxylic acids employs $NaHCO_3$ leading to evolution of CO_2 . This is commonly called the bicarbonate test for carboxylic acids.



Example

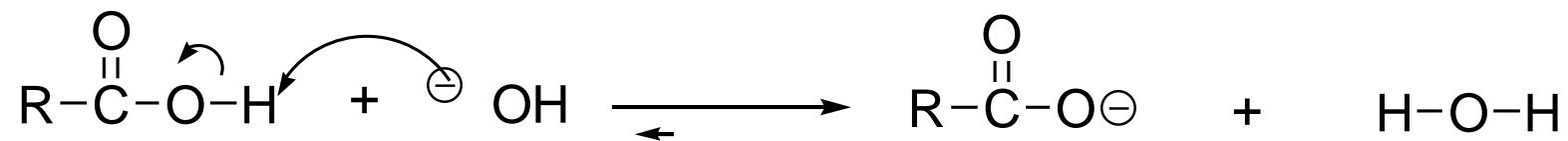


Reactions of Carboxylic Acids with Strong Bases

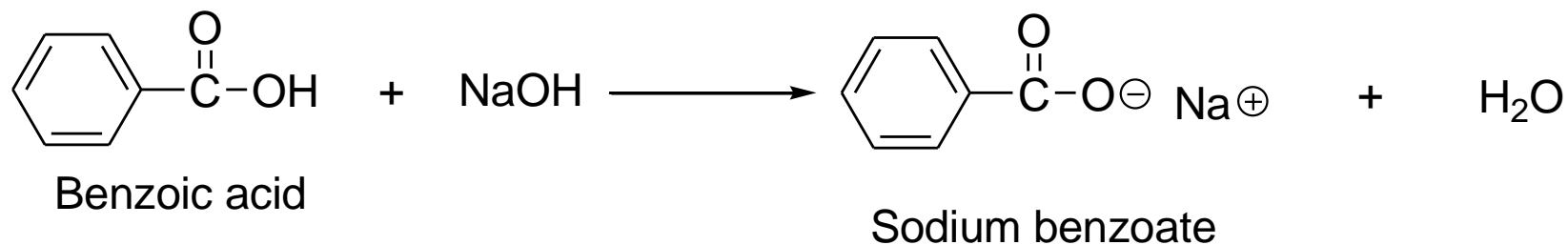


Bases such as metal hydroxides (NaOH and KOH) and amines abstract the acidic proton on carboxylic acids to form carboxylate salts.

Mechanism

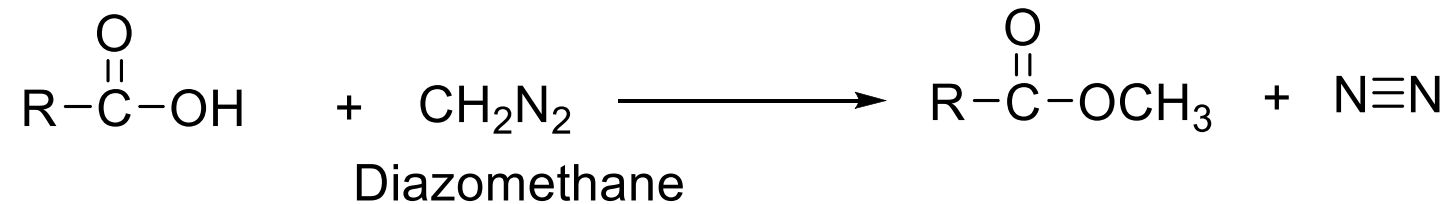


Example

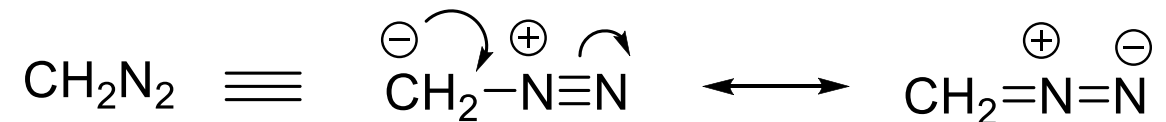


Reaction of Carboxylic Acids with Diazomethane

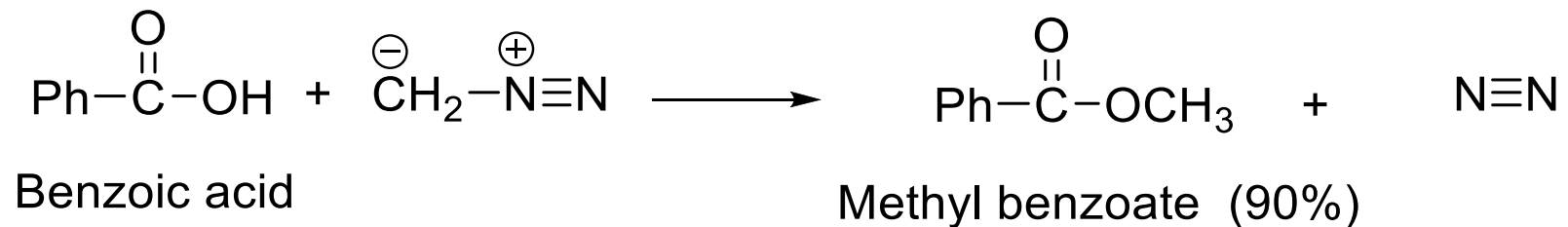
Diazomethane reacts rapidly with carboxylic acids to provide methyl esters.



Diazomethane can be written in two resonance stabilized forms.

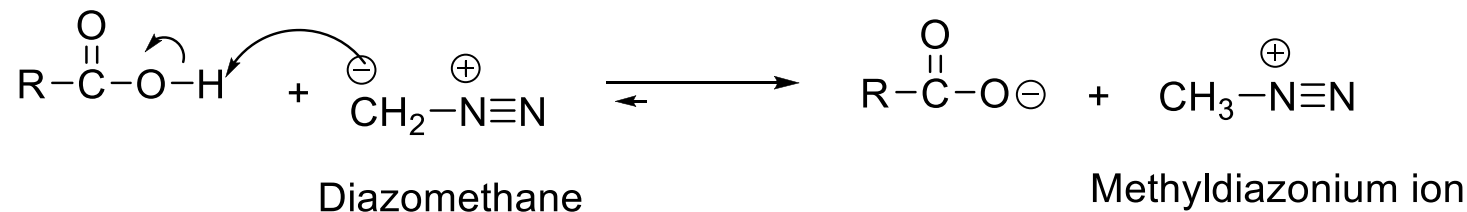


Example

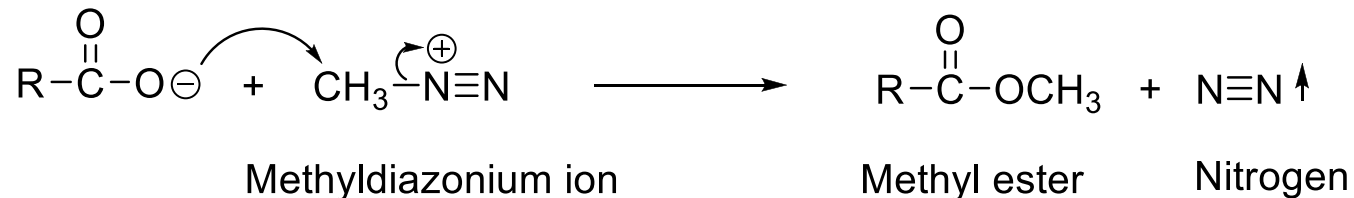


Mechanism of Esterification with Diazomethane

Step 1: Deprotonation of the acidic proton on the carboxylic acid by diazomethane provides a carboxylate anion and a methyldiazonium ion.



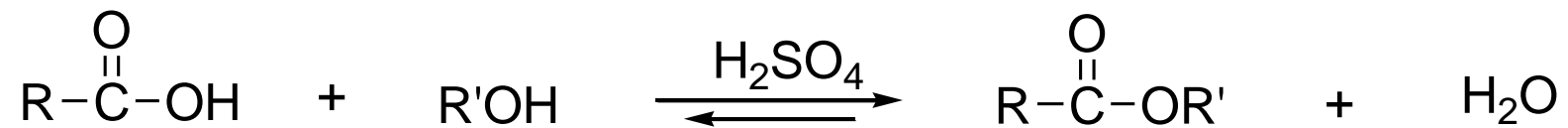
Step 2: Loss of nitrogen



Although the carboxylate anions are weak nucleophiles they react with very reactive electrophilic alkylating agents like methyldiazonium ion with loss of nitrogen gas (a good leaving group).

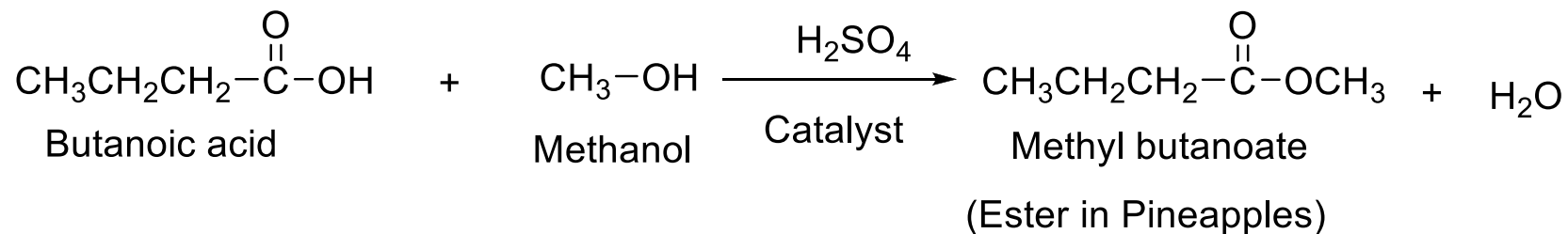
Acid-Catalysed Esterification of Carboxylic Acids

The traditional method for converting carboxylic acids to esters is through an acid-catalyzed esterification in the presence of an alcohol: Commonly referred to as the Fischer esterification.



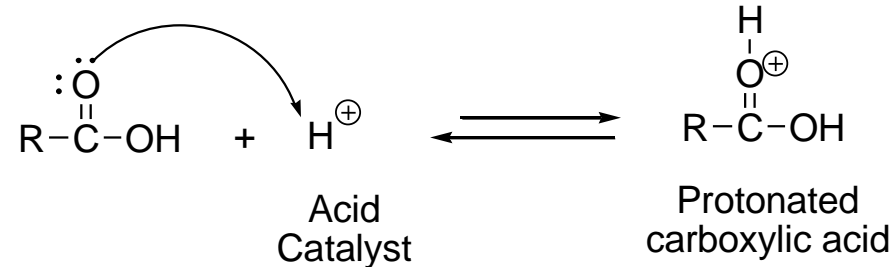
The acid-catalyst can be provided by strong mineral acids such as H_2SO_4 , HCl and H_3PO_4 or organic acids such as benzenesulphonic acid or *p*-toluenesulphonic acid.

Example

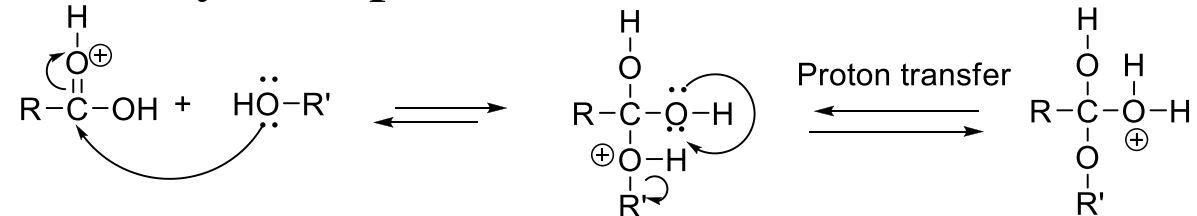


Mechanism of the Acid-Catalysed Esterification of Carboxylic Acids

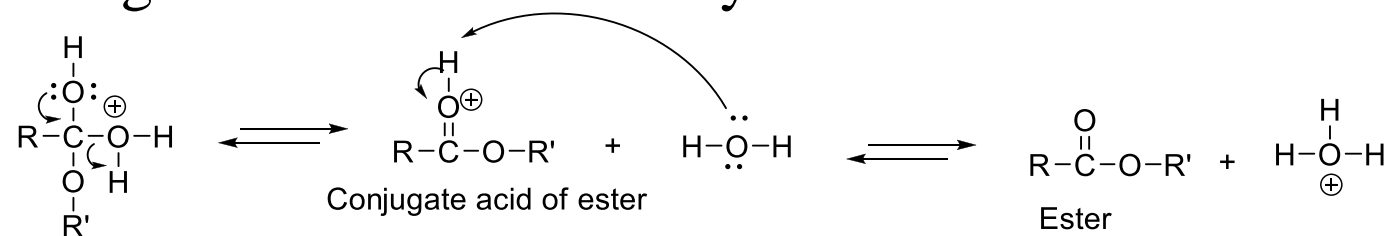
Step 1: Protonation of the carbonyl oxygen of the carboxylic acid (activation of the carbonyl carbon).



Step 2: Nucleophilic attack of the alcohol to the activated carbonyl and proton transfer

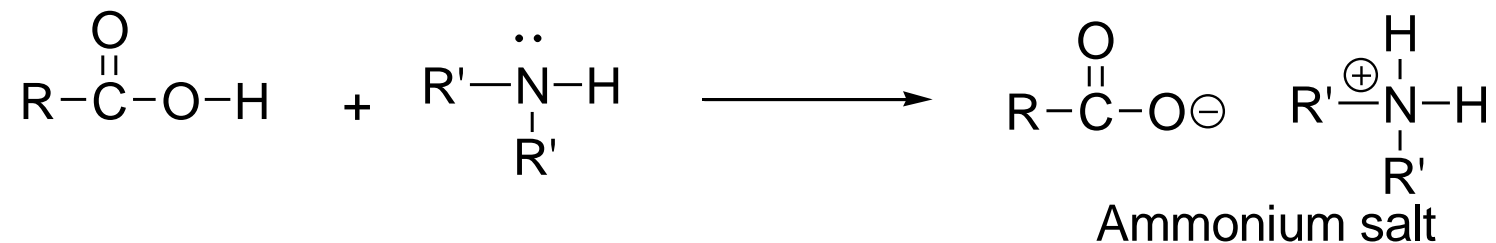


Step 3: Loss of water to give the conjugate acid of the ester and regeneration of acid catalyst.

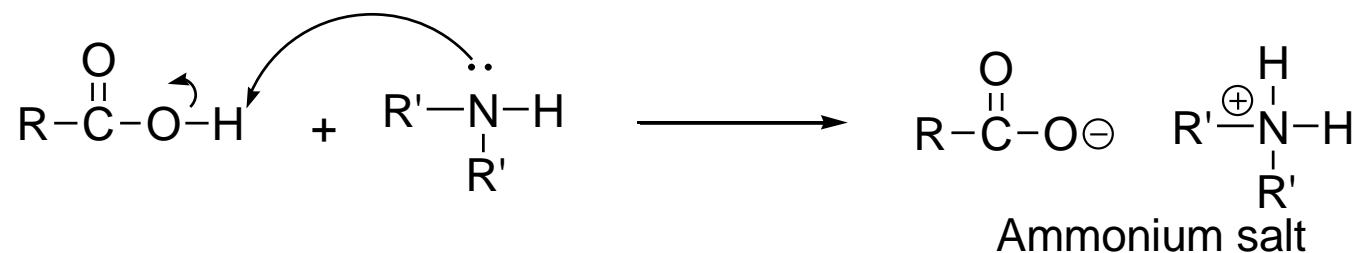


Reaction of Carboxylic Acids with Amines

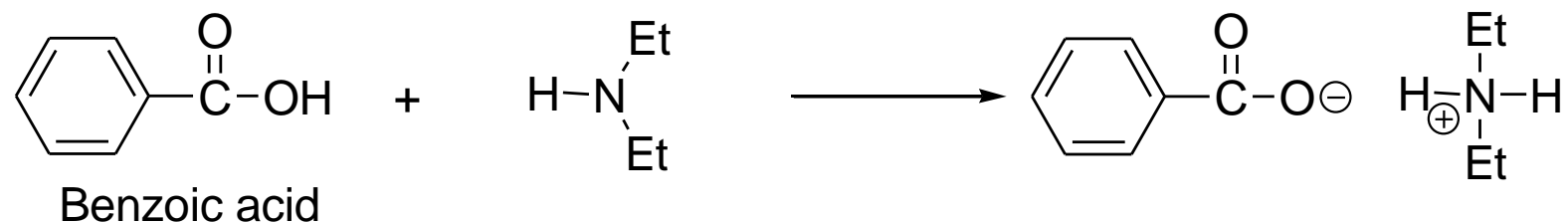
Amines, being organic bases, react with carboxylic acids to form ammonium salts.



Mechanism

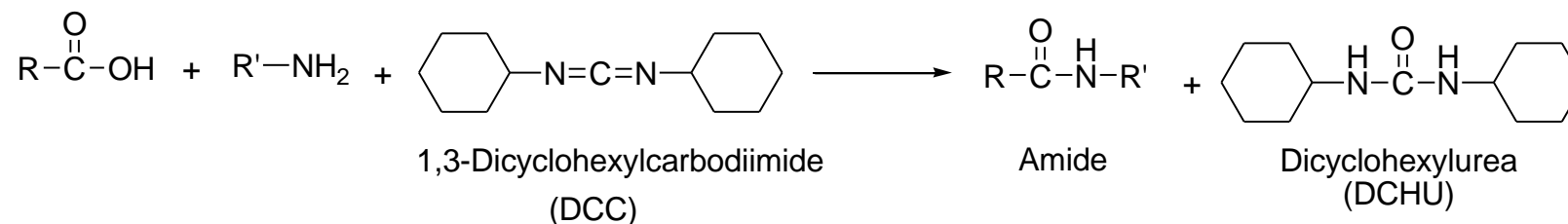


Example

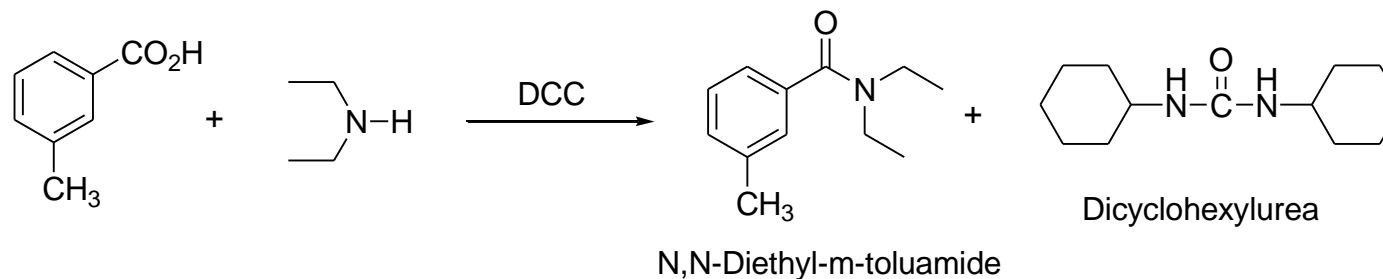


Reaction of Carboxylic Acids with Amines in Presence of DCC

Primary and secondary amines react with carboxylic acids in the presence of DCC to form amides.



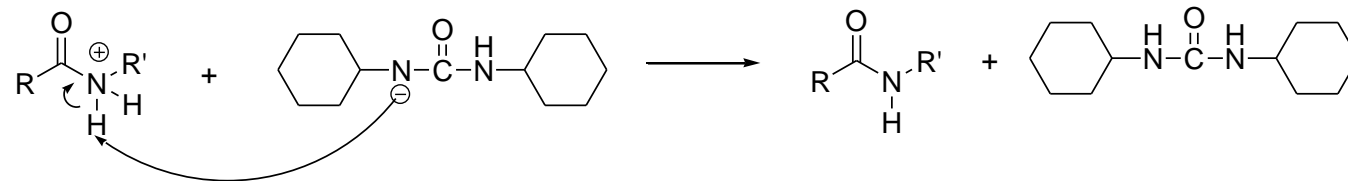
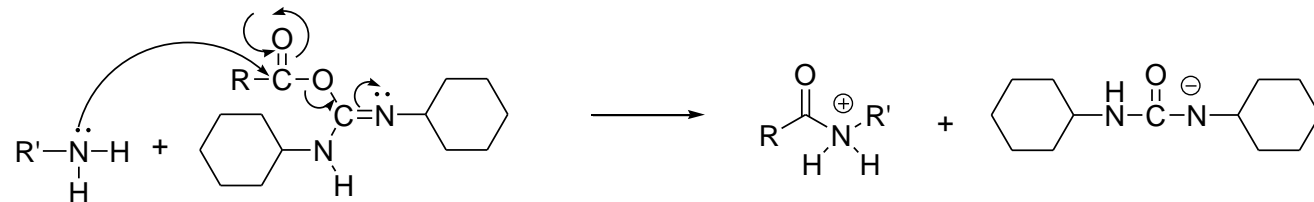
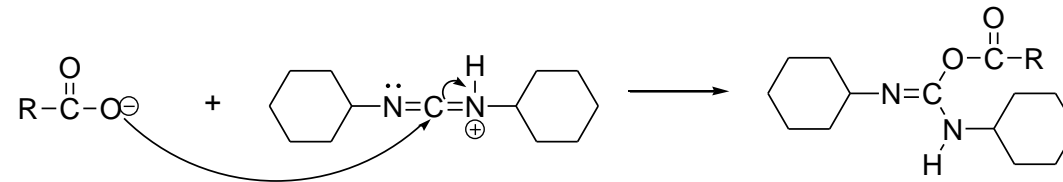
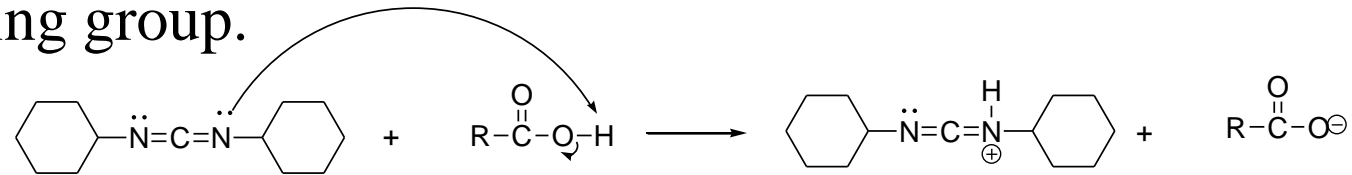
DCC serves to activate the carboxyl group of the carboxylic acid to aid in coupling to the amino group.



N,N-Diethyl-*m*-toluamide (Deet) is a common mosquito & tick repellent readily made from *m*-toluic acid using DCC.

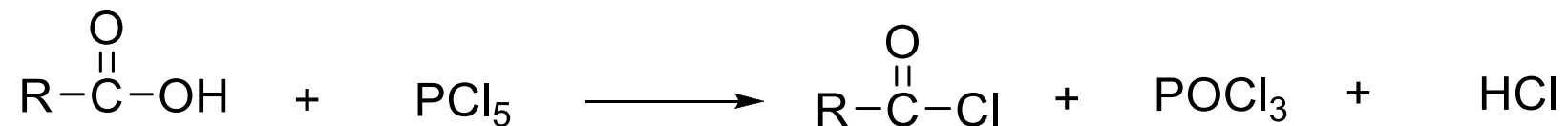
Mechanism of Coupling Carboxylic Acids with Amines Using DCC

The DCC serves to activate the hydroxyl group attached to the carbonyl of the carboxyl group; thus converting it to a good leaving group.



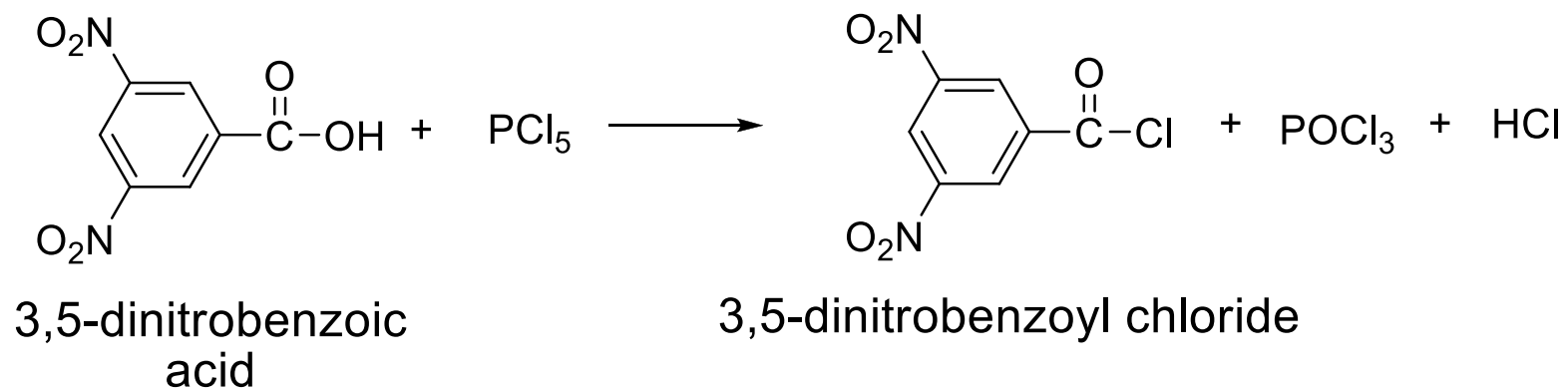
Reaction of Carboxylic Acids with Phosphorus Pentachloride

Carboxylic acids react with phosphorus pentachloride to provide acid chlorides.



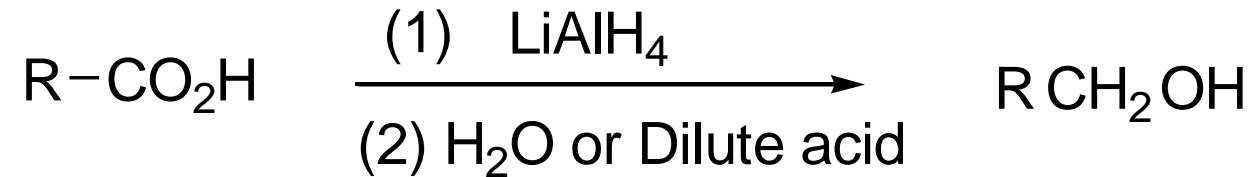
The success of the reaction depends on the strength of the P=O bond that is formed in phosphorus oxytrichloride.

Example

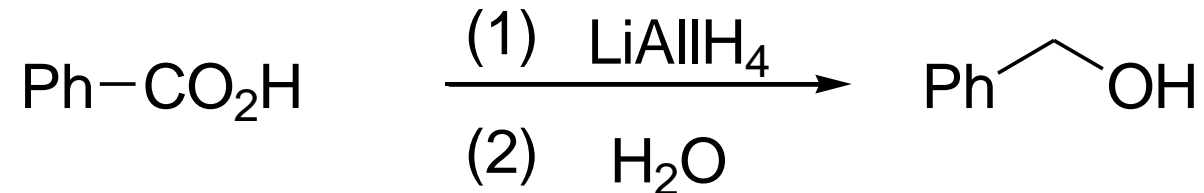


Reduction of Carboxylic Acids to Primary Alcohols

Carboxylic acids are reduced to primary alcohols when treated with a strong reducing agent such as LiAlH_4 .



Example



Medium strength reducing agents such as sodium borohydride (NaBH_4) that reduce aldehydes and ketones are not sufficiently strong to reduce carboxylic acids.

