

CHAPTER 9



CARBONYL COMPOUNDS II: CARBOXYLIC ACID AND FUNCTIONAL DERIVATIVES



“Organic compounds which contain carbonyl group (C=O) attached to hydroxyl group (-OH) are referred as carboxylic acid.”

PHYSICAL PROPERTIES OF CARBOXYLIC ACID:

- They are liquids with a sharp odor.
- They are soluble in polar solvents such as water.
- They have high boiling point as compared to alcohols due to stronger hydrogen bond.

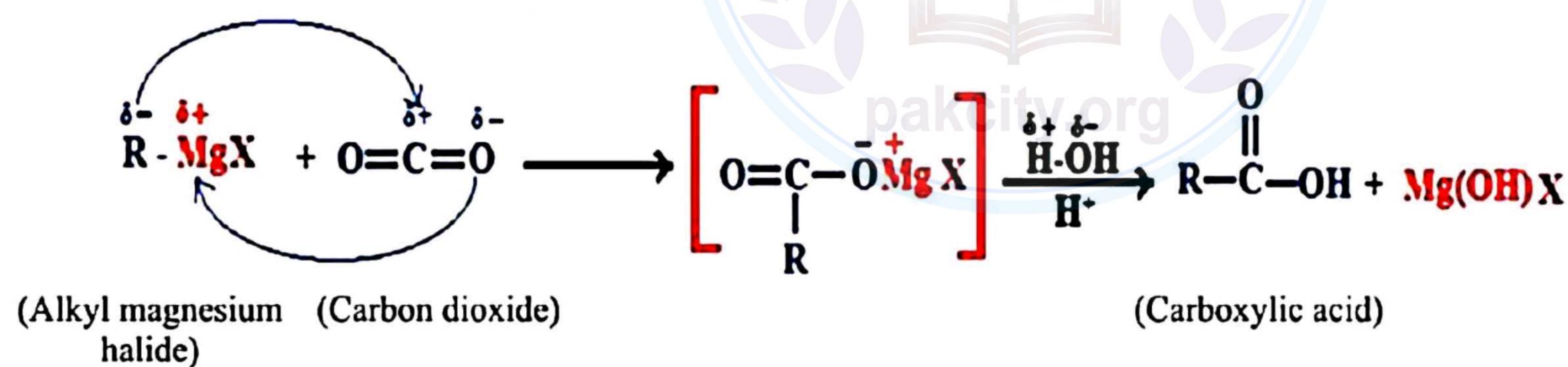
ACIDITY OF CARBOXYLIC ACID:

“Carboxylic acids are stronger acids than alcohols, phenols and water. However, they are weaker acids compared to mineral acids.”

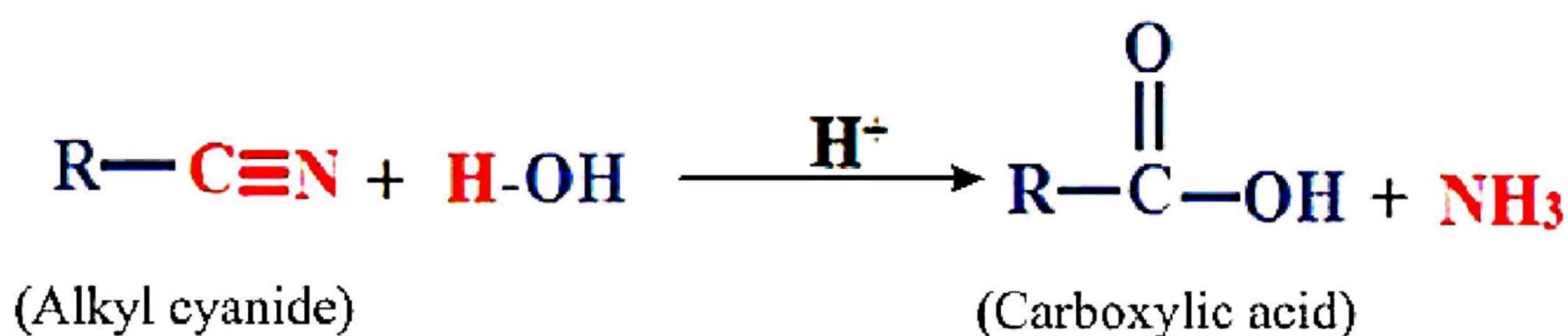
Name of Compound	Molecular Formula	pKa Value
Acetic acid	CH ₃ COOH	5
Phenol	C ₆ H ₅ OH	10
Ethyl alcohol	C ₂ H ₅ OH	16
Water	H ₂ O	15.7

PREPARATION OF CARBOXYLIC ACID:

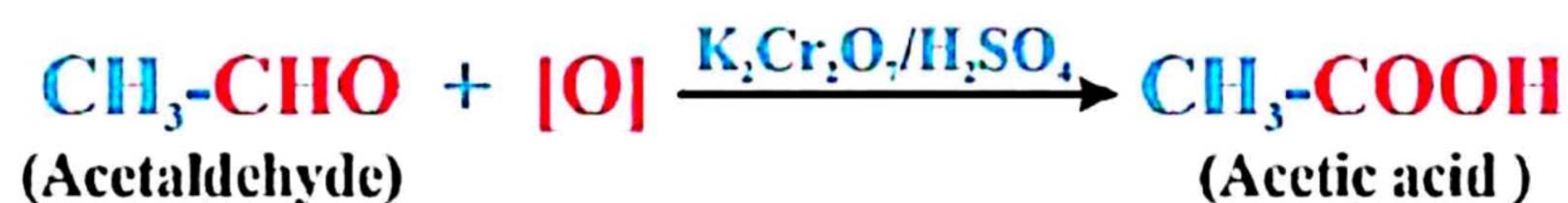
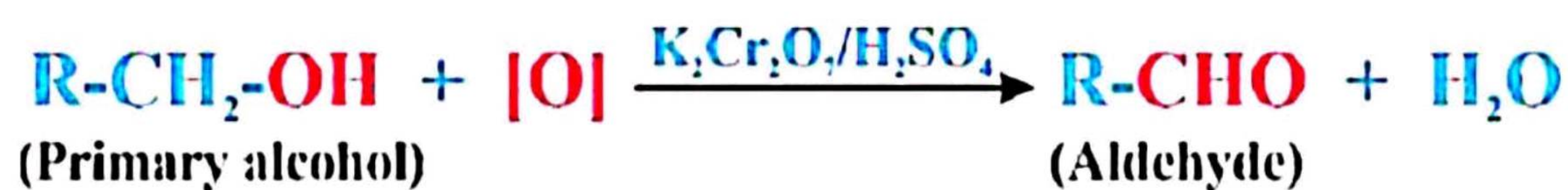
1 By the Carbonation of Grignard Reagent



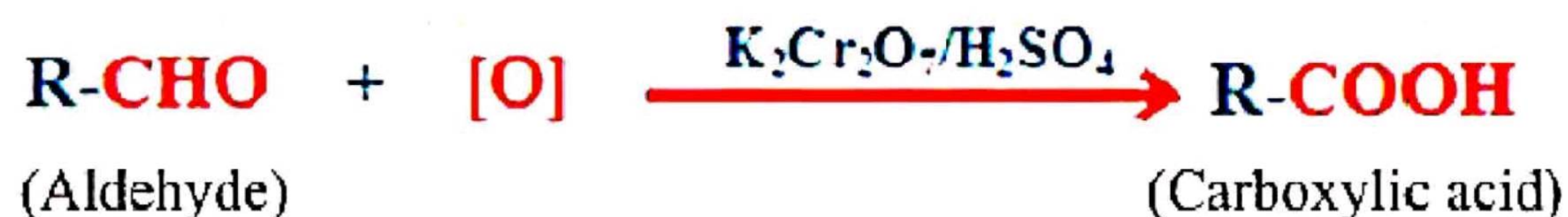
2 By the Hydrolysis of Nitriles



3 By the Oxidation of Primary Alcohols



4 By the Oxidation of Aldehyde



5 By the Oxidation of Alkyl Benzene



DERIVATIVES OF CARBOXYLIC ACIDS

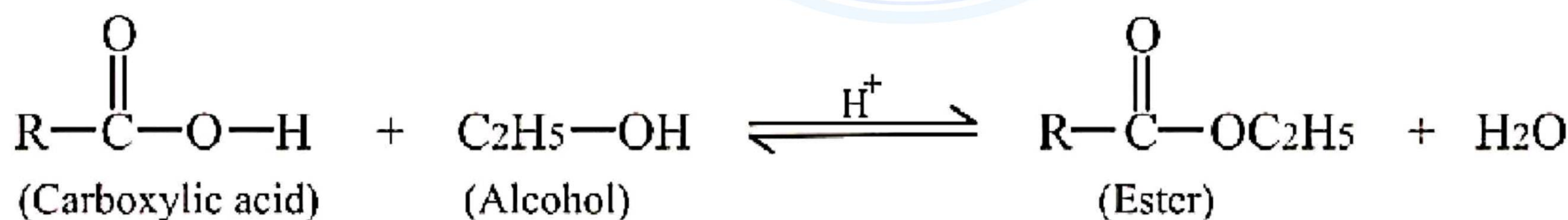


Certain compounds are structurally derived from carboxylic acids by replacing a part of functional group of the carboxylic acid. Some common derivatives of carboxylic acids are given as:

(i) Esters: They are formed by replacing the hydrogen atom of carboxylic group with an alkyl or aryl group. Their general formula is R-COOR.

Conversion of Carboxylic Acids into Ester

The process in which carboxylic acid reacts with alcohol to form ester is called esterification.



e.g: Ethyl acetate (CH₃COOC₂H₅), Methyl propionate (C₂H₅COOCH₃)

(ii) Acid Halides: They are formed by replacing the hydroxyl group of carboxylic acid with a halogen atom (X). Their general formula is RCOX.

e.g. Acetyl chloride (CH₃COCl), Propionyl chloride (C₂H₅COCl) etc.



Self-Assessment

Show the following conversions by means of chemical reactions:

- Methyl cyanide into acetic acid
- Acetic acid into an amide
- Ethanoic acid into ethanol



- $\text{CH}_3\text{CN} + 2\text{H}_2\text{O} \rightarrow \text{CH}_3\text{COOH} + \text{NH}_3$
- $\text{CH}_3\text{COOH} + \text{NH}_3 \rightarrow \text{CH}_3\text{COONH}_4 \xrightarrow{\text{heat}} \text{CH}_3\text{COONH}_2 + \text{H}_2\text{O}$
- $\text{CH}_3\text{COOH} + 4[\text{H}] \xrightarrow{\text{LiAlH}_4} \text{C}_2\text{H}_5\text{OH} + \text{H}_2\text{O}$

Uses of some common carboxylic acids and their derivatives

- ❖ Citric acid is used as flavor enhancer.
- ❖ Maleic acid is used as food additive.
- ❖ Tartaric Acid is used in food industry.
- ❖ Acetic acid is used as vinegar.
- ❖ Salicylic acid is used in the production of aspirin.
- ❖ Acet amide is used in drug synthesis.
- ❖ Acetic anhydride is used in making cellulose acetate.

Common name	Structure	Occurrence and derivation of name	Applications
Formic acid	HCOOH	Ants (Latin; Formica)	Preservative and antibacterial agent in livestock feed
Acetic acid	CH_3COOH	Vinegar (Latin; Acetum)	Vinegar production, food preservative and flavoring agent
Propionic acid	$\text{CH}_3\text{CH}_2\text{COOH}$	Milk, butter and cheese (Greek Protos, First; pion, fat)	Animal feed additive for preventing mold growth
Butyric acid	$\text{CH}_3(\text{CH}_2)_2\text{COOH}$	Butter (Latin; Butyrum)	Flavoring agent in food products
Valeric acid	$\text{CH}_3(\text{CH}_2)_3\text{COOH}$	Valerian root (Latin; Valere, to be strong)	Manufacture of valerate esters used in perfumes
Caproic acid	$\text{CH}_3(\text{CH}_2)_4\text{COOH}$	Goat (Latin; Caper)	Pharmaceuticals and plasticizers


Multiple Choice Questions

- (i) The most common compound found in pineapple is:
(a) Acetic acid (b) Ethanol
(c) Acetone (d) Ethyl butanoate
- (ii) Two molecules of acetic acid on condensation gives:
(a) Ethyl acetate (b) Aceticamide
(c) Acylhalide (d) Acetic anhydride
- (iii) Carboxylic acid is stronger acid than:
(a) HCl (b) HNO₃
(c) C₂H₅OH (d) H₂SO₄
- (iv) The reagent that cannot produce an acyl halide in reaction with a carboxylic acid is:
(a) PCl₃ (b) PCl₅
(c) HCl (d) SOCl₂
- (v) Benzoic acid is the product of oxidation of:
(a) Benzene (b) Ethyl Benzene
(c) Aniline (d) Phenol
- (vi) Formation of acyl halide and amide by carboxylic acid involved
(a) Replacement of hydrogen (b) Replacement of carbonyl group
(c) Replacement of hydroxyl group (d) Replacement of oxygen
- (vii) Formic acid is naturally found in:
(a) Venom of ants (b) Bees string
(c) Vinegar (d) Butter
- (viii) Among the following compounds, the one with the highest boiling point is:
(a) Ethanol (b) Acetaldehyde
(c) Acetic acid (d) Ethyl chloride
- (ix) The formula of caproic acid is:
(a) C₄H₉COOH (b) C₅H₁₁COOH
(c) C₆H₁₃COOH (d) C₇H₁₅COOH
- (x) The reaction of acetic acid with ethanol in the presence of conc. sulphuric acid gives:
(a) Ethyl acetate (b) Acetamide
(c) Ethane (d) Acetic anhydride

Descriptive Questions

1. How is carboxylic acid prepared by:
- Carbonation of Grignard reagent
 - Hydrolysis of alkyl nitriles
 - Oxidation of primary alcohols

Already Discussed Above

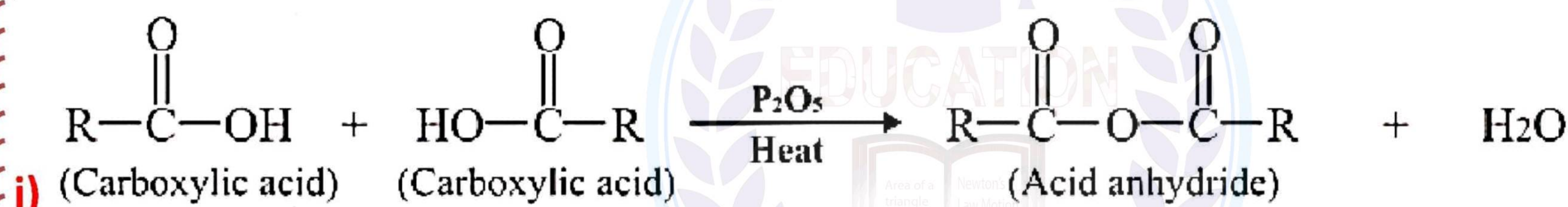
2. Explain the structure of carboxylic acid. 

Ans. Structure of carboxylic acid is explained by hybrid orbital theory. The carbonyl carbon is sp^2 hybridized, possessing three sp^2 hybrid orbitals and one p_z unhybridized orbital. These three sp^2 hybrid orbitals are oriented almost at an angle of 120° to give trigonal geometry whereas p_z unhybridized orbital of carbonyl carbon form pi bond with p_z orbital of oxygen atom.

3. Discuss the acidic nature of carboxylic acid. How is it stronger than other organic compounds and weaker than mineral acids?

Already Discussed Above

4. Convert the followings:
- Carboxylic acid into acid anhydride
 - Ester into carboxylic acid
 - Toluene into benzoic acid



5. Explain the following physical properties of carboxylic acids:
- Solubility
 - Boiling point

Already Discussed Above

6. Write the names of four derivatives of carboxylic acids and give the equation for their preparation from acetic acid.

Already Discussed Above