Chapter 24

Carboxylic Acids

Student Learning Outcomes

After studying this chapter, students will be able to:

- Describe the reactions of carboxylic acids with metals, bases and carbonates including names and formulae of the salts produced.
- Describe the formation of ethanoic acid by the oxidation of ethanol; with acidified aqueous potassium manganate (VII) & by bacterial oxidation during vinegar production
- Describe the reaction of a carboxylic acid with an alcohol using an acid catalyst to form an ester
- Describe the industrial applications of carboxylic acids and esters, including their use as solvents, flavours, fragrances, and plastics.
- Explain the role of carboxylic acids and esters in daily life, including their use in food preservation, cosmetics, and pharmaceuticals.

Organic acids or carboxylic acids are the class of organic compounds containing a carboxyl group (-COOH) attached to an alkyl group or hydrogen. They are generally weak acids as compared to the mineral acids because they do not give proton easily. They occur naturally in living organisms and they can also be synthesized.

24.1 Preparation of Acetic Acid or Ethanoic Acid

Oxidation of Ethanol

Ethanol is oxidized by the acidified potassium manganate (VII) to first ethanal which then further undergoes oxidation under the reaction conditions to give ethanoic acid.

Hot acidified potassium manganate (VII) acts as a very efficient oxidizing agent and oxidizes ethanol to ethanoic acid and during this reaction the purple colour of the reagent changes to colourless.

$$\underset{\text{Ethanol}}{CH_3-CH_2-OH} + [O] \xrightarrow{KMnO_4/H^+} \underset{\text{Ethanal}}{CH_3-\overset{\overset{O}{\|}}{C}-H} + H_2O$$

$$CH_3-\overset{\overset{O}{\|}}{C}-H + [O] \xrightarrow{KMnO_4/H^+} \underset{\text{Ethanoic acid}}{CH_3-\overset{\overset{O}{\|}}{C}-OH} + H_2O$$

Preparation of Ethanoic acid by Oxidative Fermentation

Alcoholic foodstuffs like grain, malt, rice or potato mesh are converted to vinegar when they undergo fermentation reaction in the presence of bacteria. These bacteria can produce vinegar from alcoholic foodstuffs if sufficient oxygen is provided. The overall chemical reaction in this fermentation process is:

$$\underset{\text{Ethanol}}{CH_3CH_2OH} + O_2 \longrightarrow \underset{\text{Ethanoic acid}}{CH_3COOH} + H_2O$$

In this process, alcohol is fermented to vinegar in a tank provided with a continuous supply of oxygen. The liquid present in the tank is stirred continuously when the oxygen is bubbled through it. In this method, vinegar containing 15% ethanoic acid can be prepared in only 24 hours.

24.1 Quick Check!

1. Can you oxidize methanol with $KMnO_4$ just like ethanol?
2. Explain the difference between a fermentation reaction and a chemical reaction.

24.2 Reactions of Carboxylic Acids as Acids

Reaction with Metals

Generally carboxylic acids are much weaker acids than the mineral acids. However, some carboxylic acids react with more reactive metals rather slowly to give a salt evolving hydrogen gas. For example, dilute ethanoic acid reacts with magnesium metal to give magnesium ethanoate and hydrogen gas.

$$2CH_3COOH + Mg \longrightarrow (CH_3COO)_2 Mg + H_2$$

Ethanoic acid — Magnesium Ethanoate

Reaction with bases

Reactions of carboxylic acids with bases like metal hydroxides are simple neutralization reactions. Ethanoic acid reacts with sodium hydroxide to give sodium ethanoate and water.

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

Ethanoic acid — Sodium Hydroxide — Sodium ethanoate

Reaction of Carboxylic Acids with Carbonates

When solid sodium carbonate is mixed with an aqueous solution of ethanoic acid, effervescence takes place due to evolution of CO_2 gas and sodium ethanoate is formed in the solution.

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

Ethanoic acid — Sodium Carbonate — Sodium ethanoate

Reaction proceeds slowly with marble chips ($CaCO_3$).

$$2CH_3COOH + CaCO_3 \longrightarrow (CH_3COO)_2Ca + CO_2 + H_2O$$

Ethanoic acid — Calcium carbonate — Calcium ethanoate

24.3 Reaction of Carboxylic Acids with Alcohols (Esterification)

Carboxylic acids form esters when they are heated with excess of alcohols in the presence of concentrated H_2SO_4, as a catalyst. Reaction is called esterification reaction.

$$\underset{\text{Ethanoic acid}}{CH_3COOH_3} + \underset{\text{Ethanol}}{CH_3CH_2OH} \rightleftharpoons^{H_2SO_4} \underset{\substack{\text{Ethyl ethanoate}\\(\text{an ester})}}{CH_3COOC_2H_5} + H_2O$$

$$\underset{\text{Ethanoic acid}}{CH_3COOH} + \underset{\text{Methanol}}{CH_3OH} \rightleftharpoons^{H_2SO_4} \underset{\text{Methyl ethanoate}}{CH_3COOCH_3} + H_2O$$

24.2 Quick Check!

1. Is ethanoic acid a weak acid?
2. How will calcium carbonate react with ethanoic acid?

24.4 Industrial Applications of Carboxylic Acids and Esters

Carboxylic acids and Esters as Solvents

Acetic acid dissolves many compounds such as oils, sulphur, iodine and water. In industry, acetic acid is used as a solvent for resins, paints and lacquers.

Esters are also commonly used as solvents. Ethyl acetate is used to extract caffeine from coffee. It is also used as nail polish and paint remover. Some volatile esters are used as solvents for coatings, paints, varnishes, plastics, resins and lacquers.

Interesting Information

Pure acetic acid is also called glacial acetic acid. It is a corrosive and colourless solid, completely miscible with water.

Carboxylic acids and Esters as Flavouring agents

Flavouring agents are substances added to give an additional taste or flavour to a substance. They also help in masking unpleasant tastes of drugs especially used by children. Organic acids like tartaric acid, citric acid and malic acid are very commonly used as flavour enhancers in food industry. The sour taste of foods is largely due to these acids. They are also responsible to improve the taste of some food and beverage products especially soft drinks.

Esters have pleasant odours and flavours. They are added to food

products to improve their smell or taste.

Carboxylic Acid and Esters as Synthetic Fibers

Esters have also an important role to play in the production of synthetic polymers. A very important polymer, polyester is made by reacting diols and dicarboxylic acids. Esters are also important in the manufacture of soaps and detergents.

Carboxylic acids and their derivatives are very commonly used to give different types of plastics. For example, acetic acid is used in the production of cellulose acetate plastic. Palmitic and stearic acids are extensively used in the production of soaps, cosmetics, pharmaceuticals, candles and protective coatings. Oleic acid is used in the manufacture of soaps and detergents. Acrylic acid is a starting reagent to prepare many long-chain polymers called acrylates.

Figure 24.1: Uses of carboxylic acids in daily life

24.5 Carboxylic Acids and Esters in Daily Life

Food preservatives are chemical compounds which are added in food stuff to prevent or retard the growth of microorganisms, for example, benzoic acid, acetic acid, propionic acid and methyl and ethyl esters of 4-hydroxy benzoic acid. The presence of these preservatives helps to maintain the quality of food and extend shelf-life. The foods which are preserved include jams, juices, fruit juices, milk and many other drinks. Acetic acid is very widely used as preservative in pickles.

Figure 24.2: Jam, Juices and pickles

Carboxylic acids and the compounds obtained from them are very commonly used as medicines such as aspirin and ibuprofen. Addition of some carboxylic acids during preparation of medicines help to improve drug delivery, absorption, and overall performance.

Citric acid esters are primarily plasticizers which are used in many industries. Polymethyl methacrylate is used as a substitute of glass and it is named as Plexiglass.

Figure 24.3: Polyester

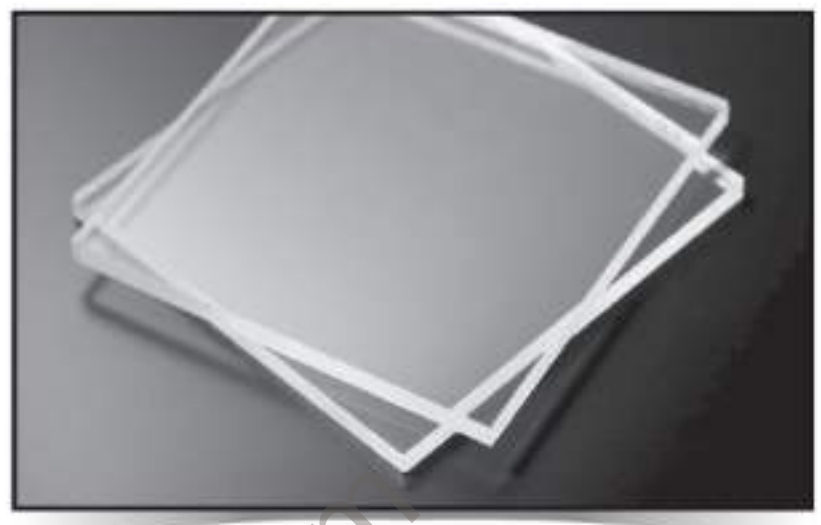

Figure 24.4: Plexiglass

Carboxylic acids occur in many common household fragrant items. A list of such items is given in the Table 24.1:

Table 24.1 Carboxylic Acids in House hold items

Item	Carboxylic Acid
Vitamin C	Ascorbic acid
Lemons	Citric acid
Vinegar	Acetic acid
Apple, grapes, carrots	Malic acid

Esters are an important component of many fruits and are responsible to enhance their flavours. They generally have a pleasant smell and they are commonly used as fragrances in many food products used in daily life. The following table shows the names of the esters and the flavours attached with them.

Table 24.2. Esters and their Flavours

Esters	Flavour
Methyl butyrate	Apple
Ethyl butyrate	Pine apple
n-Amyl acetate	Pears, Bananas
n-Octyl acetate	Orange
Methyl salicylate	Apricot

24.3 Quick Check!

- Explain the function of a preservative.
- Give examples of some citrous fruits.

EXERCISE

A Multiple Choice Questions

Choose and tick the correct answer from the given choices.

1. Identify the ester functional group:

   (a) –COOR (b) –COOH

   (c) $>C=O$ (d) $-CH_2-OH$

2. During the oxidation of ethanol by acidified $KMnO_4$, which element is reduced?

   (a) K (b) O

   (c) Mn (d) H

3. Fermentation of foodstuff in the presence of acetic acid bacteria needs a sufficient supply of oxygen. What is the role of oxygen in this process?

   (a) It enhances the reactivity of bacteria

   (b) It oxidizes ethanol which is formed during the reaction

   (c) It inhibits the destruction of bacteria

   (d) It inhibits the oxidation of acetic acid

4. Which organic acid is used as a component of food?

   (a) Formic acid (b) Oxalic acid

   (c) Propanoic acid (d) Acetic acid

5. Which of the following acids is present in apples?

   (a) Citric acid (b) Tartaric acid

   (c) Acetic acid (d) Malic acid

6. Which substances will react to produce $CH_3-CH_2-CH_2-COOC_2H_5$?

   (a) $CH_3CH_2CH_2COOH$ and CH_3OH

   (b) CH_3CH_2COOH and CH_3CH_2OH

   (c) $CH_3CH_2CH_2COOH$ and CH_3CH_2OH

   (d) $CH_3CH_2CH_2CH_2COOH$ and CH_3OH

7. What is the formula of ester formed by the reaction of methanol with propanoic acid?

   (a) $CH_3COOCH_2CH_3$ (b) $CH_3CH_2COCH_3$

   (c) $CH_3CH_2COOCH_3$ (d) $CH_3CH_2OCOCH_3$

8. Which polymer is made by reacting a diol and a dicarboxylic acid?

(a) Polyethene (b) Polyester

(c) Polystyrene (d) Polyamide

9. Which compound is used as a synthetic fiber?

(a) Methyl acetate (b) Polyester

(c) Resin (d) n-Amyl acetate

B Short Answer Questions

24.1 What is an esterification reaction?

24.2 Name an oxidizing agent used to oxidize alcohols.

24.3 Why sufficient oxygen is provided during fermentation to prepare acetic acid from ethanol?

24.4 What is the role of carboxylic acids in the preparation of beverages?

24.5 Give a practical example in which an acid or an ester is used as a flavouring agent.

24.6 Which carboxylic acids are very oftenly used as flavour enhancers?

24.7 Which property of acetic acid does make it suitable to act as preservative in pickle?

C Constructed Response Questions

24.1 How does ethanol react with propanoic acid?

24.2 How does acetic acid react with Mg and $MgCO_3$?

24.3 How carboxylic acids are used as solvents?

24.4 How carboxylic acid are used in daily life?

D Descriptive Questions

24.1 Explain fermentation reaction which is used to prepare acetic acid on commercial scale.

24.2 Describe the industrial applications of carboxylic acids and esters.

24.3 What are flavouring agents? Which carboxylic acids are used as flavouring agents?

24.4 Explain the reactions of carboxylic acids with metals and carbonates.

24.5 Describe applications of esters in daily life.