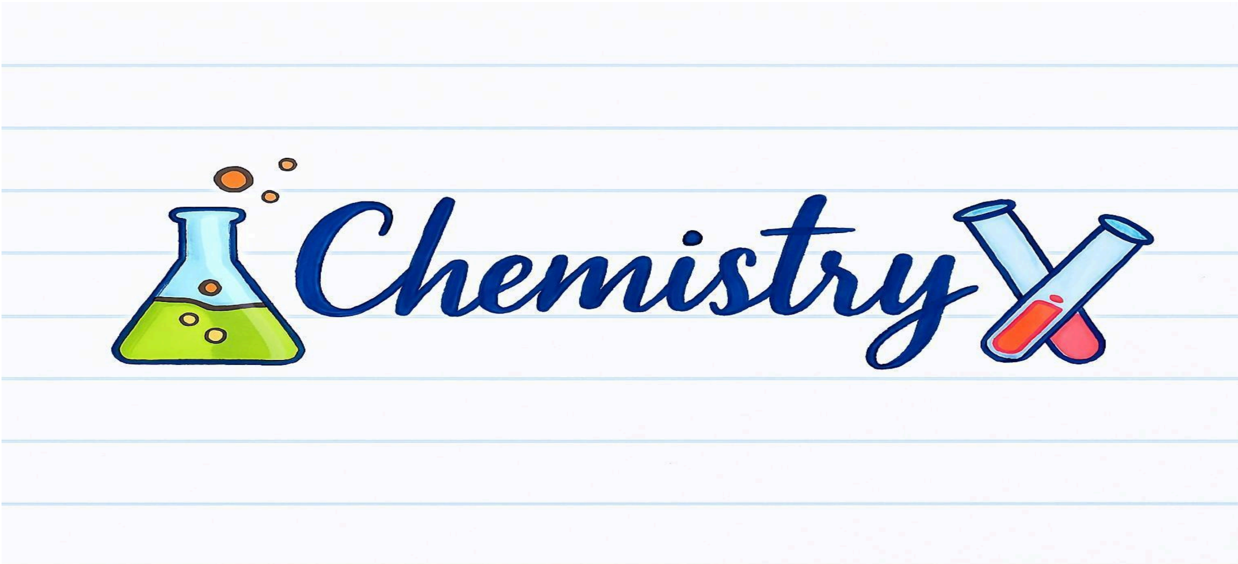

Class: 12th

Subject: Chemistry

Chapter 13: CARBOXYLIC ACIDS

🩸 Keypoints Important MCQs

1. Organic compounds containing –COOH group are called:

(a) Alcohols

(b) Aldehydes

(c) Carboxylic acids ✅

(d) Ketones

2. Carboxylic acids are classified into:

(a) Aliphatic and aromatic ✅

(b) Saturated and unsaturated

(c) Aldehydes and ketones

(d) Neutral and acidic

3. Aliphatic carboxylic acids are also called:

(a) Aromatic acids

(b) Fatty acids ✅

(c) Hydroxy acids

(d) Amino acids

4. Carboxylic acids can be produced by:

(a) Oxidation of alcohols and aldehydes ✅

(b) Reduction of ketones

(c) Neutralization of bases

(d) Hydrolysis of esters only

5. Lower members of carboxylic acids are:

(a) Insoluble solids

(b) Water soluble with pungent smell ✅

(c) Colourless gases

(d) Odourless liquids

6. Solubility of carboxylic acids in water:

(a) Increases with molecular mass

(b) Decreases with molecular mass ✅

(c) Remains constant

(d) Depends only on temperature

7. Carboxylic acids have higher boiling points than:

(a) Aldehydes

(b) Alcohols ✅

(c) Ketones

(d) Esters

8. Acid chlorides, amides, esters and anhydrides are:

(a) Isomers

(b) Derivatives of carboxylic acids ✅

(c) Hydrocarbons

(d) Amino acids

9. Acetic acid is synthesized commercially from:

(a) Ethanol

(b) Acetylene ✅

(c) Benzene

(d) Methane

10. Amino acids join together to form:

(a) Esters

(b) Peptides ✅

(c) Alcohols

(d) Aldehydes

🩸 Important MCQs:

1. Organic compounds containing (–COOH) group are called:

(a) Alcohols

(b) Aldehydes

(c) Carboxylic acids ✅

(d) Ketones

2. The carboxyl group is made up of:

(a) Hydroxyl + Alkyl

(b) Carbonyl + Hydroxyl ✅

(c) Carbonyl + Alkyl

(d) Hydroxyl + Phenyl

3. General formula of aliphatic carboxylic acids is:

(a) R−OH

(b) R−CHO

(c) R−COOH ✅

(d) Ar−COOH

4. General formula of aromatic carboxylic acids is:

(a) R−COOH

(b) Ar−COOH ✅

(c) R–OH

(d) Ar–OH

5. Methanoic acid is commonly known as:

(a) Acetic acid

(b) Formic acid ✅

(c) Butyric acid

(d) Oxalic acid

6. Ethanoic acid is commonly known as:

(a) Formic acid

(b) Acetic acid ✅

(c) Benzoic acid

(d) Malonic acid

7. Oxalic acid is an example of:

(a) Aromatic monocarboxylic acid

(b) Aliphatic dicarboxylic acid ✅

(c) Aromatic dicarboxylic acid

(d) Aliphatic monocarboxylic acid

8. Benzoic acid is:

(a) Aromatic monocarboxylic acid ✅

(b) Aliphatic monocarboxylic acid

(c) Aromatic dicarboxylic acid

(d) Aliphatic dicarboxylic acid

9. Malonic acid is:

(a) Aromatic monocarboxylic acid

(b) Aliphatic dicarboxylic acid ✅

(c) Aromatic dicarboxylic acid

(d) Aliphatic monocarboxylic acid

10. 1,2-Benzenedicarboxylic acid is:

(a) Aromatic dicarboxylic acid ✅

(b) Aliphatic dicarboxylic acid

(c) Aromatic monocarboxylic acid

(d) Aliphatic monocarboxylic acid

11. Higher aliphatic monocarboxylic acids are called:

(a) Hydroxy acids

(b) Fatty acids ✅

(c) Polyacids

(d) Aromatic acids

12. Formic acid was first isolated from:

(a) Vinegar

(b) Butter

(c) Red ants ✅

(d) Fats

13. Acetic acid was first isolated from:

(a) Butter

(b) Vinegar ✅

(c) Ants

(d) Oils

14. Butyric acid name is derived from:

(a) Vinegar

(b) Butter ✅

(c) Ants

(d) Fats

15. IUPAC name of acetic acid is:

(a) Methanoic acid

(b) Ethanoic acid ✅

(c) Propanoic acid

(d) Butanoic acid

16. Suffix used in IUPAC names of carboxylic acids is:

(a) −al

(b) −ol

(c) −oic acid ✅

(d) −one

17. Primary alcohols are oxidised to carboxylic acids by:

(a) NaOH

(b) $KMnO_4$

(c) $K_2Cr_2O_7/H_2SO_4$ ✅

(d) Tollen's reagent

18. Aldehydes are oxidised to acids even by mild oxidising agent:

(a) NaOH

(b) $KMnO_4$

(c) Tollen's reagent ✅

(d) HCl

19. Hydrolysis of nitriles produces:

(a) Aldehydes

(b) Ketones

(c) Carboxylic acids ✅

(d) Alcohols

20. Grignard reagent reacts with to form carboxylic acids:

(a) Oxygen

(b) Water

(c) Carbon dioxide ✅

(d) Alkyl halide

21. The first three aliphatic acids (formic, acetic, propionic) are:

(a) Colourless solids

(b) Colourless liquids with pungent smell ✅

(c) Coloured liquids

(d) Odourless liquids

22. The next three aliphatic acids (C_4–C_6) have:

(a) Pleasant fruity smell

(b) Unpleasant smell ✅

(c) No smell

(d) Sweet smell

23. The first four aliphatic acids are highly soluble in water due to:

(a) Ionic bonding

(b) Hydrogen bonding ✅

(c) Van der Waals forces

(d) Dipole–dipole interaction

24. Carboxylic acids have relatively high boiling points because:

(a) They are ionic compounds

(b) They form cyclic dimers via hydrogen bonding ✅

(c) They are aromatic

(d) They are volatile

25. Boiling point of acetic acid (CH_3COOH) is:

(a) 100 °C

(b) 118 °C ✅

(c) 141 °C

(d) 80 °C

26. Melting points of carboxylic acids show irregularity because:

(a) Odd-numbered carbon acids have lower melting points than even-numbered ✅

(b) Even-numbered carbon acids have lower melting points

(c) All acids have same melting point trend

(d) Depends only on molecular mass

27. Carboxylic acids are weaker acids than:

(a) Alcohols

(b) Mineral acids ✅

(c) Phenols

(d) Esters

28. Reaction of carboxylic acids with NaOH produces:

(a) Alcohol

(b) Salt + Water ✅

(c) Ester

(d) Aldehyde

29. Reaction of carboxylic acids with $NaHCO_3$ evolves:

(a) Hydrogen gas

(b) Oxygen gas

(c) Carbon dioxide gas ✅

(d) Nitrogen gas

30. Reaction of carboxylic acids with active metals (Na, K, Ca) produces:

(a) Salt + Hydrogen gas ✅

(b) Ester + Water

(c) Alcohol + Hydrogen gas

(d) Aldehyde

31. Reaction of carboxylic acids with $SOCl_2$ produces:

(a) Acetyl chloride ✅

(b) Acetic acid

(c) Acetone

(d) Alcohol

32. Heating carboxylic acids with alcohol in presence of conc. H_2SO_4 gives:

(a) Aldehydes

(b) Esters ✅

(c) Ketones

(d) Amides

33. Esters are commonly used as:

(a) Fuels

(b) Artificial flavours ✅

(c) Fertilizers

(d) Detergents

34. Carboxylic acids react with ammonia to form:

(a) Ammonium salts, which on heating give amides ✅

(b) Amines directly

(c) Alcohols

(d) Aldehydes

35. Carboxylic acids on reduction with $LiAlH_4$ are converted into:

(a) Alkanes

(b) Alcohols ✅

(c) Aldehydes

(d) Ketones

36. Dilute solution of acetic acid is known as:

(a) Spirit

(b) Vinegar ✅

(c) Ether

(d) Molasses

37. Acetic acid can be prepared in lab by oxidation of:

(a) Methane

(b) Ethyl alcohol or acetaldehyde ✅

(c) Benzene

(d) Ethylene

38. Hydrolysis of methyl cyanide gives acetic acid via:

(a) Ethanol

(b) Acetamide ✅

(c) Acetone

(d) Formaldehyde

39. In commercial manufacture, acetylene is converted to acetic acid using:

(a) H_2SO_4 + $HgSO_4$, then oxidation with V_2O_5 ✅

(b) NaOH + Cl_2

(c) $KMnO_4$ directly

(d) HCl + Zn

40. Acetic acid is also prepared commercially by oxidation of:

(a) Methanol

(b) Ethyl alcohol ✅

(c) Benzaldehyde

(d) Propane

41. Pure acetic acid solidifies at 17 °C and is called:

(a) Ice acid

(b) Glacial acetic acid ✅

(c) Frozen acid

(d) Solid vinegar

42. Boiling point of acetic acid is:

(a) 100 °C

(b) 118 °C ✅

(c) 141 °C

(d) 80 °C

43. Acetic acid is miscible with:

(a) Water only

(b) Water, alcohol and ether ✅

(c) Alcohol only

(d) Ether only

44. Acetic acid is used as:

(a) Fuel

(b) Coagulant for latex in rubber industry ✅

(c) Fertilizer

(d) Bleaching agent

45. Acetic acid is used in manufacture of:

(a) Polyvinyl acetate, rayon, silk ✅

(b) Nylon, polyester

(c) Wool, cotton

(d) Glass, ceramics

46. Amino acids contain both:

(a) Hydroxyl and carbonyl groups

(b) Amino and carboxyl groups ✅

(c) Alkyl and hydroxyl groups

(d) Phenyl and amino groups

47. Almost all naturally occurring amino acids are:

(a) β-amino acids

(b) α-amino acids ✅

(c) γ-amino acids

(d) δ-amino acids

48. Amino acids with two carboxyl groups are called:

(a) Neutral amino acids

(b) Acidic amino acids ✅

(c) Basic amino acids

(d) Aromatic amino acids

49. Amino acids with two amino groups are called:

(a) Neutral amino acids

(b) Basic amino acids ✅

(c) Acidic amino acids

(d) Aromatic amino acids

50. Amino acids exist in solution as:

(a) Free radicals

(b) Zwitter ions ✅

(c) Neutral molecules only

(d) Ionic salts only

51. Amino acids largely exist in solution as:

(a) Neutral molecules

(b) Free radicals

(c) Zwitter ions (internal salts) ✅

(d) Ionic salts only

52. Basic character of amino acids is due to:

(a) Carboxyl group

(b) Carboxylate ion accepting proton ✅

(c) Hydroxyl group

(d) Alkyl group

53. Acidic character of amino acids is due to:

(a) Carboxyl group

(b) Amino group releasing proton ($-NH_3^+ \longrightarrow -NH_2$) ✅

(c) Hydroxyl group

(d) Phenyl group

54. Strecker synthesis of amino acids involves reaction of aldehyde with:

(a) HCl + NaOH

(b) HCN + NH_3 ✅

(c) NaCN + H_2O

(d) $SOCl_2$

55. Ninhydrin test for amino acids gives:

(a) Green colour

(b) Bluish violet colour ✅

(c) Red colour

(d) Yellow colour

🩸 **Keypoints Important Short Questions:**

1. Define Carboxylic Acids.

Answer:

👉 Carboxylic acids are organic compounds containing the −COOH (carboxyl group) as their functional group.

2. Name the two classes of Carboxylic Acids.

Answer:

👉 Carboxylic acids are classified into aliphatic and aromatic carboxylic acids.

3. What are Aliphatic Carboxylic Acids also called?

Answer:

👉 Aliphatic carboxylic acids are also called fatty acids.

4. How can Carboxylic Acids be produced?

Answer:

👉 They can be produced by oxidation of alcohols and aldehydes or by hydrolysis of nitriles.

5. Why are lower members of Carboxylic Acids soluble in water?

Answer:

👉 Lower members are soluble due to hydrogen bonding with water molecules.

6. How does solubility of Carboxylic Acids change with molecular mass?

Answer:

👉 Solubility decreases as the molecular mass increases.

7. Why do Carboxylic Acids have higher boiling points than alcohols?

Answer:

👉 Because they form cyclic dimers through intermolecular hydrogen bonding, raising boiling points.

8. Name four derivatives of Carboxylic Acids.

Answer:

👉 The derivatives are acid chlorides, acid amides, esters, and acid anhydrides.

9. How is Acetic Acid synthesized on commercial scale?

Answer:

👉 Acetic acid is synthesized from acetylene using H_2SO_4 + $HgSO_4$ catalyst, followed by oxidation.

10. Differentiate between Polypeptides and Proteins based on molecular mass.

Answer:

👉 Polypeptides have molecular mass up to 10,000, while proteins have molecular mass greater than 10,000.

🩸 Important Short Questions:

1. Define Carboxylic Acids.

Answer:

👉 Carboxylic acids are organic compounds containing the −COOH (carboxyl group) as their functional group.

2. What is a carboxyl group made up of?

Answer:

👉 A carboxyl group consists of a carbonyl group (>C=O) and a hydroxyl group (−OH).

3. Differentiate between aliphatic and aromatic carboxylic acids.

Answer:

👉 **Aliphatic acids:** R−COOH (R = H or alkyl group).

👉 **Aromatic acids:** Ar−COOH (Ar = phenyl or aryl group).

4. Give examples of aliphatic monocarboxylic acids.

Answer:

👉 Methanoic acid (Formic acid) and Ethanoic acid (Acetic acid).

5. Name one aliphatic dicarboxylic acid and one aromatic monocarboxylic acid.

Answer:

👉 **Aliphatic** dicarboxylic acid: Oxalic acid (HOOC−COOH).

👉 **Aromatic** monocarboxylic acid: Benzoic acid (C_6H_5−COOH).

6. Why are higher aliphatic monocarboxylic acids called fatty acids?

Answer:

👉 Because they are obtained by hydrolysis of fats and oils.

7. How are common names of carboxylic acids derived? Give two examples.

Answer:

👉 Derived from their source of isolation.

• Formic acid ⟶ ants (formica).

• Acetic acid ⟶ vinegar.

8. What suffix is used in IUPAC nomenclature of carboxylic acids?

Answer:

👉 The suffix −oic acid is used.

9. How are carboxylic acids prepared from primary alcohols and aldehydes?

Answer:

👉 By oxidation with $K_2Cr_2O_7/H_2SO_4$ or by mild oxidising agents like Tollen's reagent.

10. Why does hydrolysis of nitriles produce carboxylic acid with one extra carbon atom?

Answer:

👉 Because the –CN group adds one carbon atom to the chain during hydrolysis.

11. What type of smell is shown by the first three aliphatic acids (formic, acetic, propionic)?

Answer:

👉 They are colourless liquids with pungent smell.

12. Why are the first four aliphatic carboxylic acids highly soluble in water?

Answer:

👉 Because of hydrogen bonding between acid molecules and water.

13. Why do carboxylic acids have relatively high boiling points compared to other compounds?

Answer:

👉 Due to intermolecular hydrogen bonding, they exist as cyclic dimers which raise boiling points.

14. Why do carboxylic acids show irregularity in melting points with increasing molecular mass?

Answer:

👉 Because acids with even number of carbon atoms have higher melting points than adjacent odd-numbered acids.

15. How do carboxylic acids react with bases, carbonates, and active metals?

Answer:

👉

• With bases → form salts + water.

• With carbonates/bicarbonates → form salts + CO_2 gas + water.

• With active metals → form salts + hydrogen gas.

16. What is the dilute solution of acetic acid called?

Answer:

👉 The dilute solution of acetic acid is called vinegar.

17. How is acetic acid prepared in the laboratory from ethyl alcohol?

Answer:

👉 By oxidation of ethyl alcohol or acetaldehyde using $K_2Cr_2O_7/H_2SO_4$.

18. How is acetic acid prepared in the laboratory from methyl cyanide?

Answer:

👉 By hydrolysis of methyl cyanide (ethanenitrile), which first forms acetamide, then acetic acid.

19. How is acetic acid manufactured from acetylene?

Answer:

👉 Acetylene is treated with H_2SO_4 + $HgSO_4$ catalyst to form acetaldehyde, which is oxidised with V_2O_5 to acetic acid.

20. How is acetic acid prepared commercially from ethyl alcohol?

Answer:

👉 Ethyl alcohol (from molasses fermentation) is oxidised with $K_2Cr_2O_7/H_2SO_4$ to acetaldehyde, then further oxidised to acetic acid.

21. What is the boiling point of acetic acid?

Answer:

👉 The boiling point of acetic acid is 118 °C.

22. Why is pure acetic acid called glacial acetic acid?

Answer:

👉 Because it freezes at 17 °C into an ice-like solid.

23. Name three solvents with which acetic acid is miscible.

Answer:

👉 Acetic acid is miscible with water, alcohol, and ether.

24. Write two important uses of acetic acid in industry.

Answer:

👉 It is used as a coagulant in rubber industry and in the manufacture of plastics, rayon, and silk.

25. What are amino acids and how are they classified?

Answer:

👉 **Amino acids** are organic compounds containing both $-NH_2$ (amino group) and $-COOH$ (carboxyl group).

👉 **They are** classified as neutral, acidic, and basic amino acids.

26. Define Zwitter ion.

Answer:

👉 Amino acids exist as dipolar ions (internal salts) where the proton shifts from $-COOH$ to $-NH_2$ group.

27. Explain the acidic and basic character of amino acids.

Answer:

👉 **Acidic character:** $-NH_3^+$ group releases proton.

👉 **Basic character**: $-COO^-$ group accepts proton.

28. How are amino acids synthesized from bromoacids?

Answer:

👉 Bromoacids react with ammonia to form amino acids.

29. What is Strecker synthesis of amino acids?

Answer:

👉 Aldehyde + HCN + NH_3 ⟶ α-amino nitrile ⟶ hydrolysis ⟶ α-amino acid.

30. What is a peptide bond? Differentiate between polypeptides and proteins.

Answer:

👉 **Peptide** bond is the −CO−NH− linkage formed by condensation of amino acids.

👉 **Polypeptide:** molecular mass up to 10,000.

👉 **Protein:** molecular mass greater than 10,000.

🩸 Exercise

Q1. Fill in the blanks:

(i) Formula of malonic acid is .

Answer: $HOOC-CH_2-COOH$ ✅

(ii) Methyl nitrile upon acidic hydrolysis produces .

Answer: Acetic acid (CH_3COOH) ✅

(iii) Melting points of carboxylic acids containing even number of carbon atoms are than the next lower and higher members containing odd number of carbon atoms.

Answer: higher ✅

(iv) Acetic acid on heating with produces acetic anhydride.

Answer: phosphorus pentoxide (P_2O_5) ✅

(v) Acid chloride and acid anhydride are called of acid.

Answer: derivatives ✅

(vi) Pure acetic acid is called .

Answer: glacial acetic acid ✅

(vii) Formula of alanine is .

Answer: $CH_3-CH(NH_2)-COOH$ ✅

(viii) Proline is a amino acid.

Answer: neutral ✅

(ix) A peptide having a molecular mass more than 10,000 is called .

Answer: protein ✅

Q.2 Indicate True and False:

(i) Acetic acid exists as a dimer in benzene.

Answer: True ✅

(ii) First three aliphatic acids have fruity smells.

Answer: False ❌ (They have pungent smell)

(iii) Carboxylic acids on reduction with $LiAlH_4$ produce alkenes.

Answer: False ❌ (They produce alcohols)

(iv) Acetic acid on dehydration produces CO and H_2.

Answer: False ❌ (It produces acetic anhydride with P_2O_5)

(v) Sodium formate on heating with soda lime produces $NaHCO_3$ and hydrogen.

Answer: False ❌ (It produces methane gas)

(vi) Amino acids exist as Zwitter ion.

Answer: True ✅

(vii) Histidine is an acidic amino acid.

Answer: False ❌ (Histidine is a basic amino acid)

(viii) A peptide having molecular mass upto 10,000 is called protein.

Answer: False ❌ (It is called polypeptide; protein > 10,000)

(ix) Phthalic acid is a monocarboxylic acid.

Answer: False ❌ (It is a dicarboxylic acid)

(x) Formula of glycine is CH_2-COOH.

Answer: False ❌ (Correct formula: NH_2-CH_2-COOH)

Q.3 Multiple Choice Questions

1. Acetic acid is manufactured by:

(a) Distillation

(b) Fermentation ✅

(c) Ozonolysis

(d) Esterification

2. A carboxylic acid contains:

(a) A hydroxyl group

(b) A carboxyl group

(c) A hydroxyl and carboxyl group ✅

(d) A carboxyl and an aldehydic group

3. Which acid is used in the manufacture of synthetic fibre?

(a) Formic acid

(b) Oxalic acid

(c) Carbonic acid

(d) Acetic acid ✅

4. Which following derivative cannot be prepared directly from acetic acid?

(a) Acetamide ✅

(b) Acetyl chloride

(c) Acetic anhydride

(d) Ethyl acetate

5. Which reagent is used to reduce a carboxylic group to an alcohol?

(a) H_2/Ni

(b) H_2/Pt

(c) $NaBH_4$

(d) $LiAlH_4$ ✅

6. The solution of which acid is used for seasoning of food?

(a) Formic acid

(b) Acetic acid ✅

(c) Benzoic acid

(d) Butanoic acid

7. Organic compounds X and Y react together to form organic compound Z. What type of compounds can X, Y and Z be?

(a) Alcohol, ester, acid

(b) Acid, ester, alcohol

(c) Ester, alcohol, acid

(d) Alcohol, acid, ester ✅

8. An aqueous solution of an organic compound reacts with sodium carbonate to produce carbon dioxide gas. Which one of the following could be the organic compound?

(a) $CH_2=CH-CH_3$

(b) CH_3CHO

(c) $CH_3COOC_2H_5$

(d) CH_3-CH_2-COOH ✅

9. Which of the following is not a fatty acid?

(a) Propanoic acid

(b) Acetic acid

(c) Phthalic acid ✅

(d) Butanoic acid

10. Acetamide is prepared by:

(a) A hydroxyl group

(b) A carboxyl group ✅

(c) A hydroxyl and carboxyl group

(d) A carboxyl and an aldehydic group

🌟 Q.4 Write down the structural formulae of the following

(i) Valeric Acid (Pentanoic Acid)

Structural Formula:

$CH_3 - CH_2 - CH_2 - CH_2 - COOH$

Detailed Explanation:

- **Valeric acid** is a carboxylic acid that contains five carbon atoms.
- **Four carbon atoms** form a straight chain, and at the end of the chain there is a carboxyl group (COOH).
- **This COOH group** gives the **compound** its acidic nature.

The **general formula** of valeric acid is $C_5H_{10}O_2$.

(ii) Propionic Acid (Propanoic Acid)

Structural Formula:

$CH_3 - CH_2 - COOH$

Detailed Explanation:

- Propionic acid contains three carbon atoms.
- Two carbons form the carbon chain and the third carbon is part of the carboxyl (COOH) group.
- It is a short-chain fatty acid and is commonly used in food preservation.

General formula: $C_3H_6O_2$.

(iii) Oxalic Acid

Structural Formula:

HOOC – COOH

Detailed Explanation:

- **Oxalic acid** is the simplest dicarboxylic acid, meaning it contains two carboxyl groups (COOH) directly bonded to each other.
- There is **no carbon** chain in between.
- It is naturally present in plants such as spinach and rhubarb.

General formula: $C_2H_2O_4$.

(iv) Benzoic Acid

Structural Formula:

C_6H_5 – COOH

Detailed Explanation:

- **Benzoic acid** is an aromatic carboxylic acid.
- It **consists** of a benzene ring (C_6H_5) attached to a carboxyl group (COOH).
- The **benzene** ring provides stability and aromatic character to the molecule.

General formula: $C_7H_6O_2$.

(v) Acetic Anhydride

Structural Formula:

$(CH_3CO)_2O$

Expanded structural form:

$CH_3 - CO - O - CO - CH_3$

Detailed Explanation:

- **Acetic anhydride** is an acid anhydride formed from two molecules of acetic acid by removing one molecule of water.
- It **contains** two acyl groups (CH_3–CO–) connected by an oxygen atom.
- **It is widely** used in organic synthesis, especially esterification and acetylation reactions.

(vi) Acetyl Chloride (Ethanoic Chloride)

Structural Formula:

$CH_3 - CO - Cl$

Detailed Explanation:

- **Acetyl chloride** is an acid chloride, derived from acetic acid by replacing the –OH group of the COOH with a chlorine atom (Cl).
- It is a **very reactive** organic compound and is used in the preparation of esters and amides.

General formula: C_2H_3OCl.

✦ **SUMMARY (For Quick Revision)**

Valeric Acid: $CH_3-CH_2-CH_2-CH_2-COOH$ ⟶ 5-carbon carboxylic acid.

Propionic Acid: CH_3-CH_2-COOH ⟶ 3-carbon carboxylic acid.

Oxalic Acid: HOOC–COOH ⟶ simplest dicarboxylic acid.

Benzoic Acid: C_6H_5-COOH ⟶ aromatic carboxylic acid.

Acetic Anhydride: $CH_3-CO-O-CO-CH_3$ ⟶ anhydride of acetic acid.

Acetyl Chloride: $CH_3-CO-Cl$ ⟶ acid chloride of acetic acid.

🌟 **Q.6 (a) Manufacture of acetic acid — and what is glacial acetic acid?**

Industrial methods to manufacture acetic acid

1. Carbonylation of methanol (dominant modern route)

Reaction:

$CH_3OH + CO \ \ CH_3COOH$

- **Catalysis:** homogeneous rhodium (Monsanto process) or iridium (Cativa process) catalysts with iodide promoter.

Notes: Very high selectivity and used for large-scale production.

2. Oxidation of acetaldehyde

Reaction (simplified):

$CH_3CHO + ½\, O_2 \longrightarrow CH_3COOH$

Notes: Historically important (liquid-phase oxidation with catalysts). Less used now than methanol carbonylation.

3. Oxidative oxidation of hydrocarbons (n-butane/naphtha)

- Partial oxidation of hydrocarbons (e.g., n-butane) gives acetic acid among other products. Used where suitable feedstock is available.

4. Biological/fermentation route (vinegar production)

- Ethanol is oxidized by acetic acid bacteria (Acetobacter) to give acetic acid (used for vinegar).

What is glacial acetic acid?

- **Glacial acetic acid** = essentially anhydrous (water-free) acetic acid, typically ≥99% purity.
- Named "**glacial**" because it freezes at 16.6 °C to form ice-like crystals.

Properties: colorless, pungent, miscible with organic solvents and with water (exothermic mixing). Very corrosive and a dehydrating agent in some reactions.

🌟 Q.6 (b) Conversions — starting from acetic acid (CH_3COOH)

- I'll give a practical laboratory/industrial conversion for each target compound with equations, reagents, and short notes.

(i) Acetic acid ⟶ Methane (CH_4)

Method (classical laboratory): soda-lime decarboxylation

1. Convert to sodium acetate:

$CH_3COOH + NaOH \longrightarrow CH_3COONa + H_2O$

2. Heat with soda lime (mixture of NaOH + CaO):

$CH_3COONa + NaOH$ (CaO, heat) $\longrightarrow CH_4$ ⬆️ $+ Na_2CO_3$

Net: $CH_3COOH \longrightarrow CH_4 + CO_2$ (CO_2 is captured as carbonate in the mixture).

Notes: Simple lab method to remove the carboxyl group (decarboxylation). Kolbe electrolysis is different (gives ethane from acetate radicals) and does not give methane.

(ii) Acetic acid ⟶ Acetyl chloride (CH_3COCl)

Common methods:

1. Thionyl chloride ($SOCl_2$) (preferred lab method):

$CH_3COOH + SOCl_2 \longrightarrow CH_3COCl + SO_2$ ⬆️ $+ HCl$ ⬆️

- **Conditions:** reflux with $SOCl_2$; SO_2 and HCl gases evolve.

2. Phosphorus pentachloride (PCl_5) or phosphorus trichloride (PCl_3) or oxalyl chloride ($(COCl)_2$) also convert carboxylic acids to acyl chlorides.

Notes / mechanism outline: The −OH of COOH is replaced by −Cl via formation of an activated intermediate; thionyl chloride route is convenient because gases (SO_2, HCl) are removed, driving reaction forward.

(iii) Acetic acid ⟶ Acetamide (CH_3CONH_2)

Two practical lab routes:

1. Via ammonium acetate (direct dehydration on heating):

Form ammonium acetate: $CH_3COOH + NH_3 \longrightarrow CH_3COO^- NH_4^+$ (ammonium acetate)

Heat ammonium acetate: $CH_3COO^- NH_4^+$ (Δ) $\longrightarrow CH_3CONH_2 + H_2O$

Net: Acetic acid + ammonia ⟶ acetamide + water (via ammonium acetate dehydration on heating).

2. Via acetyl chloride (more reactive intermediate):

- $CH_3COOH \longrightarrow CH_3COCl$ (with $SOCl_2$)
- $CH_3COCl + NH_3$ (excess, cold) $\longrightarrow CH_3CONH_2 + NH_4Cl$

Notes: This route is fast and high-yielding; handle acetyl chloride and HCl/NH_3 salts carefully.

(iv) Acetic acid ⟶ Acetic anhydride ($(CH_3CO)_2O$)

Laboratory methods:

1. Dehydration using a dehydrating agent (e.g., P_2O_5):

2 $CH_3COOH + P_2O_5 \longrightarrow (CH_3CO)_2O$ + “P-oxy-byproducts” (overall: dehydration).

Conditions: heating with phosphorus pentoxide; used in the lab to get small amounts.

2. Via acetyl chloride + sodium acetate:

$CH_3COCl + CH_3COONa \longrightarrow (CH_3CO)_2O + NaCl$

This is a common lab preparation.

Industrial method (ketene process):

Generate ketene ($CH_2=C=O$) by pyrolysis/dehydration of acetic acid or by cracking acetate derivatives, then react ketene with acetic acid:

$CH_2=C=O + CH_3COOH \longrightarrow (CH_3CO)_2O$

- This ketene route is the usual industrial method for large-scale acetic anhydride production.

Brief mechanistic/operational notes (very short)

- **Soda-lime decarboxylation:** thermal cleavage of carboxylate gives alkane + CO_2 captured as carbonate.
- **$SOCl_2$ / PCl_5:** convert –OH (poor leaving group) into a better leaving group (–Cl) via formation of activated intermediates; gaseous byproducts help drive reaction.
- **Ammonium acetate ⟶ acetamide:** thermal dehydration (loss of water) on heating gives the amide.
- **Acetic anhydride formation:** either dehydration of two acids or acyl transfer between an acyl chloride and acetate or ketene addition.

✦ **Summary:**

- **Acetic acid** is manufactured mainly by methanol carbonylation (Monsanto/Cativa), oxidation of acetaldehyde and by fermentation (vinegar).
- **Glacial acetic acid** = almost anhydrous acetic acid (≥99%, freezing at 16.6 °C).

Conversions from CH_3COOH:

⟶ CH_4 by soda-lime decarboxylation (via CH_3COONa + heat).

⟶ CH_3COCl by $SOCl_2$ (or PCl_5, oxalyl chloride).

⟶ CH_3CONH_2 by heating ammonium acetate (or via CH_3COCl + NH_3).

⟶ $(CH_3CO)_2O$ by dehydration (P_2O_5), via CH_3COCl + CH_3COONa, or industrially by ketene + acetic acid.

🌟 **Q.7 (a) What are fatty acids?**

Fatty acids are long-chain carboxylic acids that contain a hydrocarbon chain (usually 4–28 carbon atoms) and end with a carboxyl group (–COOH).

They may be:

- **Saturated** fatty acids ⟶ no double bonds (e.g., palmitic acid, stearic acid)
- **Unsaturated** fatty acids ⟶ one or more double bonds (e.g., oleic acid, linoleic acid)

Key Characteristics of Fatty Acids

- They are found in fats and oils (as esters called triglycerides).
- They are insoluble in water but soluble in organic solvents.
- They play important roles in energy storage, cell membranes, and metabolism.

🌟 **Q.7 (b) What is vinegar? How is vinegar prepared from ethanol?**

What is vinegar?

- **Vinegar** is a dilute aqueous solution of acetic acid (CH_3COOH) containing about 4–8% acetic acid by volume.
- It is **commonly** used as a food preservative, flavoring agent, and cleaning agent.
- **Preparation** of Vinegar from Ethanol (Oxidation / Fermentation Process)
- **Vinegar** is produced from ethanol (ethyl alcohol) by oxidation carried out by acetic acid bacteria (Acetobacter species).

This process occurs in two biological steps:

Step 1: Fermentation of sugars to ethanol (Alcoholic Fermentation)

Glucose from fruit juice or sugar solution is first converted to ethanol by yeast.

$C_6H_{12}O_6 \longrightarrow$(Yeast) $2CO_2 + 2C_2H_5OH$

(This step produces the alcohol needed for vinegar.)

Step 2: Oxidation of ethanol to acetic acid (Acetic Fermentation)

Acetobacter bacteria convert ethanol into acetic acid using atmospheric oxygen.

$C_2H_5OH + O_2 \longrightarrow$(Acetobacter) $CH_3COOH + H_2O$

The acetic acid formed dissolves in water ⟶ vinegar.

Methods Used Industrially

1. Orleans Process (Old Method)

- Wooden barrels half-filled with wine or cider
- Holes allow oxygen entry
- Vinegar forms slowly over several weeks

2. Quick Vinegar Process / Generator Process

- Ethanol solution trickles over wood shavings inoculated with Acetobacter
- Continuous supply of air
- Faster production

3. Modern Submerged Fermentation Process

- Acetobacter grown in large stainless-steel tanks
- Air is pumped continuously

- Very fast and efficient method used today

✦ **Short Summary (Exam Points)**

Fatty acids:

- Long-chain carboxylic acids
- Can be saturated / unsaturated
- Present in fats and oils

Vinegar:

- Dilute acetic acid (4–8%)
- Made from ethanol by bacterial oxidation

Preparation from ethanol:

- 1. **Sugar** ⟶ Ethanol (by yeast)
- 2. **Ethanol** ⟶ Acetic acid (by Acetobacter + oxygen)
- 3. **Acetic** acid + water = Vinegar

🌟 **Q. 8 How would you carry out the following conversions?**

(i) Acetic acid into acetamide

(ii) Acetic acid into acetone

❖ **Answer**:

(i) Acetic acid ⟶ Acetamide (CH_3CONH_2)

Method A — Ammonium acetate dehydration (simple lab method)

1. Make ammonium acetate:

$CH_3COOH + NH_3 \longrightarrow CH_3COONH_4$ (ammonium acetate)

2. Heat the solid ammonium acetate (dry) gently (about 150–200 °C):

$CH_3COONH_4 \;\Delta\; \longrightarrow\; CH_3CONH_2 + H_2O$

Conditions: dry heating of ammonium acetate (no solvent).

Notes: straightforward, commonly used in the laboratory. Loss of water converts the salt to the amide.

Method B — Via acetyl chloride (high yield, reactive route)

1. Convert acetic acid to acetyl chloride:

$CH_3COOH + SOCl_2 \longrightarrow CH_3COCl + SO_2$ ⬆️ + HCl ⬆️

2. React acetyl chloride with ammonia (excess, cold):

$CH_3COCl + 2\,NH_3 \longrightarrow CH_3CONH_2 + NH_4Cl$

- **Conditions:** keep acetyl chloride cold, add excess NH_3 to minimise formation of secondary products.

Notes: faster and higher yielding than direct dehydration; handle acetyl chloride and acidic gases with care.

Short mechanistic idea

- **A:** thermal dehydration of ammonium carboxylate ⟶ nucleophilic attack/internal proton transfers ⟶ amide + water.
- **B:** nucleophilic acyl substitution at the acyl chloride by ammonia gives the amide.
- **One-line summary:** Make ammonium acetate and heat (simple) or convert to acetyl chloride then treat with NH_3 (fast, high yield).

(ii) Acetic acid ⟶ Acetone ($(CH_3)_2CO$)

- Method A — Dry distillation of calcium acetate (classical lab method)

1. Prepare calcium acetate:

$2\ CH_3COOH + Ca(OH)_2 \longrightarrow (CH_3COO)_2Ca + 2\ H_2O$

2. Dry and strongly heat the calcium acetate (≈300–400 °C, dry distillation):

$(CH_3COO)_2Ca\ \Delta \longrightarrow (CH_3)_2CO$ ⬆️ $+ CaCO_3$

- **Conditions:** strong heating in absence of moisture; collect distillate (acetone).

Notes: classical textbook method for producing acetone from acetic acid salts.

Method B — Ketonization (catalytic route)

Overall reaction (catalytic ketonization):

$2\ CH_3COOH \longrightarrow (CH_3)_2CO + CO_2 + H_2O$

- **Conditions:** high temperature (typically 400–600 °C) over solid oxide catalysts (e.g., CaO, ZrO_2, mixed metal oxides).

Notes: industrial/heterogeneous catalytic method — acetic acid molecules couple (loss of CO_2) to give acetone; water is produced. Practical for larger-scale/continuous processes using appropriate catalysts.

Short mechanistic idea

- **Dry distillation:** thermal decomposition of the carboxylate salt gives an enolate/acetone precursor which collapses to acetone and carbonate.
- **Ketonization:** surface reaction on basic/oxide catalysts — two acyl fragments combine with decarboxylation (one C becomes CO_2) and rearrangement to give the ketone.

One-line summary: Convert acetic acid to its calcium salt and dry-distill to get acetone (lab), or use catalytic ketonization of acetic acid (2 → acetone + CO_2 + H_2O) on oxide catalysts for larger scale.

🌟 Q. 9 Write down the mechanisms 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) Mechanism between acetic acid and ethanol

Reaction:

$CH_3COOH + CH_3CH_2OH \rightleftharpoons CH_3COOCH_2CH_3 + H_2O$

(Fischer esterification – acid-catalysed)

Steps:

1. Protonation of carbonyl oxygen

$CH_3C{=}O{-}OH + H^+ \longrightarrow CH_3C{=}OH^+{-}OH$

Carbonyl becomes more reactive.

2. Nucleophilic attack by ethanol

$CH_3C{=}OH^+{-}OH + CH_3CH_2OH \longrightarrow CH_3C(OH)(OCH_2CH_3){-}OH^+$

Ethanol oxygen attacks carbonyl carbon.

3. Proton transfer → convert –OH into good leaving group

$CH_3C(OH)(OCH_2CH_3){-}OH^+ \longrightarrow CH_3C(OH)(OCH_2CH_3){-}OH_2^+$

4. Loss of water and formation of carbonyl

$CH_3C(OH)(OCH_2CH_3){-}OH_2^+ \longrightarrow CH_3C(=O^+H)OCH_2CH_3 + H_2O$

5. Deprotonation → ester

$CH_3C(=O^+H)OCH_2CH_3 \longrightarrow CH_3COOCH_2CH_3 + H^+$

(ii) Mechanism between acetic acid and ammonia

Reaction:

$CH_3COOH + NH_3 \longrightarrow CH_3CONH_2 + H_2O$

(formation of acetamide)

Step 1: Acid–base reaction

$CH_3COOH + NH_3 \longrightarrow CH_3COO^- \ NH_4^+$

Ammonium acetate is formed.

Step 2: On heating — nucleophilic attack

Protonated acid: $CH_3C{=}OH^+{-}OH$

NH_3 attacks carbonyl carbon $\longrightarrow$

$CH_3C(OH)(NH_3^+){-}OH$

Step 3: Proton transfer

$CH_3C(OH)(NH_2){-}OH_2^+$

Step 4: Dehydration

$CH_3C(OH)(NH_2){-}OH_2^+ \longrightarrow CH_3C(=O)NH_2^+ + H_2O$

Step 5: Deprotonation

$CH_3C(=O)NH_2^+ \longrightarrow CH_3CONH_2$

(iii) Mechanism between acetic acid and thionyl chloride ($SOCl_2$)

Reaction:

$CH_3COOH + SOCl_2 \longrightarrow CH_3COCl + SO_2 + HCl$

Step 1: Attack on sulfur of $SOCl_2$

O of CH_3COOH attacks S of $SOCl_2 \longrightarrow$

Acyl chlorosulfite intermediate:

$CH_3CO–O–SOCl$

Step 2: Proton transfer

Intermediate loses $H^+ \longrightarrow$ HCl is released.

Step 3: Nucleophilic attack by chloride

Cl^- attacks carbonyl carbon $\longrightarrow$

Intermediate collapses and releases SO_2.

Step 4: Products

$CH_3COCl + SO_2$⬆️ + HCl⬆️ are formed.

Reason reaction goes to completion:

SO_2 and HCl gases escape, driving equilibrium forward.

🌟 **Q. 10 What happens when the following compounds are heated?**

(i) Calcium acetate

(ii) Sodium formate and soda lime

(iii) Ammonium acetate

❖ **ANSWER**

(i) Heating of Calcium Acetate

Compound: $(CH_3COO)_2Ca$

Reaction: Dry distillation of calcium acetate produces acetone and calcium carbonate.

$(CH_3COO)_2Ca \xrightarrow{\Delta} (CH_3)_2CO + CaCO_3$

Explanation / Mechanism:

1. The calcium acetate salt decomposes when strongly heated (≈300–400 °C).

2. Two CH_3COO^- groups combine; one loses CO_2, the remaining CH_3 groups form the ketone.

3. Acetone distills off; $CaCO_3$ remains as solid residue.

Practical note: This is a classical lab method to prepare acetone from acetic acid salts.

(ii) Heating of Sodium Formate with Soda Lime

- **Compound:** HCOONa + NaOH/CaO (soda lime)

- **Reaction:** Decarboxylation of sodium formate produces methane.

$HCOONa + NaOH \longrightarrow (CaO, heat)\ CH_4 \uparrow + Na_2CO_3$

Explanation / Mechanism:

1. Sodium formate reacts with soda lime (NaOH + CaO).

2. Decarboxylation occurs — the $-COO^-$ group is removed as CO_2.

3. A methane molecule (CH_4) is formed.

4. CO_2 reacts with remaining NaOH/CaO to form sodium carbonate.

Practical note: This is the classical laboratory method to prepare methane from formic acid salts.

(iii) Heating of Ammonium Acetate

- **Compound:** CH_3COONH_4
- **Reaction:** On heating, ammonium acetate gives acetamide and water.

$CH_3COONH_4 \longrightarrow (\Delta)\ CH_3CONH_2 + H_2O$

Explanation / Mechanism:

1. Ammonium acetate is the salt of acetic acid and ammonia.

2. Heating causes dehydration — water is removed.

3. The carbonyl carbon is attacked by the ammonia part internally → amide formation.

4. Acetamide is obtained as solid; water vapor evolves.

Practical note: This is a common laboratory method for preparing amides from carboxylic acids via ammonium salts.

🌟 **Q. 11 What are amino acids? Explain their different types with one example in each case.**

❖ **Definition of Amino Acids:**

Amino acids are organic compounds that contain both an amino group ($-NH_2$) and a carboxyl group ($-COOH$) attached to the same carbon atom, known as the α-carbon.

- The α-carbon also carries a hydrogen atom and a side chain (R group), which varies for each amino acid.

The general formula of an amino acid is:

$H_2N-CHR-COOH$

- **Amino acids** are the building blocks of proteins, meaning that proteins are polymers made by linking amino acids through peptide bonds.
- **The properties** and functions of a protein depend on the sequence and nature of amino acids it contains.

Types of Amino Acids:

Amino acids are classified based on the nature of their side chains (R groups). The main types are:

1. Non-polar (hydrophobic) amino acids:

- These **amino acids** have hydrocarbon side chains that are non-polar.
- **They do** not **interact** well with water, so they are usually found in the interior of proteins, away from water.

Example: Glycine (H_2N-CH_2-COOH) — it is the smallest amino acid, with just a hydrogen as its side chain, providing flexibility to protein chains.

2. Polar (hydrophilic) amino acids:

- Side chains contain polar groups such as $-OH$, $-SH$, or $-CONH_2$.
- They can form hydrogen bonds with water or other molecules and are usually found on the surface of proteins.

Example: Serine ($H_2N-CH_2-OH-COOH$) — the hydroxyl group makes it polar and reactive in enzymatic reactions.

3. Acidic amino acids:

- These have an extra carboxyl group ($-COOH$) in their side chain.

- They are **capable** of donating H^+ ions, so they behave as acids.
- **Acidic amino** acids participate in electrostatic interactions and are often present in enzyme active sites.

Example: Aspartic acid ($H_2N{-}CH_2{-}COOH{-}COOH$) — contains a second carboxyl group.

4. Basic amino acids:

- **These have** side chains containing **amino groups** ($-NH_2$ or $-NH_3^+$) that can accept H^+ ions, so they are basic.
- They **often participate** in binding negatively charged molecules and catalysis in proteins.

Example: Lysine ($H_2N{-}(CH_2)_4{-}NH_2{-}CH{-}COOH$) — has a long chain ending in an amino group, giving it strong basic properties.

5. Sulfur-containing amino acids:

- These amino acids contain –SH (thiol) groups in their side chains.
- The thiol groups can form disulfide bonds (–S–S–), which are crucial for stabilizing protein 3D structure.

Example: Cysteine ($H_2N{-}CH(CH_2{-}SH){-}COOH$) — forms disulfide bonds in proteins.

6. Aromatic amino acids:

- These have aromatic rings in their side chains.
- Aromatic rings contribute to protein stability, absorb UV light, and can participate in stacking interactions.

Example: Phenylalanine ($H_2N-CH(C_6H_5)-COOH$) — contains a benzene ring in its side chain, making it hydrophobic.

✦ **Summary:**

Amino acids are the building blocks of proteins, containing both $-NH_2$ and $-COOH$ groups attached to the α-carbon. They are classified based on their side chains into non-polar, polar, acidic, basic, sulfur-containing, and aromatic amino acids. Each type has distinct chemical properties and biological functions. Non-polar amino acids are hydrophobic, polar amino acids are hydrophilic, acidic and basic amino acids carry charges, sulfur-containing amino acids stabilize proteins through disulfide bonds, and aromatic amino acids contribute to structure and UV absorption. Examples include glycine, serine, aspartic acid, lysine, cysteine, and phenylalanine.

🌟 **Q. 12 Write a short note on acidic and basic characters of an amino acid.**

❖ **Answer:**

Amino acids contain both an amino group ($-NH_2$) and a carboxyl group ($-COOH$) attached to the α-carbon. Due to these functional groups, amino acids exhibit both acidic and basic properties, making them amphoteric.

Acidic character:

- The carboxyl group (–COOH) can donate a proton (H^+) to a base.
- This makes the amino acid behave as an acid in aqueous solutions.

Example: In water, glycine can release a proton from its –COOH group:

$H_2N-CH_2-COOH \longrightarrow H_2N-CH_2-COO^- + H^+$

Basic character:

- The **amino group** ($-NH_2$) can accept a proton (H^+) from an acid.
- This gives the amino acid a basic property.

Example: In water, glycine can accept a proton on $-NH_2$:

$H_2N-CH_2-COOH + H^+ \longrightarrow H_3N^+-CH_2-COOH$

Zwitterion formation:

- At a certain pH (called the isoelectric point, pI), the amino acid exists as a zwitterion, where the $-COO^-$ and $-NH_3^+$ groups are both present.

- **In this form,** the amino acid is neutral overall but has both positive and negative charges, showing its amphoteric nature.

✦ **Summary:**

The acidic character of amino acids comes from their carboxyl group, while the basic character comes from the amino group. This dual property allows amino acids to act as buffers in biological systems and form zwitterions in aqueous solutions.

🌟 **Q. 13 What is a peptide bond? Write down the formula of a dipeptide.**

❖ **Answer:**

Peptide Bond:

- A peptide bond is a covalent bond formed between the carboxyl group (–COOH) of one amino acid and the amino group ($-NH_2$) of another amino acid.
- During peptide bond formation, a molecule of water (H_2O) is eliminated in a condensation reaction (also called a dehydration reaction).
- The bond links the carbon atom of the carboxyl group to the nitrogen atom of the amino group of another amino acid.
- This bond is also known as an amide bond.

Reaction (general):

$H_2N-CHR_1-COOH + H_2N-CHR_2-COOH \longrightarrow$
$H_2N-CHR_1-CO-NH-CHR_2-COOH + H_2O$

Here, R_1 and R_2 are side chains of the respective amino acids.

Dipeptide:

- A dipeptide is formed when two amino acids are joined by a single peptide bond.

Its general formula is:

$H_2N-CHR_1-CO-NH-CHR_2-COOH$

In this structure:

$-CO-NH-$ is the peptide bond.

The amino group of the first amino acid and the carboxyl group of the second remain available for further chain formation.

Example:

If glycine (H_2N-CH_2-COOH) and alanine ($H_2N-CH(CH_3)-COOH$) form a dipeptide, the formula will be:

$H_2N-CH_2-CO-NH-CH(CH_3)-COOH$

✦ **Summary:**

A peptide bond is the key linkage between amino acids in proteins, formed by a condensation reaction, and a dipeptide is the simplest unit showing one peptide bond between two amino acids.

🌟 **Q. 14 What are zwitter ions?**

❖ **Answer:**

Definition of Zwitterions:

A zwitterion is a molecule that has both a positive and a negative charge on different atoms but is overall electrically neutral.

- In the case of amino acids, a zwitterion is formed when the amino group ($-NH_2$) accepts a proton (H^+) and becomes $-NH_3^+$, while the carboxyl group ($-COOH$) loses a proton and becomes $-COO^-$.
- **This occurs** at a specific pH, known as the isoelectric point (pI), where the amino acid carries no net charge.

Formation of Zwitterions:

1. Amino acids contain both $-NH_2$ and $-COOH$ groups.

2. In an aqueous solution, the $-COOH$ group can donate H^+, forming $-COO^-$.

3. The $-NH_2$ group can accept H^+, forming $-NH_3^+$.

4. As a result, the amino acid exists in a dipolar form, carrying both positive and negative charges simultaneously.

General structure of a zwitterion:

$^{+}H_3N-CHR-COO^{-}$

- **Here**, R is the side chain of the amino acid.
- The **molecule** is neutral overall, but internally it has opposite charges.

Properties of Zwitterions:

- They have high melting points compared to non-ionic compounds.
- They are soluble in water due to their ionic nature.
- They do not migrate in an electric field at their isoelectric point because the positive and negative charges balance each other.
- Zwitterions act as buffers, helping to maintain pH in biological systems.

Example: Glycine Zwitterion

- **Glycine** (H_2N-CH_2-COOH) in water at neutral pH exists as:

$^{+}H_3N-CH_2-COO^{-}$

- The **amino** group is positively charged and the carboxyl group is negatively charged.

✦ **Summary:**

Zwitterions are dipolar ions formed by amino acids in aqueous solutions where the amino group is protonated and the carboxyl group is deprotonated, resulting in a molecule with both positive and negative charges but overall neutrality. They are important for the solubility, buffering action, and stability of amino acids in biological systems.

🌟 **Q. 15 What are amino acids, proteins, and peptides? How are they related?**

❖ **Answer:**

1. Amino Acids:

- **Amino acids** are organic compounds that contain both an amino group ($-NH_2$) and a carboxyl group ($-COOH$) attached to the same carbon atom (α-carbon).
- **The α-carbon** also carries a hydrogen atom and a side chain (R group), which differs among amino acids.
- **General formula:** $H_2N-CHR-COOH$
- Amino acids are the building blocks of proteins.

Example: Glycine (H_2N-CH_2-COOH)

2. Peptides:

- Peptides are molecules formed when two or more amino acids are joined together by peptide bonds (also called amide bonds).
- A peptide bond is a covalent bond formed between the carboxyl group (–COOH) of one amino acid and the amino group ($-NH_2$) of another amino acid through a condensation reaction (releasing water).

Types of peptides:

- **Dipeptide:** 2 amino acids
- **Tripeptide:** 3 amino acids
- **Oligopeptide:** few amino acids (4–20)

General formula of a dipeptide:

$H_2N-CHR_1-CO-NH-CHR_2-COOH$

3. Proteins:

- **Proteins** are large, complex molecules made of one or more long chains of amino acids linked by peptide bonds.
- They **are polypeptides** with a defined 3D structure and perform various biological functions such as catalysis (enzymes), transport (hemoglobin), structural support (collagen), and immunity (antibodies).
- **Proteins** can contain hundreds or thousands of amino acids in a specific sequence.

Relationship Between Amino Acids, Peptides, and Proteins:

1. Amino acids are the basic building blocks.

2. When two or more amino acids link via peptide bonds, they form a peptide.

3. Longer chains of amino acids (polypeptides) fold into specific shapes to form functional proteins.

4. In short:

Amino acids $\longrightarrow$ Peptides $\longrightarrow$ Proteins

Example:

- **Glycine + Alanine** $\longrightarrow$ Glycylalanine (dipeptide)
- **Many dipeptides +** tripeptides $\longrightarrow$ Polypeptide chain $\longrightarrow$ Functional protein

✦ **Summary:**

Amino acids are the monomers, peptides are short chains of amino acids, and proteins are long, functional chains of amino acids. They are directly related: amino acids link to form peptides, and peptides combine and fold to form proteins. This relationship forms the foundation of protein chemistry and biological function.

🌟 **Q. 16 Study the facts given in (a), (b) and (c) below and then answer questions which follow:**

Q.16(a)

Given:

- A is an organic compound made up of C, H, and O.
- Vapour density = 15

Hint: Molecular mass = 2 × vapour density

Step 1: Calculate molecular mass

Molecular mass of A = 2 × 15 = 30

So, Molar mass of A = 30 g/mol

Step 2: Determine molecular formula

A contains C, H, O ⟶ assume formula $C_xH_\gamma O^z$

Check small simple molecules:

CH_2O

- C = 12, H_2 = 2, O = 16 ⟶ 12 + 2 + 16 = 30
- Fits perfectly

Type of compound: Aldehyde (formaldehyde)

✦ **Summary:**

- **Molecular** mass of A = 30 g/mol
- **Molecular** formula = CH_2O
- A is **formaldehyde**, the simplest aldehyde containing a carbonyl group.

Q.16(b)

Given:

- **On reduction**, A gives a compound X with the following properties:

1. X is a colourless liquid, miscible with water

2. X is neutral to litmus

3. X reacts with conc. H_2SO_4 and salicylic acid to produce a characteristic smell

We already know from part (a) that A = CH_2O (formaldehyde).

Step 1: Identify the type of reaction

- Reduction of an aldehyde ⟶ forms a primary alcohol.
- Reduction involves adding H_2 to the carbonyl group (C=O).

Reaction:

$HCHO + H_2 \longrightarrow CH_3OH$

Therefore, X = CH_3OH (methanol)

Step 2: Check the properties of X

1. Colourless liquid ⟶ methanol is colourless

2. Miscible with water ⟶ small alcohols (methanol, ethanol) are completely miscible in water due to hydrogen bonding

3. Neutral to litmus ⟶ alcohols are neither acidic nor basic (neutral)

Step 3: Reaction with salicylic acid

When methanol is warmed with conc. H_2SO_4 and salicylic acid, esterification occurs:

$C_6H_4(OH)COOH + CH_3OH \longrightarrow(H_2SO_4)\ C_6H_4(OH)COOCH_3 + H_2O$

- **Product** = methyl salicylate (oil of wintergreen)
- **Characteristic smell:** Sweet, pleasant aroma

Explanation:

- H_2SO_4 acts as a catalyst
- Methanol reacts with the carboxyl group of salicylic acid to form the ester

✦ Summary:

- **Compound X** = CH_3OH (methanol)
- **Formed** by reduction of formaldehyde (A)
- **Properties:** colourless, miscible with water, neutral
- **Reacts with** salicylic acid + H_2SO_4 to give methyl salicylate, producing a pleasant smell

Q.16(c)

Given:

- X (from part b) is subjected to strong oxidation, producing B with the following properties:

1. B is a pungent smelling mobile liquid

2. Miscible with water, alcohol, or ether

3. Corrosive, produces blisters on skin

4. B can be obtained by passing vapours of A with air over platinum black catalyst

5. Liberates H_2 with sodium

6. Gives CO_2 with $NaHCO_3$

Questions:

1. Molecular mass of A

2. Identify A, X, and B

3. Give five reactions to confirm their identities

4. State one large-scale use

Step 1: Molecular mass of A

From part (a):

Molecular mass of A = 2 × vapour density

= 2 × 15

= 30

✅ Molecular mass of A = 30 g/mol

Step 2: Identify A, X, and B

1. A = HCHO (Formaldehyde)

- Molar mass = 30 g/mol
- Simple aldehydej

2. X = CH_3OH (Methanol)

- Formed by reduction of A

3. B = HCOOH (Formic acid)

- Formed by oxidation of methanol (X) or by passing HCHO vapour with air over Pt catalyst

Properties explained:

➢ Pungent liquid → characteristic smell of formic acid

➢ Miscible with water, alcohol, ether → small polar molecule

➢ Corrosive → forms blisters on skin

➢ vLiberates H_2 with Na → acidic hydrogen reacts

➢ Gives CO_2 with $NaHCO_3$ → reacts as a carboxylic acid

Reactions forming B:

CH_3OH →([O]) HCOOH

or

$HCHO + O_2 \longrightarrow (Pt)\ HCOOH$

Step 3: Five reactions to confirm identities

A (Formaldehyde, HCHO)

1. Tollens' Test:

$HCHO + [Ag(NH_3)_2]^+ \longrightarrow HCOOH + Ag$⬇️

2. Fehling's Test:

$HCHO + Cu^{2+} \longrightarrow HCOOH + Cu_2O$⬇️ (red precipitate)

X (Methanol, CH_3OH)

3. Reaction with Na:

$CH_3OH + Na \longrightarrow CH_3ONa + ½\ H_2$⬆️

4. Esterification with acetic acid:

$CH_3OH + CH_3COOH \longrightarrow (H_2SO_4)\ CH_3COOCH_3 + H_2O$

B (Formic acid, HCOOH)

5. Reaction with $NaHCO_3$:

$HCOOH + NaHCO_3 \longrightarrow HCOONa + CO_2$⬆️ $+ H_2O$

Step 4: One large-scale use

1. A (Formaldehyde): Used for manufacture of plastics, resins, and disinfectants

2. X (Methanol): Used as solvent, fuel, and in chemical synthesis

3. B (Formic acid): Used in preservatives, leather tanning, and as a reducing agent

Example: Large-scale use → formaldehyde for manufacturing urea-formaldehyde resin

Step 5: Summary

- Molecular mass of A = 30 g/mol
- A = Formaldehyde (HCHO), X = Methanol (CH_3OH), B = Formic acid (HCOOH)

Confirmatory reactions:

1. Tollens' test for HCHO

2. Fehling's test for HCHO

3. Reaction with Na for CH_3OH

4. Esterification for CH_3OH

5. Reaction with $NaHCO_3$ for HCOOH

Large-scale use: Formaldehyde → plastics and resins, Methanol → fuel/solvent, Formic acid → preservatives

Note:

This chapter is designed to provide a solid foundation of knowledge, with the goal of deepening understanding and encouraging further exploration of the subject. The content has been carefully selected to support effective learning and inspire students to engage with the topic more deeply.

Author: Muhammad Asghar

Purpose: To contribute to education by offering insightful, valuable content that enhances learning and understanding.