CHAPTER 20

CARBOXYLIC ACIDS AND FUNCTIONAL DERIVATIVES

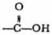
After completing this lesson, you will be able to:

- Describe preparation of carboxylic acids by carbonation of Grignard's Reagent, hydrolysis of nitriles, oxidation of primary alcohols oxidation aldehydes and oxidation of alkyl benzenes. (Applying)
- Discuss reactivity of carboxylic acids. (Applying)
- Describe the chemistry of carboxylic acids by conversion to carboxylic acid derivatives: acyl halides, acid anhydrides, esters, amides and reactions involving interconversion of these. (Analyzing)
- Describe e reactions of carboxylic acid derivatives. (Applying)
- Describe isomerism in carboxylic acids. (Understanding) ...

Q1. What are Carboxylic Acids? Give examples.

Answer

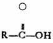
Organic compounds which contain functional group



$$-\overset{O}{\overset{\|}{C}}-OH$$

In their molecule are called carboxylic acids. Aliphatic carboxylic acids have the carboxyl group attached with an open chain of carbon atoms. They may be represented by the general formula

$$C_nH_{2n}+l\text{ -}COOH$$

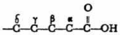


Or, $R-\overset{\overset{O}{\|}}{C}-OH$ where R=H or any alkyl group. There are organic compounds which contain more than one carboxylic group in their molecule. Thus, we have dicarboxylic acids and tricarboxylic acids etc.

Q2. Give different methods of nomenclature of carboxylic acids.

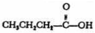
Answer

I) Many carboxylic acids are known by their common names, which were given to them before the systematic names were evolved. The positions of other groups attached with the chain containing the carboxyl group are indicated by the Greek letters a p etc. the carbon adjacent to the carboxylic group is called the a (alpha) carbon the carbon atom in the carboxyl group in not the a carbon e.g.



$$-\overset{\delta}{C}-\overset{\gamma}{C}-\overset{\beta}{C}-\overset{\alpha}{C}-\overset{\overset{O}{\|}}{C}-OH$$

2) The IUPAC system. From the name of alkane, which contains the same number of carbon atoms as the longest continuous chain the carboxyl group the ending -e is dropped and in its place the ending -oic acid added. For example, the carboxylic acid

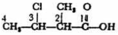


$$CH_3CH_2CH_2-\overset{\overset{O}{\|}}{C}-OH$$

has four carbon atoms in the chain containing carboxyl group. The name of the alkane having a straight chain of four carbon atoms is butane. Therefore, the name of the four-carbon acid,

$CH_3-CH_2-CH_2-COOH$ will be butanoic acid

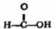
The carbon atoms of the chain containing the carboxyl group are numbered to indicate the position s of other groups attached with it. The carbon atom of the carboxyl group is given the number I.



$$\overset{4}{C}H_3-\overset{\overset{Cl}{|}}{\overset{3}{C}H}-\overset{\overset{CH_3}{|}}{\overset{2}{C}H}-\overset{\overset{O}{\|}}{\overset{1}{C}}-OH$$

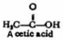
3-Cholor-2-Methylbutanoic acid

The names and the structural formulas of a few carboxyl acids are given below. Boiling points and melting points are also given.



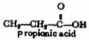
$$H-\overset{\overset{O}{\|}}{C}-OH$$

Formic acid
or
Methanoic acid
b.p., 101°C
m.p., 8·4°C



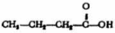
$$H_3C-\overset{\overset{O}{\|}}{C}-OH$$

A cetic acid
or
E thanoic acid
b.p., 118°C
m.p., 16°C,



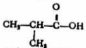
$$CH_3-CH_2-\overset{\overset{O}{\|}}{C}-OH$$

Propionic acid
or
Propanoic acid
b.p., 142°C
m.p., −21°C



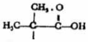
$$CH_3-CH_2-CH_2-\overset{\overset{O}{\|}}{C}-OH$$

n-Butyric acid
or
Butanoic acid
b.p., 164°C
m.p., −5°C

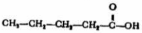


$$CH_3-\underset{\underset{CH_3}{|}}{CH}-\overset{\overset{O}{\|}}{C}-OH$$

Isobutyric acid or
2—Methyl propanoic
acid
b.p., 154°C
m.p., −47°C



$$H_3C-\underset{|}{\overset{\overset{CH_3}{|}}{C}}-\overset{\overset{O}{\|}}{C}-OH$$

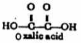


$$CH_3-CH_2-CH_2-CH_2-\overset{\overset{O}{\|}}{C}-OH$$

CH_3

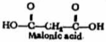
Trimethylacetic acid
or
2,2—Dimethylpropanoic acid
b.p., 164°C
m.p., 35·5°C

n—Valeric acid
or
Pentanoic acid
b.p., 186°C
m.p., −35°C



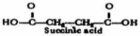
$HO-\overset{\overset{O}{\|}}{C}-\overset{\overset{O}{\|}}{C}-OH$

Oxalic acid
or
Ethanedioic acid
m.p., 186°C
(decomp.)



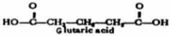
$HO-\overset{\overset{O}{\|}}{C}-CH_2-\overset{\overset{O}{\|}}{C}-OH$

Malonic acid
or
Propanedioic acid
m.p., 130—135°C
(decomp.)



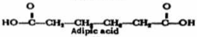
$HO-\overset{\overset{O}{\|}}{C}-CH_2-CH_2-\overset{\overset{O}{\|}}{C}-OH$

Succinic acid
or
Butanedioic acid
m.p., 182°C



$HO-\overset{\overset{O}{\|}}{C}-CH_2-CH_2-CH_2-\overset{\overset{O}{\|}}{C}-OH$

Glutaric acid
or
Pentanedioic acid
m.p., 97·7°C



$HO-\overset{\overset{O}{\|}}{C}-CH_2-CH_2-CH_2-CH_2-\overset{\overset{O}{\|}}{C}-OH$

Adipic acid
or
Hexanedioic acid
m.p., 151—153°C

Note that the dicarboxylic acids are name in the IUPAC system by adding dioic acid to the name of the alkane containing the same number of carbon atoms as the carbons chain containing the two carboxyl groups.

Q3. What are different of carboxylic acids?

Answer

Physical Properties

- The polar nature of both the O — H and C=O bonds (due to the electro negativity difference of the atoms) results in the formation of strong hydrogen bonds with other carboxylic acid molecules or other H-bonding systems (e.g. water). The implications are:
- higher melting and boiling points compared to analogous alcohols

- high solubility in aqueous media
- hydrogen bonded dimers in gas phase and dimers or aggregates in pure liquid

Q4. Write a note on structure and acidity of carboxylic acids.

Answer

Structure

The CO_2H unit is planar and consistent with sp^2 hybridization and a resonance interaction of the lone of the hydroxyl oxygen with the system of the carbonyl.

Acidity

Carboxylic acids are the most acidic simple organic compounds (pKa — 5). But they are only weak acids compared to acids like HCl or H_2SO_4. (Remember the lower the pKa, the stronger the acid)

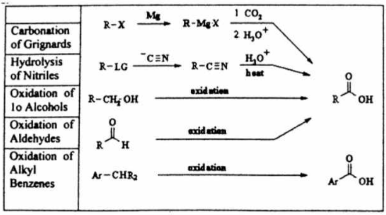
Resonance stabilization of the carboxylate ion allows the negative charge to be delocalized between the two electronegative oxygen atoms (compare with alcohols, pκa — 16).

Adjacent electron withdrawing substituents increase the acidity by further stabilizing the carboxylate.

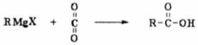
Carboxylic Aca	Structure	pKa
Ethanoic acid	CH_3CO_2H	4.7
Propanoic acid	$CH_3CH_2CO_2H$	4.9
Fluoroethanoic acid	CH_2FCO_2H	2.6
Chloroethanoic acid	CH_2ClCO_2H	2.9
Dichloroethanoic acid	$CHCl_2CO_2H$	1.3
Trichlœoethanoic acid	CCl_3CO_2H	0.9
Nitrœthanoic acid	$O_2NCH_2CO_2H$	1.7

Q5. Give different methods of preparations of carboxylic acids.

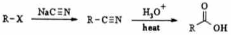
Answer



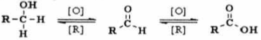
1) Carbonation of Grignard Reagents, RMgX, by CO_2



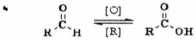
2) Hydrolysis of Nitriles



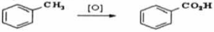
3) Oxidation of Primary Alcohols



4) Oxidation of Aldehydes



5) Oxidation of Alkyl Benzenes



[O] = $Cr_2O_7^{2-}$ or MnO_4^- / H_2SO_4 / heat

Q6. Explain reactivity of carboxylic acids. Answer

The carboxyl group shows the chemistry of both the carbonyl $(\overset{O}{\overset{\|}{-C}}\text{-}OH)$ and the hydroxyl (-0H) groups. In most reactions, the carboxyl group is retained. However, the reactivity of these molecules is due to the presence of carbonyl group.

Reactions of Carboxylic Adds

Conversion to Carboxylic Acid Derivatives

This point has already been discussed in 20.5. I. Carboxylic acids undergo the following types of reactions.

i) The reaction in which hydrogen atom of the carboxyl group is involved (salt formation).

ii) The reaction in which OH group is replaced by another group. iii) The reactions involving carboxyl group as a whole.

a) Reaction involving H atom of the carboxyl group.

Carboxylic acids are weaker acids than mineral acids. They furnish H when dissolved in water

In the presence of water (HO) the proton breaks away as H30+ ion.

1) **Reactions with bases**

Carboxylic acids react with bases (NaOH, KOH) to form salts

$$CH_3COOH + NaOH \longrightarrow CH_3COONa + H_2O$$

2) **Reaction with carbonates and bicarbonates**

Carboxylic acids decompose carbonate and bicarbonates evolving carbon dioxide gas with effervescence.

$$2CH_3COOH + Na_2CO_3 \longrightarrow 2CH_3COONa + CO_2 + H_2O$$

$$CH_3COOH + NaHCO_3 \longrightarrow CH_3COONa + CO_2 + H_2O$$

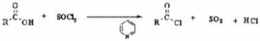
3) Reactions with metals

Carboxylic acids reaction with active metals such as Na, K, Ca, Mg etc to form their salts with the evolution of hydrogen gas,

$$2CH_3COOH + 2Na \longrightarrow 2CH_3COONa + H_2$$

Q7. Give Preparation of Acyl Chlorides.

Answer



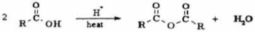
$$R-\overset{O}{\overset{\|}{C}}-OH + SOCl_2 \xrightarrow[\text{pyridine}]{} R-\overset{O}{\overset{\|}{C}}-Cl + SO_2 + HCl$$

- Acyl chlorides are prepared by treating the carboxylic acid with thionyl chloride, SOC12, in the presence of a base.
- Acyl chlorides are by far the most commonly encountered of the acyl halides.

Q8. Give Preparation of Acid Anhydrides and Esters.

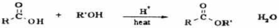
Answer

1) Preparation of Add Anhydrides



$$2\ R-\overset{O}{\overset{\|}{C}}-OH \xrightarrow[\text{heat}]{H^+} R-\overset{O}{\overset{\|}{C}}-O-\overset{O}{\overset{\|}{C}}-R + H_2O$$

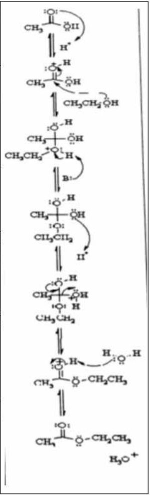
2) Preparation of Esters



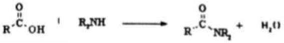
$$R-\overset{O}{\overset{\|}{C}}-OH + R'OH \xrightarrow[\text{heat}]{H^+} R-\overset{O}{\overset{\|}{C}}-OR' \quad H_2O$$

- This reaction is also known as the Fischer esterification.
- Esters are obtained by refluxing the parent carboxylic acid with the appropriate alcohol with an acid catalyst.
- The equilibrium can be driven to completion by using an excess of either the alcohol or the carboxylic acid, or by removing the water as it forms.
- Alcohol reactivity order: $CH_3OH > 1^0 > 2^0 > 3^0$ (steric effects)
- Esters can also be made from other carboxylic acid derivatives, especially acyl halides and anhydrides, by reacting them with the appropriate alcohol in the presence of a weak base.
- If a compound contains both hydroxy- and carboxylic acid groups, then cyclic esters or ketones can form via an intramolecular reaction. Reactions that form 5- or 6membered rings are particularly favorable.

MECHANISM FOR REACTION FOR ACID ca zed ESTERIFICATION

1: An acid/base reaction. Protonation of the carbonyl makes it more electrophilic.	
2: The alcohol O functions as the nucleophile attacking the electrophilic C in the C=O, with the electrons moving towards the oxonium ion, creating the intermediate.	
3: An acid/base reaction. Deprotonate the alcoholic oxygen.	
4: An acid-base reaction. Need to make an -OH leave it doesn't matter which one, so convert it into a g leaving group by protonation.	
5: Use the electrons of an adjacent oxygen to help "push out" the leaving group, a neutral water molecule.	
6:An acid-base reaction. Deprotonation of the oxonium ion reveals the carbonyl in the ester product.	

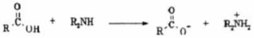
Preparation of Amides



$$RCOOH + R_2NH \longrightarrow RCONR_2 + H_2O$$

- In general, it is not easy to prepare amides directly from the parent carboxylic acid.
- The acid will protonate the amine preventing further reaction since the carboxylate is a poor electrophile and the ammonium ion is not nucleophilic.

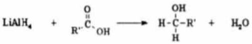
It is much easier to convert the carboxylic acid to the more reactive acyl chloride first.



$$RCOOH + R_2NH \longrightarrow RCOO^- + R_2NH_2^+$$

Reduction to Alcohols

Reduction of Carboxylic Acids



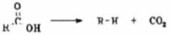
$$LiAlH_4 + R'COOH \longrightarrow H\text{-}CH(OH)\text{-}R' + H_2O$$

- Carboxylic acids are less reactive to reduction by hydride than aldehydes, ketones or esters.
- Carboxylic acids are reduced to primary alcohols.
- As a result of their low reactivity, carboxylic acids can only be reduced by LiAlH4 and NOT by the less reactive $NaBH_4$

Q9. Give Decarboxylation of Carboxylic acids.

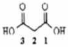
Answer

Decarboxylation



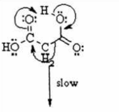
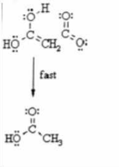
$R-COOH \longrightarrow R-H + CO_2$

- Loss of carbon dioxide is called decarboxylation.
- Simple carboxylic acids rarely undergo decarboxylation.
- Carboxylic acids with a carbonyl group at the 3- (or ß-) position readily undergo thermal decarboxylation, e.g. derivatives of malonic acid.



malonic acid

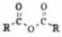
- The reaction proceeds via a cyclic transition state giving an enol intermediate that tautomerizes to the carbonyl.

Mechanism of Decarboxylation	
Step 1: Remember curly arrows flow.... Start at the protonation o the carbonyl, break the O-H bond and form the bond break the C-C and make the C=C. Note the concrete nature of this reaction and the cyclic transition state.	
Step2: Tautomerization of the enol of the carboxylic acid leads t the acid product (not shown here).	

Elaboration of Reactions that Interconvert Carboxylic Acids

The carboxylic acid derivatives are a family of closely related functional groups

acyl halide



acid anhydride

ester

amide

carboxylic acid

each contain a C=O group with a heteroatom attached (note : this is what distinguishes them from aldehydes and ketones) they can all be prepared from the "parent" carboxylic acid on hydrolysis they all convert back to the parent carboxylic acid they share a common reactivity pathway with nucleophiles: nucleophilic acyl substitution.

IMPORTANT Reactivity order: acyl chloride > anhydride > ester = carboxylic acid

> amide > carboxylate

The most important things to know about carboxylic acid derivatives are:

- How to prepare the derivatives from the carboxylic acid itself (Chapter 19)
- The relative reactivity of the carboxylic acid derivatives.
- That hydrolysis of derivatives gets you back to the carboxylic acid.
- The mechanism of nucleophilic acyl substitution.

Q10. Give Different Reactions of Carboxylic Acid Derivatives.

Answer

1) Elaboration of Reactions that Interconvert Carboxylic Acids Derivatives

2) Reactions of Acyl Halides, Friedel-Crafts Acylation (review)

3) Reactions of Acid Anhydrides,

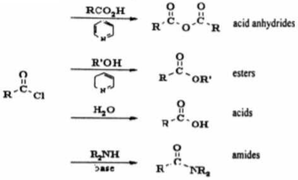
4) Reactions of Esters, Hydrolysis, Reduction, and with Grignard reagents

5) Reactions of Amides, Hydrolysis and Reduction

6) Reactions of Nitriles, Hydrolysis, Reduction, and with Grignard reagents

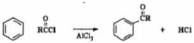
Q11.Give Reactions of Acyl Halides, Friedel-Crafts Acylation Reactions of Acyl Halides.

1) Interconversion Reactions of Acyl Chlorides



1) Acyl chlorides are the most reactive of the carboxylic acid derivatives and therefore can be readily converted into other carboxylic acid derivatives (see above).
2) They are sufficiently reactive that they react quite readily with cold water and hydrolyze to the carboxylic acid.
3) The HCl by-product is usually removed by adding a base such as pyridine or triethyl amine.

Friedel-Crafts Acylation of Benzene



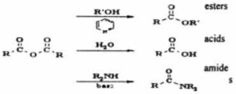
4) Overall transformation: Ar — H to Ar-COR (a ketone)
5) Named after Friedel and Crafts who discovered the reaction.
6) Reagent: normally the acyl halide (e.g. usually RCOCl) with aluminum trichloride, $AlCl_3$, a Lewis acid catalyst.
7) The $AlCl_3$ enhances the electrophilicity of the acyl halide by complexing with the halide.
8) Electrophilic species: the acyl cation or acylium ion (i.e. RCO +) formed by the "removal" of the halide by the Lewis acid catalyst.
9) Friedel Crafts reactions are limited to arenes as or more reactive than mono-halobenzene.

10) Other source of acylium can also be used such as acid anhydrides with AIC13

11) Note how the reaction can still be reviewed as a Nucleophilic Acyl Substitution of the acid halide since overall we have a nucleophile (here the p bond of an aromatic ring) replaces the leaving group (chloride) at the electrophilic C=O.

2) Reactions of Acid Anhydrides, Hydrolysis

Interconversion Reactions of Acid Anhydrides

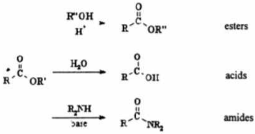


I) Acid anhydrides are the second most reactive of the carboxylic acid derivatives and can therefore, be fairly readily converted into the other less reactive carboxylic acid derivatives (see above).

2) A base in often added to neutralize the carboxylic acid by product that is formed.

3) Reactions of Esters, Hydrolysis, Reduction, and with Grignard's Reagent

Interconversion Reactions of Esters



I) Esters can be converted into other esters (transesterification), the parent carboxylic acid (hydrolysis) or amides (see above).

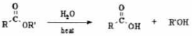
2) Transesterification: heat with alcohol and acid catalyst

3) Hydrolysis: heat with aq. acid or base (e.g. aq. H2S04 or aq. NaOH) (see hydrolysis of esters for more details)

4) Amide preparation: heat with the amine, methyl or ethyl esters are the most reactive

Q12. Give Hydrolysis of Esters.

Answer



1) Carboxylic esters hydrolyze to the parent carboxylic acid and an alcohol.

2) Reagents: aqueous acid (e.g. H2S04) / heat, or aqueous NaOH / heat (known as "saponification").

Reaction under BASIC conditions

I) The mechanism shown below leads to acyl-oxygen cleavage (see step 2).

2) The mechanism is supported by experiments using 180 labeled compounds and esters of chiral alcohols.

3) This reaction is known as "saponification" because it is the basis of making soap from glycerol triesters in fats.

4) The mechanism is an example of the reactive system type.

Reaction under acidic conditions

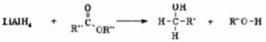
Note that the acid catalyzed mechanism is the reverse of the Fischer esterification.

The mechanism shown below also leads to acyl-oxygen cleavage (see step 5).

The mechanism is an example of the less reactive system type.

Q13. Give Reduction of Esters.

Answer



$$LiAlH_4 + R''\overset{O}{\overset{\|}{C}}OR'' \longrightarrow H-\overset{OH}{\underset{H}{C}}-R' + R''O-H$$

I) Carboxylic esters are reduced give 2 alcohols, one from the alcohol portion of the ester and a 10 alcohol from the reduction of the carboxylate portion.

2) Esters are less reactive towards Nu than aldehydes or ketones

3) They can only be reduced by LiAlH4 and NOT by the less reactive NaBH4

4) The reaction requires that 2 hydrides (H-) be added to the carbonyl group of the ester

5) The mechanism is an example of the reactive system type Note the aldehyde intermediate.

Q14. Reaction of LialH$_4$ with an ester along with mechanism.

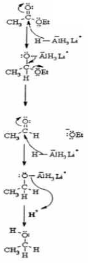
Answer

Step I:

The nucleophilic H from the hydride reagent adds to the electrophilic C in the polar carbonyl group of the ester. Electrons from the C=O move to the electronegative O creating an CH3 intermediate metal alkoxide complex.

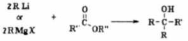
Step2: The tetrahedral intermediate collapses and displaces the alcohol portion of the ester as a leaving group, this produces a ketone as an intermediate.

Step3: Now we are reducing an aldehyde. The nucleophilic H from the hydride reagent adds to the electrophilic C in the polar carbonyl group of the aldehyde. from the C=O move to the electronegative O creating an intermediate metal alkoxide complex.



Step4: This is the work-up step, a simple acid/base reaction. Protonation of the alkoxide oxygen creates the primary alcohol product from the intermediate complex.

Reactions of RLi and RMgX with Esters



$$\begin{matrix} 2RLi \\ or \\ 2RMgX \end{matrix} + R''\overset{O}{\overset{\|}{C}}OR'' \longrightarrow R-\overset{OH}{\underset{R}{C}}-R'$$

I) Carboxylic esters, R'C02R'', react with 2 equivalents of organolithium or Grignard reagents to give tertiary alcohols.

2) The tertiary alcohol that results contains 2 identical alkyl groups (from R in the scheme)

3) The reaction proceeds via a ketone intermediate which then reacts with the second equivalent of the organometallic reagent (review)

4) Since the ketone is more reactive than the ester, the reaction cannot be used as a preparation of ketones.

5) The mechanism is an example of the reactive system type.

Q15.Give Reaction of Rmgx with an Ester along with mechanism.

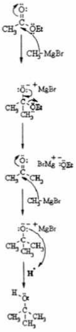
Answer

Step 1: The nucleophilic C in the organometallic reagent adds to the electrophilic C in the polar carbonyl group of the ester. Electrons from the portion of the ester as a leaving group; this produces a ketone as an intermediate.

Step2: The tetrahedral intermediate collapses and displaces the alcohol

Step3: The nucleophilic C in the organometallic reagent adds to the electrophilic C in the polar carbonyl group of the ketone. Electrons from the C=O move to the electronegative O creating an intermediate metal alkoxide complex.

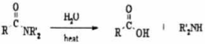
Step4: This is the work-up step, a simple acid/base reaction. Protonation of the alkoxide oxygen creates the alcohol product from the intermediate complex



Q16. Give Reactions of Amides, Hydrolysis and Reduction

Answer

Interconversion Reactions of Amides



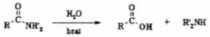
$$R-\overset{O}{\overset{\|}{C}}-NR'_2 \xrightarrow[heat]{H_2O} R-\overset{O}{\overset{\|}{C}}-OH + R'_2NH$$

- Amides are the least reactive of the neutral carboxylic acid derivatives.
- The only interconversion reaction that amides undergo is hydrolysis back to the parent carboxylic acid and the amine.
- Reagents: Strong acid (e.g. H2S04) or strong base (e.g. NaOH) / heat.

- More details on the following page.

Q17.Give Hydrolysis of Amides along with mechanism.

Answer



$$R-\overset{O}{\overset{\|}{C}}-NR'_2 \xrightarrow[heat]{H_2O} R-\overset{O}{\overset{\|}{C}}-OH + R'_2NH$$

I) Amides hydrolyze to the parent carboxylic acid and the appropriate amine.

2) The mechanisms are similar to those of esters.

3) Reagents: Strong acid (e.g. H_2SO_4) / heat (preferred) or strong base (e.g. NaOH) / heat.

Reaction under acidic conditions

Note that the acid catalyzed mechanism is analogous to the acid catalyzed hydrolysis of esters.

The mechanism shown below proceeds via protonation of the carbonyl not the amide N (see step 1).

The mechanism is an example of the less reactive system type.

Mechanism of the acid catalyzed hydrolysis of amides

Step I: An acid/base reaction. Since we only have a weak nucleophile and a poor electrophile, we need to activate the ester. Protonation of the amide carbonyl makes it more electrophilic.

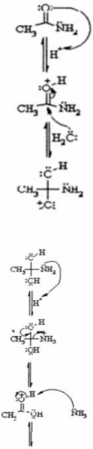
Step 2: The water O functions as the nucleophile attacking the electrophilic C in the C=O, with the electrons moving towards the oxonium ion, creating the tetrahedral intermediate.

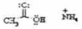
Step 3: An acid/base reaction. Deprotonate the oxygen that came from the water molecule.

Step 4: An acid/base reaction. Need to make the -NH2 leave, but need to convert it into a good leaving group first by protonation.

Step 5: Use the electrons of an adjacent oxygen to help "push out" the leaving group, a neutral ammonia molecule.

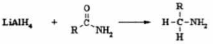
Step6: An acid/base reaction. Deprotonation of the oxonium ion reveals the carbonyl in the carboxylic acid product and regenerates the acid catalyst.



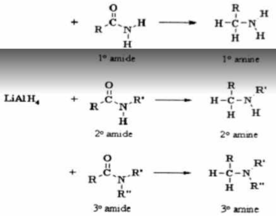


Q18.Give Reduction of Amides along with mechanism.

Answer



- Amides, RCONR+2, can be reduced to the amine, $RCH_2NR^{+}_2$ by conversion of the C=O to - CH2-
- Amides can be reduced by $LiAlH_4$ but NOT the less reactive $NaBH_4$
- Typical reagents: $LiAlH_4$ / ether solvent followed by aqueous work-up.
- • Note that this reaction is different to that of other C=O compounds which reduce to alcohols
- The nature of the amine obtained depends on the substituents present on the original amide. Look at the N substituents in the following examples (those bonds don't change!)



- R, R' or k" may be either alkyl or aryl substituents.
- In the potential mechanism note that it is an O system that leaves. This is consistent with O systems being better leaving groups that the less electronegative N

systems.

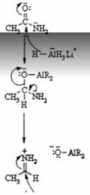
Q19.Give Reaction of LialH4 with an amide along with mechanism.

Answer

Step 1: The nucleophilic H from the hydride reagent adds to the electrophilic C in the polar carbonyl group of the ester. Electrons from the C=O move to the electronegative O creating an intermediate metal alkoxide complex.

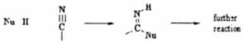
Step2: The tetrahedral intermediate collapses and displaces the O as part of a metal alkoxide leaving group, this produces a highly reactive iminium ion an intermediate.

Step3: Rapid reduction by the nucleophilic H from the hydride reagent as it adds to the electrophilic C in the iminium system. 't electrons from the C=N move to the cationic N neutralizing the charge creating the amine product.



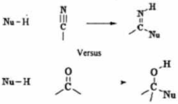
Q20.Reactions of Nitriles, Hydrolysis, Reduction, and reactions with Grignard's Reagent.

Answer



Nitriles typically undergo nucleophilic addition to give products that often undergo a further reaction.

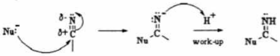
The chemistry of the nitrile functional group, CEN, is very similar to that of the carbonyl, C=O of aldehydes and ketones. Compare the two schemes:



However, it is convenient to describe nitriles as carboxylic acid derivatives because: the oxidation state of the C is the same as that of the carboxylic acid derivatives hydrolysis produces the carboxylic acid

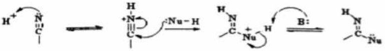
Like the carbonyl containing compounds, nitriles react with nucleophiles via two scenarios:

Strong nucleophiles (anionic) add directly to the to form an intermediate imine salt that protonates (and often reacts further) on work-up with dilute acid.



Examples of such nucleophilic systems are: RMgX, RLi, RCDCM, LiAlH4

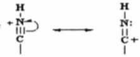
Weaker nucleophiles (neutral) require that the CFN be activated prior to attack of the Nu. This can be done using an acid catalyst which protonates on the Lewis basic N and makes the system more electrophilic.



Examples of such nucleophilic systems are

H_2O, ROH

The protonation of a nitrile gives a structure that can be redrawn in another resonance form that reveals the electrophilic character of the C since it is a carbocation.



Q21. Give Hydrolysis of Nitriles along with mechanism.

Answer

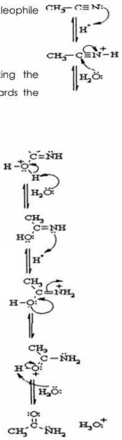
Reaction type: Nucleophilic Addition then Nucleophilic Acyl Substitution

Elaboration

Nitriles, RC = N, can be hydrolyzed to carboxylic acids, RCO_2H via the amide, $RCONH_2$.

Reagents: Strong acid (e.g. H2S04) or strong base (e.g. NaOH) / heat.

Mechanism of the acid Catalyzed Hydrolysis of Nitriles



Step1: An acid/base reaction. Since we only have a weak nucleophile so activate the nitrile, protonation makes it more electrophilic.

Step2: The water O functions as the nucleophile attacking the electrophilic C in the CON, with the electrons moving towards the positive center.

Step3: An acid base reaction. Deprotonate the oxygen that came from the water molecule. The remaining task is a tautomerization at N and O centers.

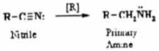
Step4: An acid/base reaction. Protonate the N gives us the -NH2 we need....

Step 5: Use the electrons of an adjacent O to neutralize the positive at the N and form the bond in the C=O.

Step6: An acid/base reaction. Deprotonation of the oxonium ion reveals the carbonyl in the amide intermediate....halfway to the acid.

Q22. Give Reduction of Nitriles.

Answer



$$\underset{\text{Nitrile}}{R-C\equiv N:} \xrightarrow{[R]} \underset{\text{Primary Amine}}{R-CH_2\ddot{N}H_2}$$

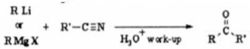
Reactions usually in Et_2O or THF followed by H_3O^+ work-up

Reaction type: Nucleophilic Addition

Elaboration

- The nitrile, RCN, gives the 10 amines by conversion of the C = N to — CH_2—NH_2
- Nitriles can be reduced by $LiAlH_4$ but NOT the less reactive $NaBH_4$
- Typical reagents: $LiAlH_4$ / ether solvent followed by aqueous work-up.
- Catalytic hydrogenation (H2 / catalyst) can also be used giving the same products.
- R may be either alkyl or aryl substituents

Reactions of RLi or RMgX with Nitriles



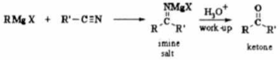
$$\begin{matrix} RLi \\ \text{or} \\ RMgX \end{matrix} + R'-C\equiv N \xrightarrow[H_3O^+ \text{ work-up}]{} R-\overset{O}{\overset{\|}{C}}-R'$$

Reaction usually in Et_2O or THF

Reaction type: Nucleophilic Acyl Substitution Then Nucleophilic Addition

Elaboration

- Nitriles, RC = N, react with Grignard reagents or organolithium reagents to give ketones.
- The strongly nucleophilic organometallic reagents add to. the C N bond in a similar fashion to that seen for aldehydes and ketones.
- The reaction proceeds via an imine salt intermediate that is then hydrolyzed to give the ketone product.



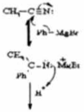
$$RMgX + R'-C\equiv N \longrightarrow \underset{\text{imine salt}}{R-\overset{NMgX}{\overset{\|}{C}}-R'} \xrightarrow[\text{work-up}]{H_3O^+} \underset{\text{ketone}}{R-\overset{O}{\overset{\|}{C}}-R'}$$

- Since the ketone is not formed until after the addition of water, the organometallic reagent does not get the opportunity to react with the ketone product.
- Nitriles are less reactive than aldehydes and ketones.
- The mechanism is an example of the

Mechanism of Reaction ofrmgx with a Nitrile

Step1: The nucleophilic C in the organometallic reagent adds to the electrophilic C in the polar nitrile group. Electrons from the move to the electronegative N creating an intermediate imine salt

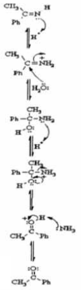
complex.



Step2: An acid/base reaction. On addition of aqueous acid, the intermediate salt protonates giving the imine.

Step3: An acid/base reaction. Imines

undergo nucleophilic addition, but require activation by protonation (i.e. acid catalysis)



Step4: Now the nucleophilic O of a water molecule attacks the electrophilic C with the p bond breaking to neutralize the change on the N.

Step5: An acid/base reaction. Deprotonate the O from the water molecule to neutralize the positive charge.

Step6: An acid/base reaction. Before the N system leaves, it needs to be made into a better leaving group by protonation

Step7: Step': Use the electrons on the O in order to push out the N leaving group, a neutral molecule of ammonia.

Step 8: An acid/base reaction. Deprotonation reveals the carbonyl group of the ketone product.

Q23.Give occurrences of different carboxylic acids.

Answer

Caprylic acid is present in coconut

Lauric acid is also present in coconut

Myristic acid is present in nutmeg

Arachidic acid is present in peanut oil Citric acid is present in cin1S fruits e.g. lemon, limes, grapes, oranges.

Tartaric acid is present in tamarind.

Lactic acid is present in apples, tomatoes and molasses.

Acetic acid is present in gapes.

Malic acid is present in green apples and plums.

Benzoic acid is found in berries.

Butyric acid is present in rancid butter.

Caproic acid is present in goat fat.

Caprylic acid is present in milk.

Palmitic acid is present in palm oil.

Stearic acid is present in waxes, animal fats and oils.

Amino acids are the building blocks of proteins.

Acetoacetic acid and pyruvic acid are the acids of biochemical significance.

Lactic acid is found in sour milk.

Tartaric acid is found in wine.

Acetic acid is found in vinegar.

Q24. Give field applications of different carboxylic acids.

Answer

1) Carboxylic acids as food preservatives.

Formic acid is used as preservative for silage (including fresh hay) and other livestock feed.

Boric acid was used as a food preservative in caviar (a product made from salt-cured fish-eggs) but its use has been banned now.

Salicylic acid Its use has been banned now.

Benzoic acid is used as a preservative in jams, beer, preserved fruit, pickles, fruit juice, desert sauces and syrups.

Acetic acid is used as a preservative in fish fingers, butter, margarine, processed cheese, curry powder, cooking oil.

Lactic acid is used as a preservative in beer, tinned foods especially vegetables and fruit, fresh fruit and vegetables.

Propionic acid is used as a preservative in dairy products, particularly in cheese and in baking products.

Q25. Give tastes of different carboxylic esters.

Answer

1) Taste of different carboxylic acids.

Esters are derived from carboxylic acids by reaction of carboxylic acids and alcohols in the presence of hydrochloric acid or sulfuric acid, a process called esterification.

Ester flavors are a range of fruity, sugary and sweet that occur in many beer types as a normal part of their brewing process.

Examples of ester flavors are:

Ethyl formate gives raspberries their characteristic taste.

Ethyl acetate has a bittersweet, wine-like burning taste.

Isoamyl acetate has a taste reminiscent of pears or bananas.

Ethyl propionate has rum like taste. (Rum is distilled alcoholic beverage made from sugarcane byproducts).

Ethyl butyrate —found in pineapples- tastes like sugar water.

Ethyl valerate has apple like taste.

Ethyl hexanoate is an apple-flavoured ester.

Ethyl heptanoate has wine-like odour and taste with a burning after-taste. Ethyl octanoate found in pineapples has sweet taste.

EXERCISE

Q1. Select the right answer from the choices given with each question.

1) A carboxylic acid contains functional group:

a) A Hydroxyl group

b) A Carboxyl group

c) A Hydroxyl and Carboxyl group

d) A Carboxyl and aldehyde group

2) From the following carboxylic acids which acid has higher acidity:

a) Ethanoic acid

b) Propanoid acid

c) Chloro ethanoid acid

d) Nitro ethanoid acid

3) Which reagent is used to reduce carboxylic acid?

a) He/Ni

b) H_2/Pt

c) $NaBH_4$

d) $LiAlH_4$

4) Stronger acid is:

a) CH_3COOH

b) $HCOOH$

c) CH_3CH_2COOH

d) $CH_3CH_3CH_2COOH$

5) Acetamide is prepared by:

a) Heating ammonium acetate

b) Heating methyl cyanide

c) Heating ethyl acetate

d) The hydrolyers of methyl cyanide

6) Carboxylic acids react with metal to from salts with the evolution of:

a) CO_2

b) H_2

c) CO

d) CH_4

7) Ethane-I, 2 dioic acid is also called:

a) Benzoic acid

b) Oxalic acid

c) Formic acid

d) Malonic acid

8) Carboxylic acid can be prepared by the action of Grignard's reagent with:

a) O_2

b) CO_2

c) KCl

d) N_2

9) The IUPAC names for formic acid is:

a) Methanoic acid

b) Acetic acid

c) Ethanoic acid

d) Butanoic acid

10) The reaction of alcohol with acetic acid is known as:

a) Saponification b) Esterification

c) ammonolysis d) Hydrolysis

11) Esters are formed by the reaction of carboxylic acids with:

a) Alcohols b) Ethers

c) aldehydes d) Alkyl halides

12) Which one of the following has both hydroxyl and carboxylic acid group:

a) phenol b) picric acid

c) phthalic acid d) salicylic acid

13) Which of the following cannot be prepared directly from acetic acid?

a) acetamide b) acetyl chloride

c) acetic anhydride d) ethyl acetate

14) Reaction between caustic soda and a fat is called:

a) Esterification b) Hydrogenation

c) Neutralization d) Saponification

15) When a carboxylic acid reacts with alcohol, it produces a new class of compounds:

a) ethers b) esters

c) anhydride d) amide

Answers

1)	b)	2)	c)	3)	d)	4)	b)
5)	a)	6)	b)	7)	b)	8)	b)
9)	a)	10)	b)	11)	a)	12)	d)
13)	a)	14)	d)	15)	b)		

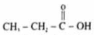
Q2. Give brief answers for the following questions.

Q1. What are aliphatic and aromatic carboxylic acids?

Answer

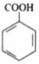
In aliphatic carboxylic acid the carboxylic group — COOH is attach to a carbon chain. Whereas in aromatic carboxylic group the carboxylic group — COOH is attached to a benzene ring.

For example:



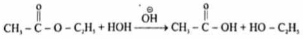
$CH_3 - CH_2 - \overset{O}{\overset{\|}{C}} - OH$

Propionic acid
(An aliphatic acid)



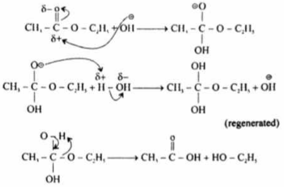
Benzoic acid
(An aromatic acid)

Q2. Give probable mechanism of alkaline hydrolysis of an ester.



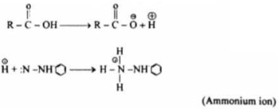
$$CH_3-\overset{O}{\overset{\|}{C}}-O-C_2H_5 + HOH \xrightarrow{\overset{\ominus}{OH}} CH_3-\overset{O}{\overset{\|}{C}}-OH + HO-C_2H_5$$

Mechanism



Q3. A carboxylic acid does not form phenyl hydrazine when treated with phenyl hydrazine. Explain?

Answer



The carboxylate ion is a poor electrophile and an ammonium ion is not a nucleophile.

Q4. Give the Mechanism for acid catalyzed hydrolysis of a nitrile?

Answer

Please see Answer ofQ24 of chapter notes.

Q5. Why acetic acid is often called glacial acetic acid?

Answer

The pure acetic acid on freezing changes into ice like solid therefore it is called glacial acetic acid.

Q6. What is use of esters?

Answer

Please see the answer of Q29 and Q30 of chapter notes.

Q7. How many nitriles be converted into carboxylic add?

Answer

Please see Answer of Q24 of chapter notes.

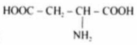
Q8. What are acidic amino acids give example?

Answer

The amino acids having one amino group and two or more than two carboxylic group is called acidic amino acid.

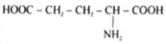
For example:

Aspartic acid



$$\mathrm{HOOC-CH_2-\underset{NH_2}{\underset{|}{CH}}-COOH}$$

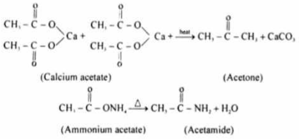
Glutamic acid



$$\mathrm{HOOC-CH_2-CH_2-\underset{NH_2}{\underset{|}{CH}}-COOH}$$

Q9. What happens when ammonium acetate and calcium acetate is heated.

Answer



$$\left.\begin{matrix}\mathrm{CH_3-\overset{O}{\overset{\|}{C}}-O}\\ \mathrm{CH_3-\underset{O}{\underset{\|}{C}}-O}\end{matrix}\right\rangle \mathrm{Ca} + \left.\begin{matrix}\mathrm{CH_3-\overset{O}{\overset{\|}{C}}-O}\\ \mathrm{CH_3-\underset{O}{\underset{\|}{C}}-O}\end{matrix}\right\rangle \mathrm{Ca} + \xrightarrow{\text{heat}} \mathrm{CH_3-\overset{O}{\overset{\|}{C}}-CH_3 + CaCO_3}$$

(Calcium acetate) (Acetone)

$$\mathrm{CH_3-\overset{O}{\overset{\|}{C}}-ONH_4 \xrightarrow{\Delta} CH_3-\overset{O}{\overset{\|}{C}}-NH_2 + H_2O}$$

(Ammonium acetate) (Acetamide)

Q10. How does carboxylic acids exist in non-polar solvent?

Answer

Carboxylic acid is partially ionized in non-polar solvent and behaves as very week acid.

For example: Acetic acid is nearly unionized on dissolving in ethers and carbon tetrachloride.

Q3. Give detailed answers for the following questions.

Q1. How will you prepare carboxylic acids from

i) **Alkyl nitrile.**

ii) **Hydrolysis of esters.**

Answer

i) Preparation of carboxylic acids from alkyl nitriles

Alkyl nitriles on boiling with mineral acids or alkalis yield corresponding carboxylic acids i.e

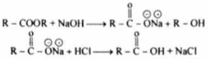
$$R-C\equiv N+H_2O\xrightarrow[\text{or}(OH^-)]{(H^+)}RCOOH+NH_4Cl$$

For example:

$$CH_3-C\equiv N+2H_2O+HCl\longrightarrow CH_3COOH+NH_4Cl$$

ii) Preparation of carboxylic acids through hydrolysis of esters

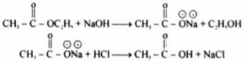
Esters on boiling with concentrated NaOH yield sodium salt of the acid, this salt when heated with dilute HCl gives the carboxylic acids i.e.



$$R-COOR+NaOH\longrightarrow R-\overset{O}{\overset{\|}{C}}-\overset{\ominus\ \oplus}{ONa}+R-OH$$

$$R-\overset{O}{\overset{\|}{C}}-\overset{\ominus\ \oplus}{ONa}+HCl\longrightarrow R-\overset{O}{\overset{\|}{C}}-OH+NaCl$$

For example:



$$CH_3-\overset{O}{\overset{\|}{C}}-OC_2H_5+NaOH\longrightarrow CH_3-\overset{O}{\overset{\|}{C}}-\overset{\ominus\ \oplus}{ONa}+C_2H_5OH$$

$$CH_3-\overset{O}{\overset{\|}{C}}-\overset{\ominus\ \oplus}{ONa}+HCl\longrightarrow CH_3-\overset{O}{\overset{\|}{C}}-OH+NaCl$$

Q2. Give the reaction of acetic acid with the following along mechanism.

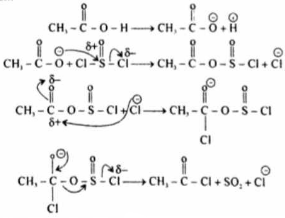
i) SOCl₂ **ii) Ethanal** **iii) NH,**

Answer

SOCl₂

$$CH_3COOH+SOCl_2\longrightarrow CH_3COCl+SO_4+HCl$$

Mechanism



$$CH_3-\overset{O}{\overset{\|}{C}}-O-H\longrightarrow CH_3-\overset{O}{\overset{\|}{C}}-\overset{\ominus}{O}+\overset{\oplus}{H}$$

$$CH_3-\overset{O}{\overset{\|}{C}}-\overset{\ominus}{O}+Cl-\overset{\delta+O}{\overset{\|}{S}}-\overset{\delta-}{Cl}\longrightarrow CH_3-\overset{O}{\overset{\|}{C}}-O-\overset{O}{\overset{\|}{S}}-Cl+\overset{\ominus}{Cl}$$

$$CH_3-\underset{\delta+}{\overset{\delta-O}{\overset{\|}{C}}}-O-\overset{O}{\overset{\|}{S}}-Cl+\overset{\ominus}{Cl}\longrightarrow CH_3-\underset{Cl}{\underset{|}{\overset{O^{\ominus}}{\overset{\|}{C}}}}-O-\overset{O}{\overset{\|}{S}}-Cl$$

$$CH_3-\underset{Cl}{\underset{|}{\overset{O^{\ominus}}{\overset{\|}{C}}}}-O-\overset{O}{\overset{\|}{S}}-\overset{\delta-}{Cl}\longrightarrow CH_3-\overset{O}{\overset{\|}{C}}-Cl+SO_2+\overset{\ominus}{Cl}$$

ii) **Reaction of Acetic acid with Ethanol**

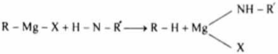
Please see Answer ofQ8 of Chapter notes.

iii) Reaction of Acetic acid with NH3

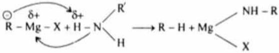
Please see Answer of Q9 of Chapter notes.

Q3. Give the reaction of amine with Grignard reagent with mechanism.

Answer



Mechanism of Reaction



Q4. What happens when following compounds are heated.

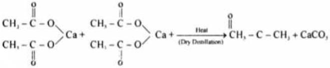
i) Calcium acetate

ii) Sodium formate and soda lime

iii) Ammonium acetate.

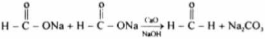
Answer

i) Calcium acetate is heated



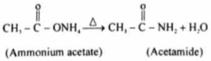
$$CH_3-\overset{O}{\overset{\|}{C}}-CH_3 + CaCO_3$$

ii) Sodium formate and soda lime is heated



$$H-\overset{O}{\overset{\|}{C}}-ONa + H-\overset{O}{\overset{\|}{C}}-ONa \xrightarrow[NaOH]{CaO} H-\overset{O}{\overset{\|}{C}}-H + Na_2CO_3$$

iii) Ammonium acetate is heated



$$CH_3-\overset{\overset{O}{\|}}{C}-ONH_4 \xrightarrow{\Delta} CH_3-\overset{\overset{O}{\|}}{C}-NH_2+H_2O$$

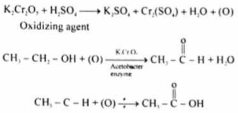
(Ammonium acetate) (Acetamide)

Q5. What is vinegar? Describe how is vinegar prepared from ethanol.

Answer

Vinegar is a mixture of dilute acetic acid along with some ingredients like sugar table salt and some flavour.

Major component of vinegar is acetic acid. Acetic acid may be prepared from ethanol through following steps by its oxidation.



$$\underset{\text{Oxidizing agent}}{K_2Cr_2O_7+H_2SO_4} \longrightarrow K_2SO_4+Cr_2(SO_4)+H_2O+(O)$$

$$CH_3-CH_2-OH+(O) \xrightarrow[\text{Acetobacter enzyme}]{K_2Cr_2O_7} CH_3-\overset{\overset{O}{\|}}{C}-H+H_2O$$

$$CH_3-C-H+(O) \overset{\cdot}{\underset{\cdot}{\longrightarrow}} CH_3-\overset{\overset{O}{\|}}{C}-OH$$

Q6. Write down the Mechanism of the following reactions.

i) Between acetic acid and ethanol

ii) Between acetic acid and ammonia

iii) Between acetic acid and thionyl chloride

Answer

i) Between acetic acid and ethanol

Please see Answer of Q8 of Chapter notes

ii) Between acetic acid and ammonia

Please see Answer ofQ9 of Chapter notes

iii) Between acetic acid and thionyl chloride

Please see Answer of Q2(i) of exercise.

Q7. How would you convert the following?

i) Acetic acid into acetamide.

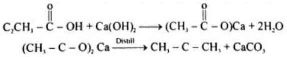
ii) Acetic acid into acetone

Answer

i) Acetic acid into acetamide.

Please see Answer ofQ9 of Chapter notes

ii) Acetic acid into acetone



$$C_2CH_3-\overset{\overset{O}{\|}}{C}-OH+Ca(OH)_2 \longrightarrow (CH_3-\overset{\overset{O}{\|}}{C}-O)Ca+2H_2O$$

$$(CH_3-C-O)_2Ca \xrightarrow{\text{Distill}} CH_3-C-CH_3+CaCO_3$$

Q8. How amides are reduced with LiAlH4? Give mechanism.

Answer

Please see Answer of Q22 of Chapter notes

Q9. What is Friedel & crafts reaction? Explain their mechanism.

Answer

Please see Answer of Q 13 of Chapter notes

Q10. Give mechanism of reaction for acid catalyzed esterification.

Answer

Please see Answer ofQ8 of Chapter notes

Short Answers and Questions

Q1: Write down the formula of the following?

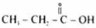
a) Succinic acid **b) Glutauic acid**

c) Adipic acid **d) Malomic acid**

e)Oxalic acid **f) Propionic acid**

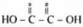
Answer

a) Propionic acid



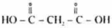
$CH_3-CH_2-\overset{\overset{O}{\|}}{C}-OH$

b) Oxalic acid



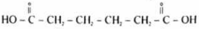
$HO-\overset{\overset{O}{\|}}{C}-\overset{\overset{O}{\|}}{C}-OH$

c) Malonic acid



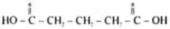
$HO-\overset{\overset{O}{\|}}{C}-CH_2-\overset{\overset{O}{\|}}{C}-OH$

d) Adipic acid



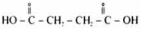
$HO-\overset{\overset{O}{\|}}{C}-CH_2-CH_2-CH_2-CH_2-\overset{\overset{O}{\|}}{C}-OH$

e) Glutaric acid



$HO-\overset{\overset{O}{\|}}{C}-CH_2-CH_2-CH_2-\overset{\overset{O}{\|}}{C}-OH$

f) Succinic acid



$HO-\overset{\overset{O}{\|}}{C}-CH_2-CH_2-\overset{\overset{O}{\|}}{C}-OH$

Q2: Write down the physical properties of carboxylic acid.

Answer

The polar nature of both the O —H and C = O bonds, due to the electronegativity difference of the atoms results in the formation of strong hydrogen bonds with other carboxylic acid molecules or other H bonding system. The implications are:

I) High melting and boiling points compared to analyses alcohols.

2) High solubility in aqueous media.

3) Hydrogen bonded dimmers in gas phase and dimmers an aggerates in pure liquids.

Q3: Write down the structure and acidity of carboxylic acid?

Answer

The CO_2H units is plane and consistent with SP^2 hybridization and a resonance interaction of the lone pairs of the hydroxyl oxygen with that system of the carboxyl.

Acidity

Carboxylic acid and the most acidic simple organic compounds (PKa — 5).

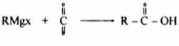
But they are weak acids compared to acids like HCl or H_2SO_4.

Resonance stabilization of the carboxylate allows the negative change to be decolorized between the two electronegative oxygen atoms. Adjacent electron with drawing substituents increases the acidity by further stabilizing the carboxylate.

Q4: Write down the preparation of carboxylic acids.

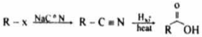
Answer

Carbonation of Grignard Reagents RMgX, by CO_2

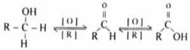


$RMgx + \underset{\overset{\|}{O}}{\overset{\overset{O}{\|}}{C}} \longrightarrow R-\overset{\overset{O}{\|}}{C}-OH$

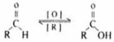
Hydrolysis of Nitriles


$$R-x \xrightarrow{NaC\equiv N} R-C\equiv N \xrightarrow[heat]{H_3^+} RCOOH$$

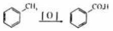
Oxidation of Primary alcohol


$$RCH_2OH \underset{[R]}{\overset{[O]}{\rightleftharpoons}} RCHO \underset{[R]}{\overset{[O]}{\rightleftharpoons}} RCOOH$$

Oxidation of Aldehydes


$$RCHO \underset{[R]}{\overset{[O]}{\rightleftharpoons}} RCOOH$$

Oxidation of Alkyl Benzenes



Q5: Write down the reaction of carboxylic acids? Carboxylic acids undergo the following types of reaction. .

Answer

i) The reaction in which hydrogen atom of the carboxyl group in which hydrogen atom of the carboxyl group is involved (salt formation).

ii) The reaction in which OH group is replaced by another group. iii) The relational involving carboxyl group as.

Reaction involving H atom of the carboxylic group. Carboxylic acids are weaker acids than mineral acids. They furnish H when dissolved in HO.

Reaction with Bases

Carboxylic acid reacts with (NaOH, KOH) to form salts.

$$CH_3COOH + NaoH \longrightarrow CH_3COONa + H_2o$$

Reaction with carbonates and bicarbonates. Carboxylic acids decomposers carbonate and bicarbonate evolving carbon dioxide gas with effervescence.

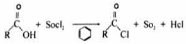
$$2CH_3COOH + Na_2CO_3 \longrightarrow 2CH_3COONa + Co_2 + H_2o$$
$$CH_3COOH + NaHco_3 \longrightarrow CH_3COONa + Co_2 + H_2o$$

Reaction with Metals

Carboxylic acids reaction with active metals such as Na, K, Ca, Mg etc to form their salts with evolution of hydrogen gas.

$$2CH_3COOH + 2Na \longrightarrow 2CH_3COONa + H_2o$$

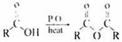
Q6: Write down the preparation of Acyl chlorides.


$$RCOOH + Socl_2 \longrightarrow RCOCl + So_2 + Hcl$$

Answer

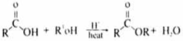
Acyl chlorides are prepared by treating the carboxylic acid with tlioxyl chloride

SOC12 in the presence of a base. Acyl chlorides are by for the most commonly encountered of the acyl halides. Preparation of Acid Anlydides.



Preparation of Esters

This reaction is known as the Fisher esterification Esters au obtained by refluxing the pacent carboxylic acids with the appropriate alcohol with an acid catalyst. ,



The equilibrium can be driven to completion by using an excess of either the alcohol or the carboxylic acid, or by removing the H20 as it forms. Esters can also be made from other carboxylic acid derivates, especially acyle halides and anlydides, by reacting them with the appropriate alcohol in the presence of a weak base. If a compound contains both hydrogen and carboxylic acid groups, then cyclic esters or lactomes can from via an intermolecular reaction. Reactions that from 5 or 6 membered rings are particularly favorable.

Q7: With mechanism for reaction for Acid catalyzed esterification. Answer

Step

Step 1

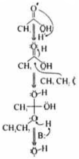
Protonation of carboxyl of acid group

Step 2

The alcohol O functions as the nucleophite and electrons moving towards the oxonium ioin, creating the tetrahedral intermediate.

Step 3

An acid/ base reaction Deprotonate the alcoholic oxygen.

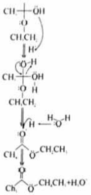


Step 4

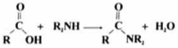
Acid base reaction in which OH leave and connect it into a good leaving group by protonation.

Step 5

The electrons of an adjacent oxygen to help "push out" the leaving group a neutral water molecule.



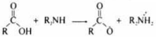
Q8: Write down the preparation of Amides.



$$RCOOH + R_2NH \longrightarrow RCONR_2 + H_2O$$

Answer

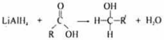
In general, it is not easy to prepare amides directly from the pacent carboxylic acid. The acid will protonate the amine preventing further, reactions since the carboxylate is a poor electrophile and the ammonium ion is not nucleophilic.



$$RCOOH + R_2NH \longrightarrow RCOO^- + R_2\overset{+}{N}H_2$$

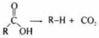
It is much easier to convert the carboxylic acid to the more reactive acyl chloride fist.

Reduction to Alcohols



$$LiAlH_4 + RCOOH \longrightarrow H-C(OH)(H)-R' + H_2O$$

Carboxylic acid is less reactive to reduction by hydride than aldehydes, ketones, or esters. Carboxylic acids are reduced to primary alcohol. As a result of their low reactivity, carboxylic acid can only be reduced by LiALH4 not by the less reactive NaBH4 Decarboxylation.



$$RCOOH \longrightarrow R-H + CO_2$$

Less of carbon dioxide is called decarboxylation. Simple carboxylic acids raxely undergo decarboxylation, Carboxylic acid with a carboxyl group at the 3 — (or P) position readily undergo thermal decarboxylation e.g. derivatives of matonic acid.

matonic acid

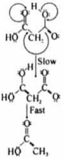
The reaction proceeds via a cyclic transition state guing an enol intermediate that tectomerizes to the carboxyl.

Decarboxylation

The protenation of the carboxyl, break the OH bond and form the bond, break the C — C and make the C = C. Note the concerted nature of this reaction and the cyclic transition state.

Step 2

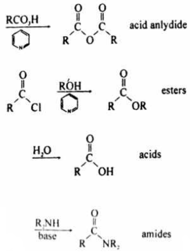
Tectomerization to the acid product.



Q9: Write down the Reactions of carboxylic Acid Derivates?

Answer

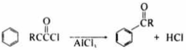
Interconversion of Acyl chlorides



Acyl chlorides are the most reactive of the carboxylic acid derivates and therefore can be readily converted into other carboxylic acid derivates.

They are sufficiently reactive that they react quite readily with cold water and hydrolyze to the carboxylic acid. The HCl by product is usually removed by adding a base such as pyridine or triethyl amine.

Friedel — crafts Acylation of Benzene

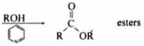


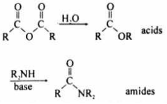
Overall transformation Ar — H to Ar — COR (Ketone). Named after Friedel craft who discovered the Reagent normally the acyle halide (usually RCOCl) with aluminium tuicltolide $AlCl_3$ a Lewis acid catalyst. The $AlCl_3$ enhances he electrophilicity of the acyl halide by complexing with the halide.

Electrophitic species the acyl cation or acylium ion (RCO+) formed by the removes of the halide by the Lewis acid catalyst. Friedel crafts reactions are limited to arnes as or more reactive than mono halobenzenes. Other sources of acylium can also be used as acid anhydrides with $AlCl_3$.

Reaction of Acid Anhydrides hydrolysis

Interconversion Reaction of Acid anhydrides

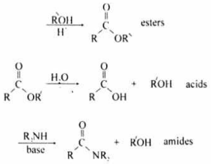




Acid anhydrides are the second most reactive of the carboxylic acids derivates and can therefore be fairly readily converted into the other less reactive cathoxylic acid derivatives. A base in often added to neutralize the carboxylic acid by product that is formed.

Q10: Write down the reaction of Esters, hydrolysis, Reduction and with Grignard's reagent?

Answer

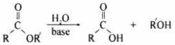


Esters can be converted into other esters the point carboxylic acid (hydrolysis) or amides.

Transebeatification heat with alcohol and acid catalyst Amide preparation heat with the amine, methyl or ethyl esters are the most reactive.

Q11: Write down the hydrolysis of Esters?

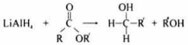
Answer



Carboxylic esters hydrolyze to the pacent carboxylic acid and an alcohol. Reagents aqueous acid (e.g. H_2SO_4) heat or aqueous NaOH heat known as saponification.

Q12: Write down the reduction of Esters?

Answer



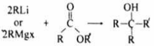
Carboxlic esters are reduced give 2 alcohols one form the alcohol portion of the ester and a I alcohol from the reduction of the carboxylate portion.

Esters are less reactive toward No than aldehydes or ketones.

They can only be reduced by $LiAlH_4$ and not by the less reactive $NaBH_4$.

Q13: Write down the reaction of RLi and Mgx with esters.

Answer



Carboxylic acid esters RC02R''react with 2 equivalents of organolithium or geignaed reagents to give tertiary alcohols. The tertiary alcohol that result contain 2 identical alhyl groups.

The reaction proceeds via a ketone intermediate which then reacts with second equivalent of the organometallic reagents. Since the Ketone is more reactive than the ester, the reaction cannot be used as a preparation of ketones. The mechanisms is an example of the reactive system type.

Q14: Write down the mechanism of the acids catalyzed hydrolysis of amides.

Answer

Step I

An acid/ base reaction sincere only have a weak nucleophite and a poor electrophile CHI NH, we need to activate the ester. Protonation of the amide carboxyl makes it more electrophitic.

Step 2

The H_2O O functions as the nucleophite attacking the electrophitic C in the C = O with the electrons moving towards the oxonium ion, creating the tetrahedral intermediate.

Step 3

An acid/ base reaction. Deprotonate the oxygen that came from the H_2O molecule.

Step 4

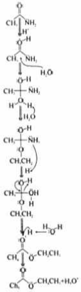
An acid base reaction needs to make the NH_2 leave but need to convert it into a good leaving group first by protonation

Step 5

Use the electrons of an adjacent to help push out the leaving group a neutral ammonia molecule.

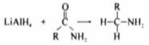
Step 6

An acid/ base reaction Deprotonation of the oxonium ion reacts the carboxyl in the carboxylic acid produced and regenerates the acid catalyst.



Q15: Write down the reduction of Amides.

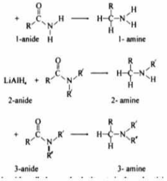
Answer



Amides $RCONR_2$ can be reduced to the amino RCH_3NR_2 by conversion of the C = O to - CH2.

Amides can be reduced by $LiAlH_4$ but Not the less reactive $NaBH_4$.

This reaction is different to that of other C = O compounds which reduce to alcohols. The nature of the amine obtained depends on the substituents present on the original amide look at the N substituents in the following



R.R' or R" may be either alkyl or acyl substituents in the potential mechanisms with O System note that it is an O system that leaves. This is consistuent with O system being better leaving groups that the less electronegative N systems.

Q16: Write down the reaction of $LiAlH_4$ with an amide.

Answer

Step 1

The nucleophitic H from the hydride reagent adds to the electophilitic C in the polar carboxyl group of the esters. Electrons from the C = O move to the elector-negative O creating an intennediate metal alkonide complex.

Step 2

The tetrahedral intermediate collapses and displace leaving

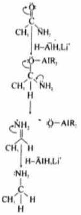
group thus produces a highly reactive imminium ion an

intemediate.

Step 3

Rapid reduction by the nucleophitic H from the hydride reagent as it adds to the electrophilic C en the iminium system

electrons from the C = N move to the cationic N neutralizingc the charge create amine product.



Q17: Write down the mechanisms of the acid catalyzed hydrolysis of nitrides.

Answer

Step 1

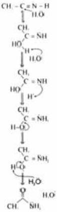
An acid/ base reaction.

Since we only a weak nucleophile so active the nitrile, protonation make it more electophitic.

Step 2

Step 6

An acid/ base reaction/ Deportonation of the oxonium ion reveals the carboxyli in the amide intermediate half way to the acid.



The water O functions as the nucleophile attacking the electrophilic C in the CN with the electons moving towards the positive center.

Step 3

An acid/ base reaction, Deprotonate the oxygen that came from the H20 molecule. The remaining task is a tautomerization are N and O centers

Step 4

An acid/ base reaction. Protonate the N gives us the — NH_2 we need.

Step 5

Use the electrons of an adjacent O to the neutralise the positive at the N and from the bond in the C = O.

Reduction of Nitricles

$$\underset{\text{Nitrile}}{R-C\equiv N:} \xrightarrow{[R]} \underset{\text{Primay amine}}{R-CH_2\ddot{N}H_2}$$

Reaction types: Nucleophetic Addition.

The nitrile RC N give the 1 ⁰ amine by conversion of the C N to CH2 — NH2

Nitriles can be reduced by LiAlH4 but Not the less reactive NaBH4. Typical reagents LiAlH4. Typical reagents LiAlH4 ether solvent followed by aqueous work up. Catalytic hydrogenation (H/ catalyst) can also be used giving the same product. R may bc either allcyl or acyl substituents.

Q18: Write down reaction of RMgx with a nitrile?

Answer

Step 1

The nucleophilic C in the organometallic reagents adds to the electrophilic C in the polar nitride group. Electrons from the C N more to the electronegative N creating and intermediate imine salt complex.

Step 2

An acid/ base reaction. On addition of aqueous acid, the intermediate salt protonates giving the imine.

Step 3

An acid/ base reaction. Ammines undergo nucleophilic addition but require activation by protonation.

Step 4

Now the Nucleophilic O of a water molecule H-oö attacks the electrophilic C with the P bond breaking to neutralize the change on then.

Step 5

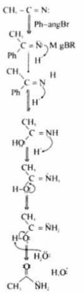
An acid/ base reaction Deprotonate the O from the H20 molecule to neutralize the positive charge.

Step 6

An acid/ -base reaction. Before the N system leaves, it needs to be made into a better leaving group by protonation.

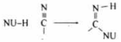
Step 7

Use the electron on the O in order to push out the N leaving group, a neutral molecule of ammonia.



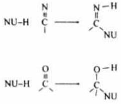
Q19: Write down the reaction of Nitriles, Hydrolysis Reduction and reaction with Grignard's regard.

Answer

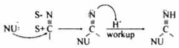


Nitriles typically undergo nucleophilic addition to give product that often undergo a further reaction.

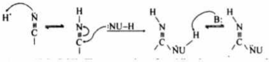
The chemistry of the nitrile functioned group C = O of aldehydes and ketones.



Strong Nucleophilic aniomic add directly to the C N to forman intermediate imine salt that protonates. .



Example are RMgx, RLi, RC CM, LiAlH4. Weaker nucleophiles neutral requires that the C N be activated prior to attack of the No. This can be done increasing an acid catalyst which protonates on the Lewis basic N and make the system more electrophilic.



Example are H_2O, ROH. The protonation of a nitile gives a structure that can be reaction in another resonance from that results the electrophilic character of the C since it is a carbocation.