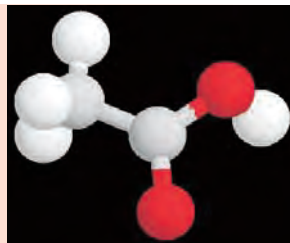


UNIT 6



Carboxylic Acids, Esters, Fats and Oils

Unit Outcomes

At the end of this unit, you should be able to:

- ✚ write the structural formula and IUPAC names of given carboxylic acids and esters;
- ✚ describe some physical and chemical properties of carboxylic acids and esters;
- ✚ predict and correctly name the products of organic reactions, including substitution, addition, elimination, esterification, hydrolysis and oxidation reactions;
- ✚ carry out activities to prepare a carboxylic acid and an ester;
- ✚ list some important fatty acids;
- ✚ test for the carboxylic acid and ester functional groups;
- ✚ understand the structures, properties, uses of fats and oils;
- ✚ describe and explain reactions in soap making (saponification);
- ✚ describe and explain the cleaning action of soap and detergents;
- ✚ understand the harmful aspects of detergents on the environment when improperly disposed; and
- ✚ demonstrate scientific enquiry skills, including: observing, classifying, comparing and contrasting, asking questions, drawing conclusions, applying concepts and problem solving.

MAIN CONTENTS

- 6.1 Carboxylic Acids
- Structure and Nomenclature of Carboxylic acids
 - Physical Properties of Carboxylic acids
 - Chemical Properties of Carboxylic acids

- Preparation of Carboxylic acids
- Fatty Acids
- Uses of Carboxylic acids

6.2 Esters

- Sources of Esters
- Structure and Nomenclature of Esters
- Physical Properties of Esters
- Chemical Properties of Esters
- Preparation of Esters
- Uses of Esters

6.3 Fats and oils

- Structure of Fats and Oils
- Physical Properties of Fats and Oils
- Hardening of oils
- Rancidity
- Soaps and Detergents

Start-up Activity

Form a group and perform the following activity:

Collect some common fresh fruits like banana, mango, grapes, apple, pineapple, etc. and some flowers from the garden. Observe the smell of all the fruits and flowers which you collected. Also taste the fruits and observe the sourness in each fruit. Now, discuss the following:

1. What type of odour (pleasant or unpleasant) do all the fruits and flowers have?
2. Do you find sourness and sweetness in all the fruits? If yes, then why do they have a different taste?

Share your ideas with the rest of the class.

INTRODUCTION

In Grade 10, you have studied about hydrocarbons and alcohols. In this unit, you will study about another important class of organic compounds called carboxylic acids and esters. These compounds are present in many fruits and flowers. Many carboxylic acids are used as food additives in jams, jellies, candies and pickles, etc. You will also study about fats and oils which are esters. Sodium or potassium salts of long chain fatty acids are called soaps which play a major role as cleansing agents.

6.1 CARBOXYLIC ACIDS

At the end of this section, you should be able to:

- list common organic acids and name their sources;
- write the general formula of saturated monocarboxylic acids;
- write the molecular formulas and names of the first six members of the saturated monocarboxylic acids;
- give the structural formula for the first four members of the saturated monocarboxylic acids;
- give the examples of mono, di and tricarboxylic acids;
- name some branched carboxylic acids;
- describe the physical properties of saturated monocarboxylic acids;
- explain the general methods of preparation of saturated monocarboxylic acids;
- explain the industrial and laboratory preparation of acetic acid;
- conduct an experiment to produce acetic acid in the laboratory;
- name and write structural formulas of some fatty acids; and
- describe some uses of common carboxylic acids.

6.1.1 Structure and Nomenclature of Carboxylic Acids

Activity 6.1



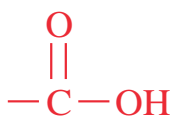
Recall your previous knowledge about hydrocarbons and alcohols in grade 10. Form a group and discuss the following:

1. Write the structures of first six alkanes and alcohols.
2. Compare their structures.
3. Which functional groups in the structure determine the properties of these compounds?

Share your ideas with the rest of the class.

Structure of Carboxylic Acids

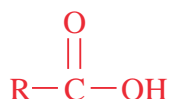
Carboxylic acids are organic compounds that contain at least one carboxyl group in their structure. A carboxyl group is a functional group consisting of a carbonyl and a hydroxyl which is usually written as —COOH or $\text{—CO}_2\text{H}$.



Carboxyl group

a Monocarboxylic acids

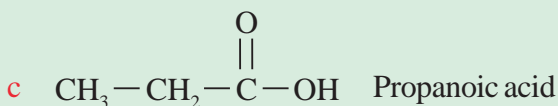
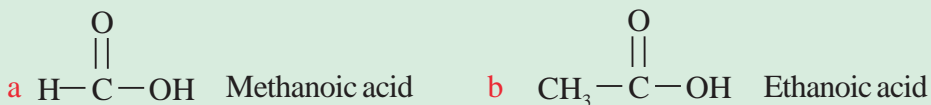
The general formula for saturated monocarboxylic acids can be written as:



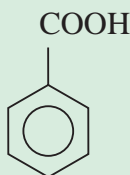
where **R** is either hydrogen or an alkyl group for aliphatic Carboxylic acids. When **R** is phenyl (aryl) group, the structure represents aromatic carboxylic acids.

Example 6.1

1. The structure of the first three saturated monocarboxylic acids are written as follows:



2. The simplest aromatic carboxylic acid is benzoic acid. Its structure is written as:



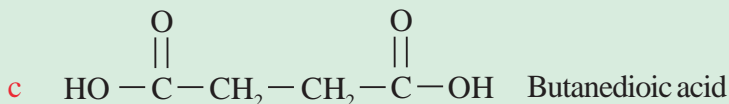
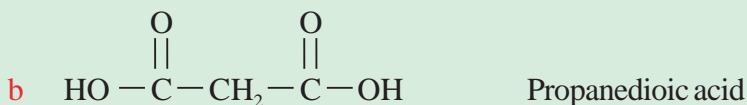
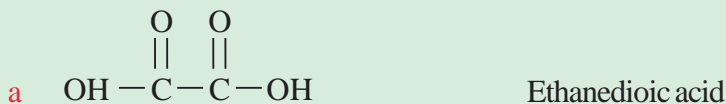
Benzene carboxylic acid (Benzoic acid)

b Di- and tricarboxylic acids

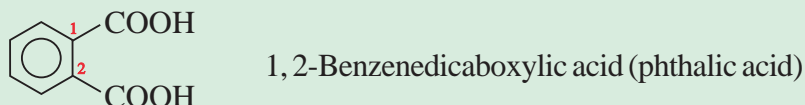
Carboxylic acids containing two carboxyl groups in their structure are called **dicarboxylic acids**.

Example 6.2

1. The structure of the first three saturated dicarboxylic acids are written as follows:



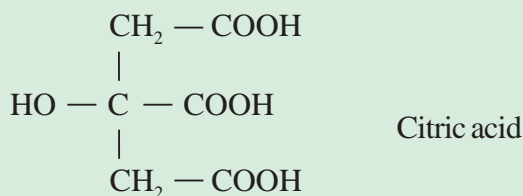
2. The simplest aromatic dicarboxylic acid is phthalic acid. Its structure is:



Similarly, carboxylic acids that contain three carboxyl groups in their structure are called **tricarboxylic acids**.

Example 6.3

Citric acid is a typical tricarboxylic acid, having the following structure:

**Activity 6.2**

Form a group and make a list of some fruits having acidic taste. Try to identify the carboxylic acids present in these fruits, and classify these acids as monocarboxylic, dicarboxylic, and tricarboxylic acids.

Present your findings to the class.

Exercise 6.1

1. Write the structure of the following monocarboxylic acids:
 - a Butanoic acid
 - b Pentanoic acid
2. Write the structure of the following dicarboxylic acids:
 - a Pentanedioic acid
 - b Hexanedioic acid
 - c 1,3-Benzenedicarboxylic acid

Nomenclature of Carboxylic Acids

i Common names carboxylic acids

a Straight chain monocarboxylic acids

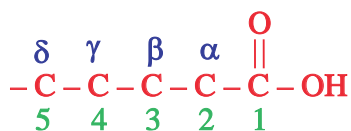
A large number of carboxylic acids have widely used common names which need to be learned. Those with an even number of carbon atoms ranging from 4 to 22 may be obtained by hydrolysis of animal and vegetable fats and oils. They are referred to as fatty acids, and they have common names derived from various sources. Formic acid derives its name from the Latin word for ants, because it is one of the toxic ingredients of the secretion injected by the stinging ant. Butanoic acid (butyric acid) derives its name from butter, in which it is found when the butter becomes rancid. Caproic, caprylic, and capric acids are involved in the odor of a goat, and their names derive from the Latin word, caper, for goat. Table 6.1 lists common names of some of the most important monocarboxylic acids.

Table 6.1 Common names of some monocarboxylic acids

Structure	Common name	Source of name
HCOOH	Formic acid	Ant (Latin, <i>formica</i>)
CH ₃ - COOH	Acetic acid	Vinegar (Latin, <i>acetum</i>)
CH ₃ - CH ₂ - COOH	Propionic acid	Milk (Greek, <i>propion</i>)
CH ₃ - CH ₂ - CH ₂ - COOH	Butyric acid	Butter (Latin, <i>butyrum</i>)
CH ₃ - CH ₂ - CH ₂ - CH ₂ - COOH	Caproic acid	Goat (Latin, <i>caper</i>)

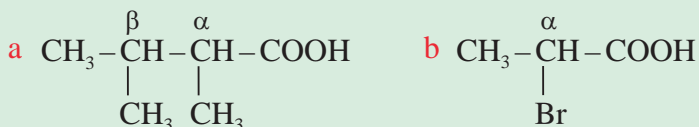
b Branched chain and substituted carboxylic acids

In common naming system, the branched chain and substituted acids are named as derivatives of straight chain carboxylic acids. In this case, the position of the side chain or substituents is indicated by Greek letters, α , β , γ , δ ... for designating the 1st, 2nd, 3rd, ... position of carbon atoms as shown below:



Example 6.4

Write the common names for:

**Solution:**

- a** It is monocarboxylic acid that consists of four carbon atoms. So, its common name is butyric acid. In addition to this, two methyl groups are attached to α - and β -position carbon atoms in the structure. Now, the complete common name is α, β -dimethylbutyric acid.
- b** Similarly, the given acid contains three carbon atoms. Hence, the common name is propionic acid. Next, the position of bromo group, which is attached to α -carbon atom in the structure. This gives the complete common name as α -bromopropionic acid.

c Dicarboxylic acids

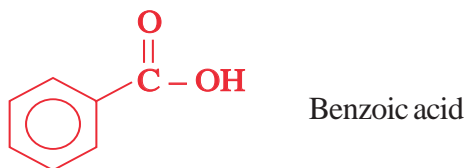
Dicarboxylic acids also possess common names which are based on their sources. Table 6.2 lists common names of some of the most important dicarboxylic acids.

Table 6.2 Common names of some dicarboxylic acids

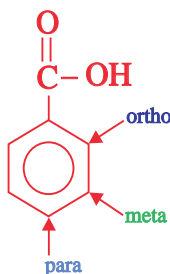
Structure	Common name
HOOC-COOH	Oxalic acid
HOOC-CH ₂ -COOH	Malonic acid
HOOC-CH ₂ -CH ₂ -COOH	Succinic acid
HOOC-CH ₂ -CH ₂ -CH ₂ -COOH	Glutaric acid
HOOC-CH ₂ -CH ₂ -CH ₂ -CH ₂ -COOH	Adipic acid
HOOC-CH ₂ -CH ₂ -CH ₂ -CH ₂ -CH ₂ -COOH	Pimelic acid

d Aromatic carboxylic acids

Compounds which have a carboxyl group directly attached to an aromatic ring are classified as **aromatic carboxylic acids**. The simplest aromatic carboxylic acid has a carboxyl group attached to benzene ring and its common name is **benzoic acid**.

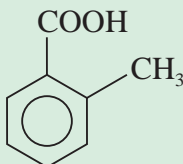


In common naming system, the name of substituted aromatic acids are written by prefixing the names of substitutes. The position of the substituent is indicated by the prefixes ortho (o-), meta (m-), para (p-) as it is shown in the structure below.



Example 6.5

1. Write the common name for:



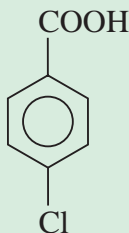
Solution:

Since the methyl group is attached to ortho- position, then the IUPAC name becomes *o*-methylbenzoic acid.

2. Write the structure for *p*-chlorobenzoic acid.

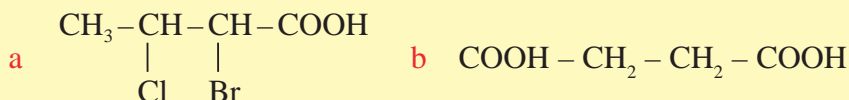
Solution:

The structure of benzoic acid with chloro group attached to *para* position is:

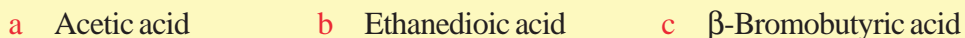


Exercise 6.2

1. Write the common names for the following carboxylic acids:



2. Write the structures of carboxylic acids from the given common names:



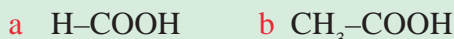
ii IUPAC names of carboxylic acids

a Straight chain monocarboxylic acid

According to IPUAC system, monocarboxylic acids are named as **alkanoic acids**. The longest chain of carbon atoms containing the carboxyl group is selected and the name is derived from the corresponding alkane by replacing the suffix “-e” with “-oic acid”.

Example 6.6

1. Write the IPUAC names for:



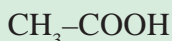
Solution:

- a The longest chain contains only one carbon atom. The corresponding alkane name is methane. Now, we drop the suffix “-e” and replace it by “-oic acid” so, the complete IPUAC name becomes methanoic acid.



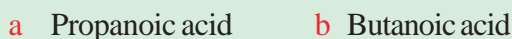
Methanoic acid

- b Similarly, the longest chain in the structure is derived from an alkane with two carbon atoms called ethane. Now, when we drop the suffix “-e” and replace it with “-oic” acid, we get the complete IPUAC name of ethanoic acid.



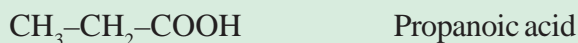
Ethanoic acid

2. Write the structure of



Solution:

- a Monocarboxylic acid with three carbon atoms is called propanoic acid.



- b Butanoic acid is IUPAC name given to monocarboxylic acid with four carbon atoms.



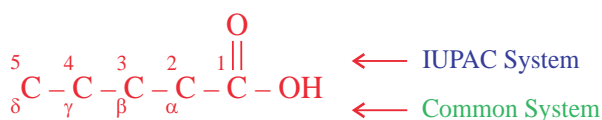
Table 6.3 lists IUPAC names for the first six monocarboxylic acids.

Table 6.3 IUPAC names of some monocarboxylic acids

Structure	IUPAC Name
HCOOH	Methanoic acid
CH ₃ COOH	Ethanoic acid
CH ₃ CH ₂ COOH	Propanoic acid
CH ₃ (CH ₂) ₂ COOH	Butanoic acid
CH ₃ (CH ₂) ₃ COOH	Pentanoic acid
CH ₃ (CH ₂) ₄ COOH	Hexanoic acid

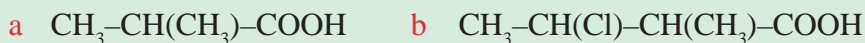
b Branched chain and substituted monocarboxylic acids

In IUPAC system, the positions of the substituents are indicated by Arabic numerals as 1, 2, 3. The numbering of the chain starts from the carboxyl carbon and it is always assigned C-1 position. Note that C-2 position in the IUPAC system corresponds to the α -position in the common naming system.



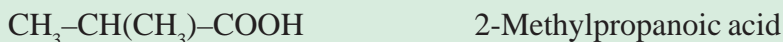
Example 6.7

1. Write the IUPAC names for:

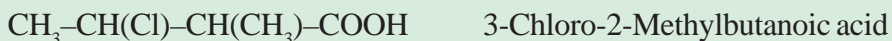


Solution:

- a The carboxylic acid given contains three carbon atoms which makes IUPAC name to be propanoic acid. There is also methyl group attached to the 2nd carbon atom, so the substituent is 2-methyl. Thus, the complete IUPAC name is 2-methylpropanoic acid.



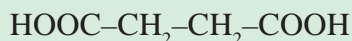
- b The longest chain in the structure consists of four carbon atoms and this gives IUPAC name of butanoic acid. The chloro group ($-\text{Cl}$) is attached to the 3rd carbon atom and the methyl group is located at the 2nd carbon atom. Based on the alphabetical order, these substituents are arranged as 3-chloro-2-methyl. Finally, the complete IUPAC name of this acid becomes 3-chloro-2-methyl butanoic acid.

**c Dicarboxylic acids**

In IUPAC system, dicarboxylic acids are named as **alkanedioic acids**. These names are obtained by replacing the suffix “-e” in the name of corresponding alkane by “-dioic acid”.

Example 6.8

1. Write the IUPAC name for:

**Solution:**

This dicarboxylic acid contains four carbon atoms. The name of the corresponding alkane is butane. Now, the suffix “-e” is replaced by “-dioic acid”. This gives the complete IUPAC name of butanedioic acid.



2. Write the structure of propanedioic acid.

Propanedioic acid refers to IUPAC name of dicarboxylic acid that contains three carbon atoms. Hence, the structure is written as shown below:

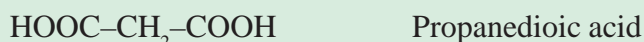


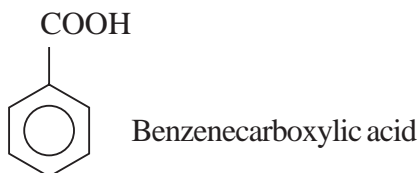
Table 6.4 lists the IUPAC names of the first six dicarboxylic acids.

Table 6.4 IUPAC names of dicarboxylic acids

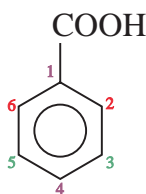
Structure	IUPAC Name
HOOC - COOH	Ethanedioic acid
HOOC - CH ₂ - COOH	Propane dioic acid
HOOC - (CH ₂) ₂ - COOH	Butane dioic acid
HOOC - (CH ₂) ₃ - COOH	Pentane dioic acid
HOOC - (CH ₂) ₄ - COOH	Hexane dioic acid
HOOC - (CH ₂) ₅ - COOH	Heptanes dioic acid

d Aromatic carboxylic acids

According to IUPAC system, aromatic carboxylic acids are named as **benzenecarboxylic acids**.

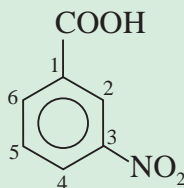


The position of the substitutes is indicated by the Arabic numerals 1, 2, 3,...starting with aromatic carbon bearing carboxyl group as C-1 and it is shown in the structure below.



Example 6.9

- Write the IUPAC name for:

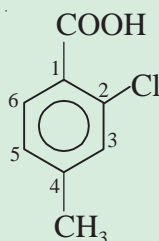


Solution:

1. The nitro group ($-\text{NO}_2$) is attached to the 3rd carbon of the aromatic ring. Hence, the complete IUPAC name becomes 3-nitrobenzenecarboxylic acid.
2. Write the structure for 2-chloro-4-methylbenzenecarboxylic acid.

Solution:

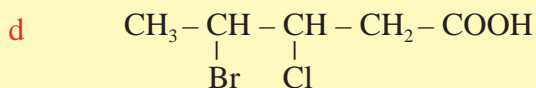
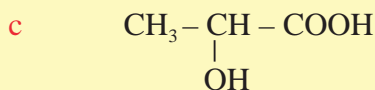
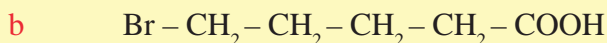
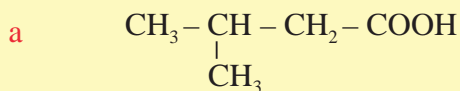
We have two substituents, chloro group ($-\text{Cl}$) attached to the 2nd carbon atom and methyl group ($-\text{CH}_3$) to the 4th carbon atom. So, the structure of this aromatic carboxylic acid is:



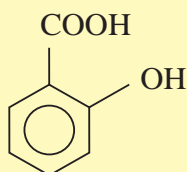
2-Chloro-4-methylbenzene carboxylic acid

Exercise 6.3

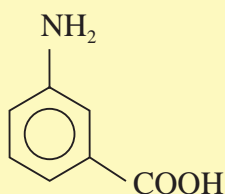
1. Write the IUPAC names for the following carboxylic acids:



e



f



2. Draw the structures of the following carboxylic acids:

- 2,3-Dichloropropanoic acid
- 4-Methylbenzoic acid
- 2-Fluorobutanoic acid
- 4-Hydroxy-2-bromobenzoic acid.

6.1.2 Physical Properties of Carboxylic Acids

Activity 6.3



Form a group and discuss the following:

- The solubility of monocarboxylic acids in water decreases with increase in molecular mass.
- The higher monocarboxylic acids are almost odourless.
- Should the alcohols possess higher or lower boiling points than that of monocarboxylic acids of comparable molar masses?

Share your ideas with the class.

1. State

The lower aliphatic acids containing up to **9 carbon** atoms are **liquids**, whereas the higher members are colourless waxy solids. Benzoic acid and most of its derivatives are also colourless solids.

2. Odour

The odours of the lower aliphatic acids progress from sharp, irritating odour of methanoic acid and ethanoic acids to the distinctly unpleasant odour of the butanoic, pentanoic and hexanoic acids. The higher acids have little odour because of their low volatility.

3. Boiling Point

Carboxylic acids have higher boiling points than alcohols of the similar size. For example, ethanoic acid (CH_3COOH) boils at 118°C while the alcohol of comparable molecular mass, propan-1-ol ($\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$) boils at 97.2°C . The higher boiling points of the carboxylic acids are also caused by hydrogen bonding between two molecules of acid to produce a **dimer**. The $-\text{OH}$ and $>\text{C}=\text{O}$ groups of one acid molecule form hydrogen bonding with $>\text{C}=\text{O}$ and $-\text{OH}$ groups of another molecule. **Figure 6.1** shows the structure of two carboxylic acids with two intermolecular H-bonds between them.

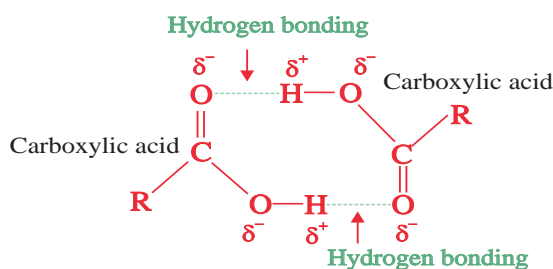


Figure 6.1 Carboxylic acid dimer.

The formation of a dimer immediately doubles the size of the molecule and so increases the Van der Waals dispersion forces between one of these dimers and its neighbours resulting in a high boiling point.

4. Solubility

In the presence of water, the carboxylic acids do not dimerize. Instead, hydrogen bonds are formed between water molecules and individual molecules of acid. Carboxylic acids up to four carbon atoms mix well with water in any proportion. The solubility in water decreases with the increasing molecular mass and higher acids are almost insoluble. The carboxylic acids dissolve in water due to formation of hydrogen bonding with water

molecules. The higher carboxylic acids are insoluble in water because of the decrease in the hydrogen bonding with water molecules as hydrocarbon increases (Figure 6.2).

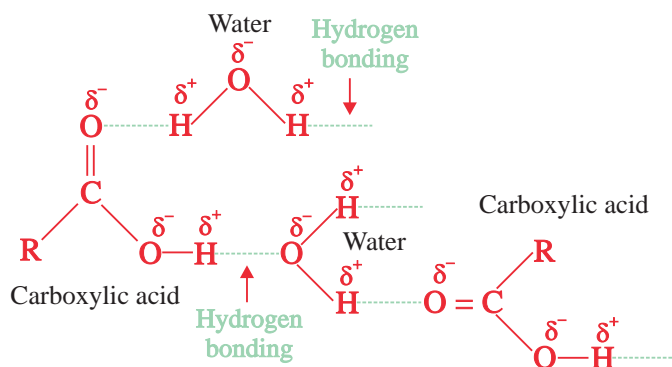


Figure 6.2 Formation of hydrogen bonding between carboxylic acids and water molecules.

Among the aromatic acids, benzoic acid is sparingly soluble in water at room temperature, although the solubility is more in hot water. However, all carboxylic acids are soluble in organic solvents like alcohol, ether, benzene etc.

The boiling points, melting points and solubilities of some carboxylic acids are given in Table 6.5.

Table 6.5 Physical constants of some carboxylic acids

Structure	IUPAC Name	Boiling point °C	Solubility, g/100 mL H ₂ O at 25°C
HCOOH	Methanoic acid	100.5	∞*
CH ₃ COOH	Ethanoic acid	118	∞*
CH ₃ CH ₂ COOH	Propanoic acid	141	∞*
CH ₃ (CH ₂) ₂ COOH	Butanoic acid	164	∞*
CH ₃ (CH ₂) ₃ COOH	Pentanoic acid	187	4.97
CH ₃ (CH ₂) ₄ COOH	Hexanoic acid	205	1.08
CH ₃ (CH ₂) ₅ COOH	Heptanoic acid	223	—
CH ₃ (CH ₂) ₆ COOH	Octanoic acid	239	0.07
CH ₃ (CH ₂) ₇ COOH	Nonanoic acid	253	—
CH ₃ (CH ₂) ₈ COOH	Decanoic acid	269	0.015

∞* means miscible in all proportions.

Exercise 6.4

- Arrange the following aliphatic carboxylic acids in the decreasing order of boiling point:

a butanoic acid	c octanoic acid
b decanoic acid	d propanoic acid
- Which aliphatic carboxylic acid is most soluble in water?

a heptanoic acid	c ethanoic acid
b hexanoic acid	d pentanoic acid
- Which aliphatic carboxylic acid has the lowest boiling point?

a pentanoic acid	c hexanoic acid
b methanoic acid	d propanoic acid
- Arrange in order of increasing boiling point:

a C_5H_{12} Pentane	c $C_4H_{11}OH$ Butanol
b C_2H_5COOH Propanoic acid	d $CH_3(CH_2)_4COOH$ Hexanoic acid

6.1.3 Chemical Properties of Carboxylic Acids

Activity 6.4



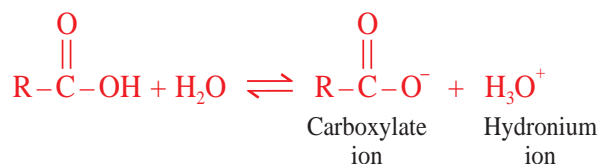
Form a group and perform the following:

Take 400 mL beaker and fill it with water to 2/3 level. Add 2 spoons of sodium bicarbonate and dissolve it. Then add few drops of litmus solution and 4-5 naphthalene balls. Now add benzoic acid, a pinch at a time and observe carefully. Explain the observations and discuss in the class.

The carboxylic acids show reactions due to the alkyl or aryl group and the carboxyl group. The carboxyl group is further considered to be made up of a carbonyl and a hydroxyl group. All these groups modify the properties of each other due to their interaction. Some of the common reactions of carboxylic acids are:

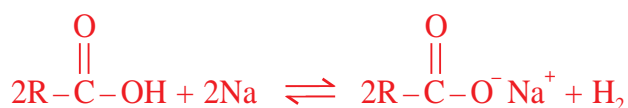
i) Reaction as an acid

In aqueous solution, the cleavage of O–H bond occurs leading to the formation of carboxylate ion and hydronium ion. Carboxylic acids ionize partially and an equilibrium exists between the ionized and un-ionized forms.



Carboxylic acids are weak acids and dissociates slightly. The following are examples of reactions of carboxylic acids as an acid.

a Reaction with metals : Carboxylic acids react with active metals *such as Na, K, Mg, Ca* etc. to form salts and hydrogen gas.

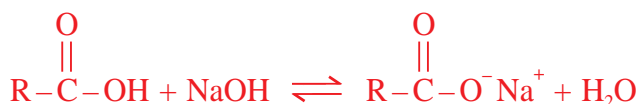


The salts of carboxylic acids are named by writing the name of the metal first, followed by the name of the acid replacing the ending **-ic acid** by **-ate**.

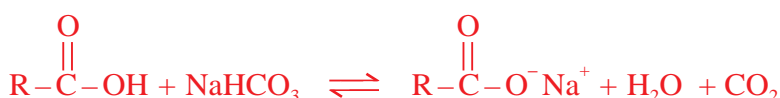
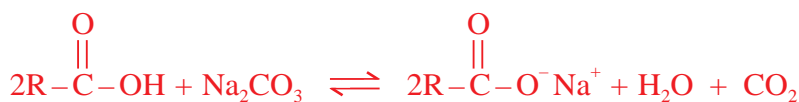
For example, sodium reacts with ethanoic acid to form sodium ethanoate and hydrogen.



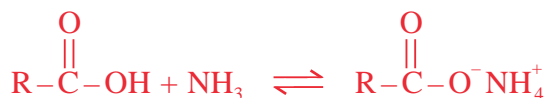
b Reaction with Bases : Carboxylic acids react with strong bases like sodium hydroxide or potassium hydroxide to form the corresponding salts and water.



Reaction with base is a simple neutralization reaction. Carboxylic acids react with weak bases like carbonates or bicarbonates to form salt, water and carbon dioxide.

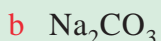


They also react with ammonia to form ammonium salts of carboxylic acids.

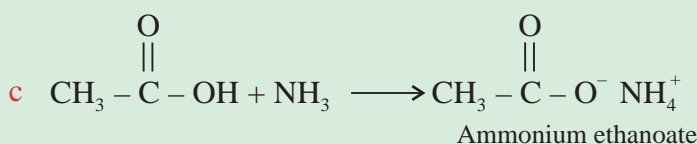
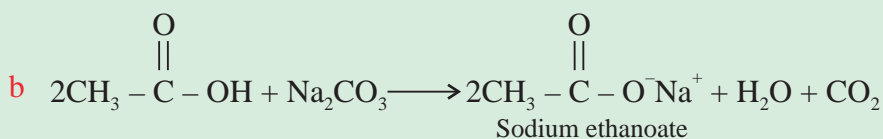
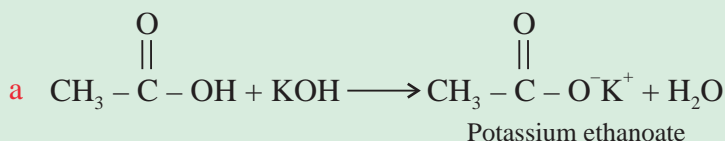


Example 6.10

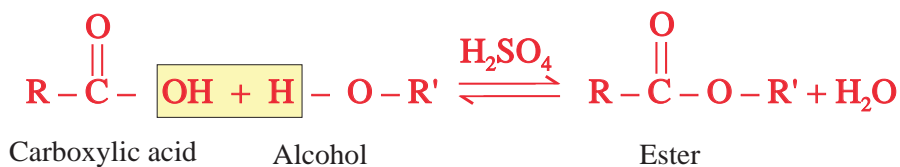
Write the chemical equations for the reaction between ethanoic acid and each of the following reagents and write the names of the products formed:



Solution:



ii) Formation of Esters : One of the important reactions of carboxylic acids involves the replacement of **-OH** group by an alkoxy group to form esters as products. In this reaction, carboxylic acids are heated with alcohols in the presence of concentrated sulphuric acid. The reaction is called esterification.



Activity 6.5



Form a group and discuss the reason why 'tella' or 'tej' turn sour when kept for longer time?

After the discussion, share your ideas with the rest of the class.

6.1.4 Preparation of Carboxylic Acids

One of the important methods for preparation of carboxylic acids is oxidation. Many saturated monocarboxylic acids are obtained by the oxidation of the corresponding primary alcohols whereas aromatic acids are obtained from the corresponding alkylbenzenes.

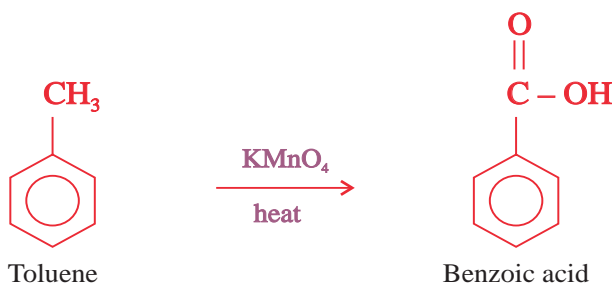
- i) Oxidation of Primary Alcohols:** The primary alcohols are readily oxidized to the corresponding carboxylic acids by their reaction with common oxidizing agents like potassium permanganate or potassium dichromate. The oxidation can also be carried out by passing the vapours of primary alcohols through copper (II) oxide.

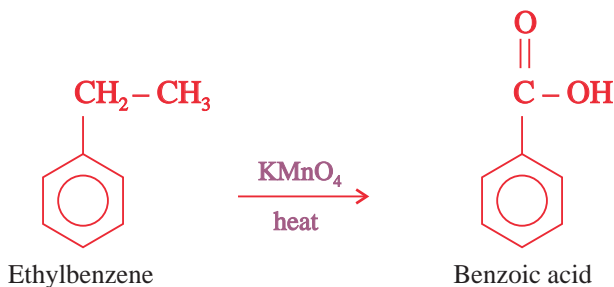


For example, oxidation of ethanol yields acetic acid (ethanoic acid).



- ii) Oxidation of Alkylbenzenes:** Aromatic compounds containing alkyl group as substituent undergo oxidation to form aromatic acids. The reaction involves oxidation with potassium permanganate or potassium dichromate under vigorous conditions. The **alkyl group** is oxidised to **carboxyl group** irrespective of its size. For example, toluene and ethylbenzene, both give benzoic acid on refluxing with KMnO_4 in alkaline medium.





iii) Preparation of acetic acid (Ethanoic acid) : Acetic acid is one of the important carboxylic acids which is used as food preservative. It can be prepared in laboratory by the oxidation of ethanol with potassium permanganate. It can also be obtained by passing the vapours of ethanol through copper oxide as described in **Experiment 6.1**.

Experiment 6.1



Laboratory Preparation of Acetic Acid

Objective: To prepare acetic acid in the laboratory by oxidation of ethanol.

Apparatus: Goggles, test tubes, test tube rack, quickfit apparatus, 250 mL beaker, pipettes, Bunsen burner, stand, clamp, tripod, wire gauze, digital balance, blue litmus paper, broken porcelain pieces.

Chemicals: Ethanol, sodium dichromate, 1 M sulphuric acid, 0.5 M sodium carbonate solution, blue litmus paper.

Procedure

Oxidation of ethanol to ethanoic acid

1. Set up the Quickfit apparatus for refluxing as shown in **Figure 6.3**.
2. Place about 10 mL of 1 M sulphuric acid into the 250 mL round-bottom flask.
3. Add 2-3 g of sodium dichromate ($\text{Na}_2\text{Cr}_2\text{O}_7$) and a few pieces of broken porcelain. Swirl the contents of the flask until the solution is complete (warm if necessary).
4. Cool the mixture under a running tap.
5. Add 1 mL of ethanol dropwise into the flask.
6. Boil under reflux for 20 minutes and distil 2-3 mL of the liquid.

- Notice the smell of the product (distilled liquid) and compare it with that of ethanol.
- Add a few drops of the distilled liquid to a small amount of solid sodium carbonate.
- Add a drop of the distilled liquid to moistened blue litmus paper.

Observation and analysis

- What happened to the colour of the solution in the flask?
- What is the role of sodium dichromate in the above reaction? Is it oxidized or reduced?
- Write the chemical equation for this reaction.
- What do you conclude from this experiment?

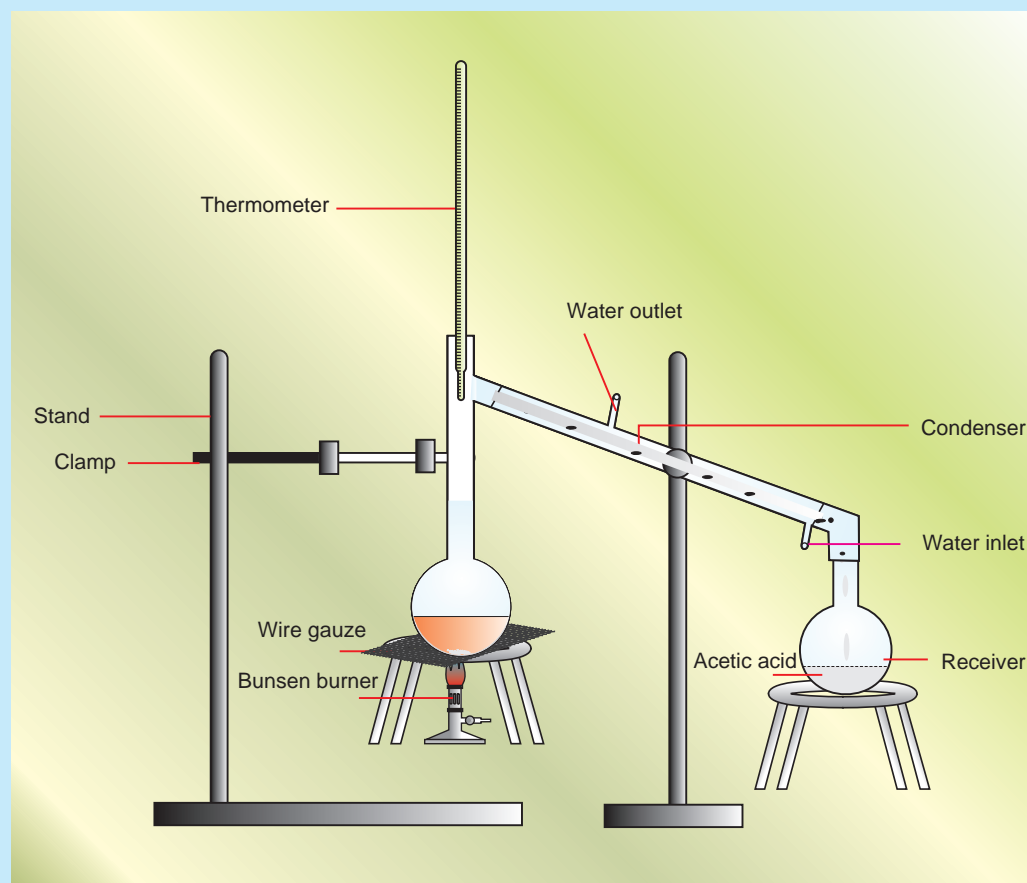


Figure 6.3 Laboratory setup for preparation of acetic acid.

Large quantities of acetic acid is obtained in industry from fermentation of ethanol. The process is known as **Quick Vinegar Fermentation Process**. In the process large wooden vats (Figure 6.4) are used which have a perforated bottom. They are packed with wood shavings moistened with old vinegar. Ethanol solution is poured from the top and trickles down slowly to the perforated bottom. From the lower portion, air is pumped in the vat. The bacteria present in old vinegar, ferment the ethanol into acetic acid. The liquor obtained at the bottom is recirculated through the tower. The maximum concentration of acetic acid obtained by this process is about 10%, which can be fractionated to yield glacial acetic acid.

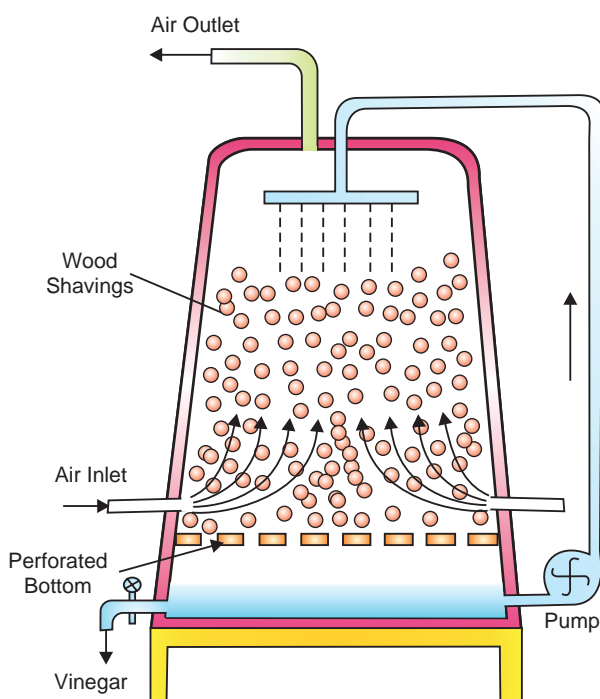


Figure 6.4 Industrial preparation of acetic acid.

6.1.5 Fatty Acids

Activity 6.6



Form a group and discuss the following question. After the discussion, share your idea with the rest of the class.

1. What are fatty acids and why are they named so?
2. Give some examples of fatty acids.

Fatty acids are a carboxylic acids with a long hydrocarbon chains. **Fatty acids** are found in all cells. The hydrocarbon chains of animal **fatty acids** are more saturated than those of vegetable origin. With only a few exceptions, the **fatty acids** are all straight-chain compounds. Most **fatty acids** contain an even number of carbon atoms.

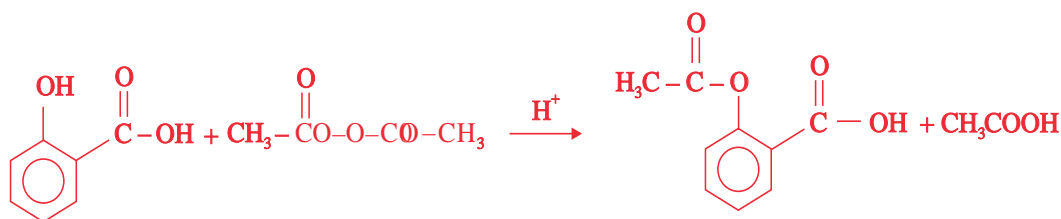
Fatty acids that do not contain carbon-carbon double bonds are termed as **saturated fatty acids**, and those that contain one or more double bonds are called **unsaturated fatty acids**. When there is only one double bond, it is usually between the ninth and tenth carbon atoms in the chain. Some common fatty acids present in different fats and oils are listed in **Table 6.6**.

Table 6.6 Examples of naturally occurring saturated fatty acids

Name	Formula
Lauric acid	$\text{CH}_3(\text{CH}_2)_{10}\text{COOH}$
Myristic acid	$\text{CH}_3(\text{CH}_2)_{12}\text{COOH}$
Palmitic acid	$\text{CH}_3(\text{CH}_2)_{14}\text{COOH}$
Stearic acid	$\text{CH}_3(\text{CH}_2)_{16}\text{COOH}$
Arachidic acid	$\text{CH}_3(\text{CH}_2)_{18}\text{COOH}$

6.1.6 Uses of Carboxylic Acids

Acetic acid is used as a solvent and as a starting material in the preparation of acetates, acetic anhydride, etc. It is also used to prepare the vinyl acetate polymer which is used in paints and adhesives. Vinegar contains about 8-10 % acetic acid which is used in many food items. Aspirin, the common painkiller, is prepared by the reaction of salicylic acid (**2-hydroxybenzoic acid**) with acetic anhydride.



Salicylic acid

Acetylsalicylic acid
(Aspirin)

Carboxylic acids are very important, industrially. Perhaps one of the most important industrial applications of long chain carboxylic acid is for **making soaps, detergents, and shampoos**. Carboxylic acids are also important in the manufacture of greases, crayons, and plastics.



They are used commercially as raw materials for the production of synthetic odors and flavors.

6.2 ESTERS

At the end of this section, you should be able to:

- list common sources of esters;
- write the general structural formula of esters;
- write the molecular formulas and names of some simple esters;
- describe the physical properties of esters;
- explain the chemical properties of esters;
- explain the general methods of preparation of esters; and
- describe some common uses of esters

6.2.1 Sources of Esters

Activity 6.7



Form a group and discuss the following:

Why do some fruits and flowers have pleasant odours?

Share your ideas with the rest of the class.

Esters are among the most widely occurring compounds in nature. Many esters are pleasant-smelling substances and are responsible for the flavor and fragrance of many fruits for example, apples, pears, banana, pineapple, strawberry, etc. Oils, fats and waxes of plants or animal origin are all esters. Many esters are found in flowers also and form the part of essential oils obtained from flowers.

6.2.2 Structure and Nomenclature of Esters

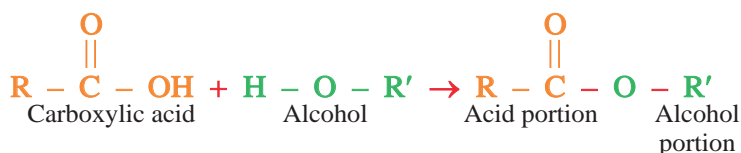
Esters are derivatives of carboxylic acids in which the hydroxyl group of carboxylic acid has been replaced by an **alkoxy group**. Esters can also be formed by the reaction between acid anhydrides and phenols. In such cases, the hydroxyl group is replaced by an alkoxy group.

Esters can be represented by the general formula

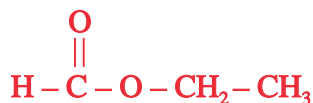


where **R** = hydrogen, alkyl or an aryl group and **R'** = alkyl or an aryl group.

Esters are named by the common system as well as by IUPAC system. In both the cases, the name consists of two parts. The first part is named on the basis of the portion coming from alcohol and the second part of the name is based on the portion from acid. Therefore, it is necessary to identify first the portions coming from alcohol and carboxylic acid.



The above reaction shows that the portion coming from alcohol is attached to the oxygen as alkyl group, and the acid portion is attached to the oxygen through carbonyl group. While writing the name of an ester, first the name of alkyl group is written first followed by the name of the acid by replacing **-ic acid** with **-ate**. When we use the common name of carboxylic acid, the name of the ester is a common name, and when IUPAC name of the acid is used, we get IUPAC name for ester. For illustration, consider the ester formed from ethyl alcohol and methanoic acid.



The common name for this ester is ethyl formate, and the IUPAC name is ethyl methanoate. The formulae and names of some esters are listed in **Table 6.7**.

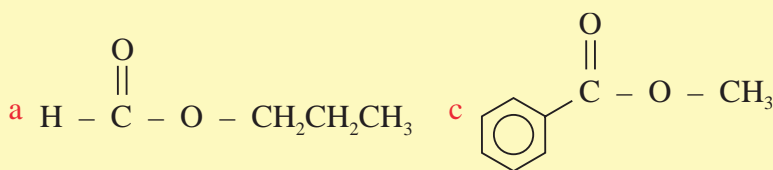
Table 6.7 Names and formulae of some common esters

Molecular Formula	Structural Formula	Common Name	IUPAC Name
$C_3O_2H_6$	$\begin{array}{c} \text{O} \\ \\ \text{CH}_3 - \text{C} - \text{O} - \text{CH}_3 \end{array}$	Methyl acetate	Methyl ethanoate
$C_3O_2H_6$	$\begin{array}{c} \text{O} \\ \\ \text{H} - \text{C} - \text{O} - \text{CH}_2 - \text{CH}_3 \end{array}$	Ethyl formate	Ethyl methanoate
$C_4O_2H_8$	$\begin{array}{c} \text{O} \\ \\ \text{CH}_3 - \text{C} - \text{O} - \text{CH}_2 - \text{CH}_3 \end{array}$	Ethyl acetate	Ethyl ethanoate
$C_4O_2H_8$	$\begin{array}{c} \text{O} \\ \\ \text{H} - \text{C} - \text{O} - \text{CH}_2 - \text{CH}_2 - \text{CH}_3 \end{array}$	Propyl formate	Propyl methanoate
$C_5O_2H_{10}$	$\begin{array}{c} \text{O} \\ \\ \text{CH}_3 - \text{C} - \text{O} - \text{CH}_2 - \text{CH}_2 - \text{CH}_3 \end{array}$	Propyl acetate	Propyl ethanoate

Note that in the given **Table 6.7** molecular formula can represent more than one structure. For example, methyl ethanoate and ethyl methanoate have the same molecular formula, $C_3O_2H_6$. Similarly, ethyl ethanoate and propyl methanoate have the same molecular formula.

Exercise 6.5

1. Name the following esters.



2. Write the structure of the following esters:
- a Isopropyl methanoate b Ethyl propanoate

6.2.3 Physical Properties of Esters

Activity 6.8



Form a group and discuss the following questions. After the discussion, share your ideas with the rest of the class.

1. Do you expect esters to have lower or higher boiling points compared to carboxylic acids of comparable molecular mass?
2. Do you expect esters to have lower or higher boiling points compared to alcohols of comparable molecular mass?

i) Odour

In sharp contrast to the disagreeable odours of carboxylic acids, esters have pleasant odour. The odour of many fruits and flowers result from mixtures of carboxylic esters, and many of them are used in perfumes and food flavoring.

ii) Boiling points

The boiling points of esters increase with increasing molecular mass. Branched-chain esters have lower boiling points than their straight-chain isomers. Esters have lower boiling points than carboxylic acids and alcohols of comparable molecular mass. This is because ester molecules cannot form hydrogen bonds with each other.

iii) Solubility

Esters of low molecular mass are fairly soluble in water. Since carboxylic esters can form hydrogen bonding with water (Figure 6.5), it is not surprising that their solubility in water is about the same as that of carboxylic acids of the same molecular mass. The solubility of esters in water decreases with increasing molecular mass. All esters are soluble in organic solvents.

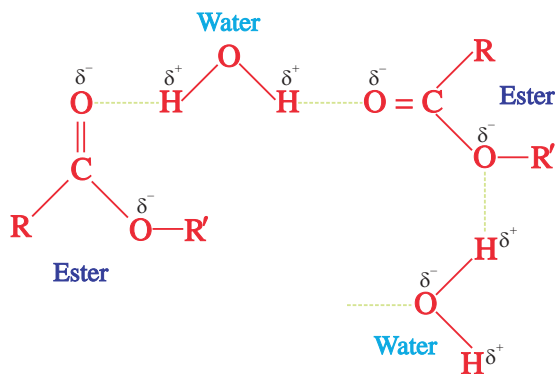


Figure 6.5 Hydrogen bonding between ester and water molecule.

6.2.4 Chemical Properties of esters

Activity 6.9



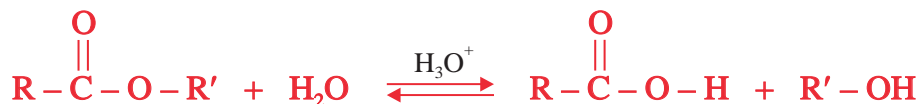
Form a group and discuss the following questions. After the discussion, share your ideas with the rest of the class.

1. What would happen when esters are treated with water?
2. Recall the reactants that form esters. What was the by-product of the condensation reaction?

i) Hydrolysis

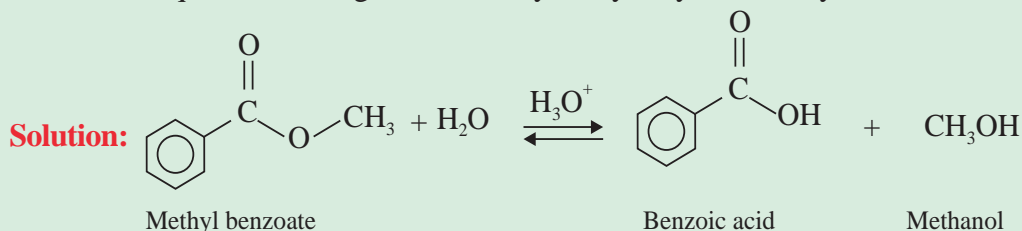
One of the most important reactions of esters is their hydrolysis, which yields corresponding carboxylic acids and alcohols. The hydrolysis reaction is speeded up in presence of a mineral acid which act as catalyst in this reaction.

The general reaction for acid-catalyzed hydrolysis of esters can be written as:



Example 6.11

Write an equation showing the acid-catalyzed hydrolysis of methyl benzoate.



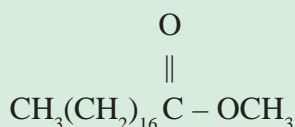
Esters also undergo base-catalyzed hydrolysis to give salts of carboxylic acids and alcohols. Base-catalyzed ester hydrolysis is called **saponification**. Sodium hydroxide or potassium hydroxide are the bases generally used for hydrolysis. For synthetic purpose, base catalysis is often preferred, because the reaction is not reversible.

The general reaction for base-catalyzed hydrolysis of esters:

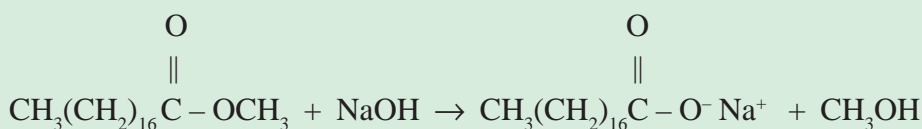


Example 6.12

Write an equation showing the base-catalyzed hydrolysis of methyl octadecanoate.



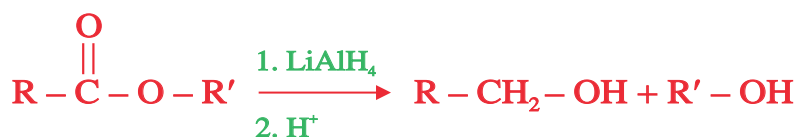
Solution:



In biological systems, many ester hydrolysis reactions take place, for example, in the digestion of fats. These reactions occur under very mild conditions, and in the presence of certain biological catalysts known as **enzymes**.

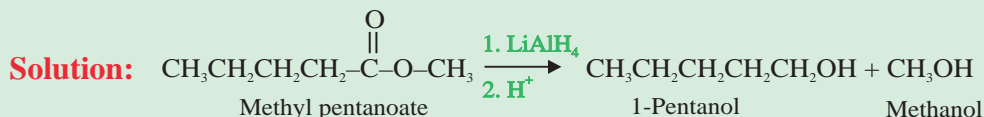
i) Reduction

Esters are reduced to primary alcohols by special reducing agents like lithium aluminium hydride, LiAlH_4 . The general reaction for reduction of esters is given by:

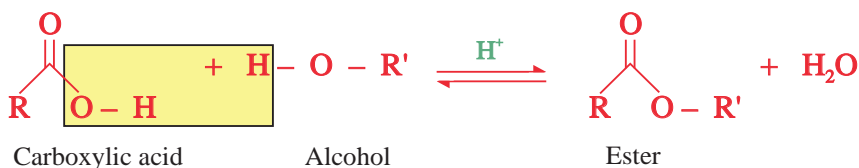


Example 6.13

Write an equation showing the reduction of methyl pentanoate.

**6.2.5 Preparation of Esters**

Esters can be synthesized by heating a mixture of a carboxylic acid and an alcohol in the presence of an acid catalyst such as H_2SO_4 . This reaction is called esterification and is a common method for the preparation of esters.

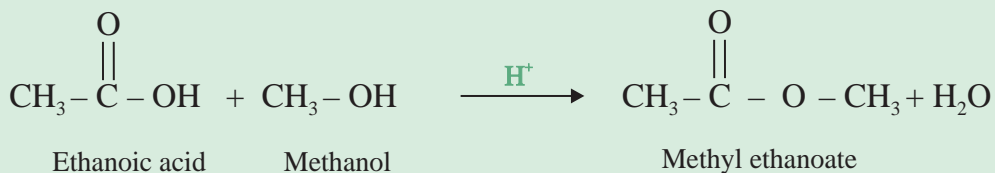


In this condensation reaction, the hydroxyl group ($-\text{OH}$) from the acid and a hydrogen atom ($-\text{H}$) from the alcohol are eliminated in the form of water, as indicated by the dotted rectangle in the above reaction.

Example 6.14

Write an equation showing the preparation of methyl ethanoate from methanol and ethanoic acid.

Solution:

**Exercise 6.6**

Write the reactions for the preparation of each of the following esters using appropriate acids and alcohols:

- | | |
|---|--|
| <p>a Ethyl acetate</p> <p>b Ethyl butanoate</p> | <p>c Methyl benzoate</p> <p>d Phenyl ethanoate</p> |
|---|--|

6.2.6 Uses

Esters have numerous uses as solvents, medicines, clothing (*e.g.* polyesters), fragrances in perfumes, and plasticizers (*e.g.* octyl phthalate).

Most esters of small acids and alcohols are non-corrosive, non-toxic liquids with good properties for use as solvents. Esters are used as solvents for oils and fats, nail polishes, varnishes, paints, gums and resins. Because of their pleasant fruity smells, esters are used in making artificial flavours and perfumes. **Table 6.8** depicts some common fruits and the esters responsible for their flavours (see also **Figure 6.6**).

Table 6.8 Some common fruits and the esters responsible for their flavour

Fruit	Ester present
Apple	Ethyl isovalerate
Pineapple	Methyl butanoate and Ethyl butanoate
Banana	Isopentyl acetate
Orange	Octyl acetate



Apple



Oranges



Pineapple



Bananas

Figure 6.6 Some fruits containing ester.

6.3 FATS AND OILS

At the end of this section, you should be able to:

- define fats and oils ;
- write the general structural formula for fats and oils;

- present the structures of some common triglycerides;
- describe physical properties of fats and oils;
- explain the hardening of oils (process of converting oils to hard fats);
- explain rancidity;
- define soap and detergent;
- explain saponification;
- prepare soap; and
- explain the cleaning action of soaps.

6.3.1 Source and Structure of Fats and Oils

Activity 6.10



Form a group and perform the following activity:

Collect samples of butter, lard, tallow, peanut oil, soyabean oil and olive oil. Classify them according to vegetable or animal origin and according to their physical state. Do you find any relation between their source and the physical state?

Share your ideas with the rest of the class.

Fats and oils belong to a class of biomolecules called lipids. They are triesters of glycerol which are collectively known as triglycerides or triacylglycerols.

The distinction between a fat and an oil depends on their physical states. If the substance is solid or semisolid at ordinary temperature, it is termed as a fat and if it is fluid, it is called an oil.

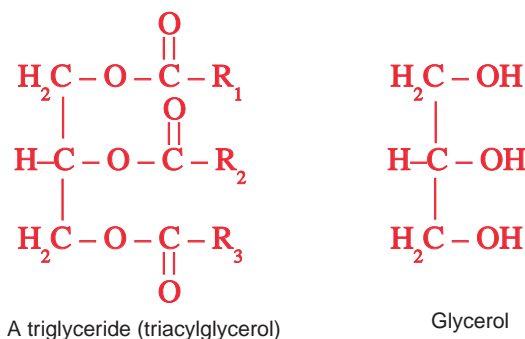
Fats and oils are widely found in nature especially in living things. Animal fats and oils are derived both from terrestrial (land) and marine (water) animals. Marine fats include liver oils, blubber oils, and fish oils.

Vegetable fats and oils are found in greatest abundance in fruits and seeds. While fats and oils occur in the roots, stalks, branches and leaves of plants.

Structure of Fats and Oils

Fats and oils are triesters. Variation in the structure of fats and oils occur in the fatty acid portion of the triglyceride (or triacylglycerol).

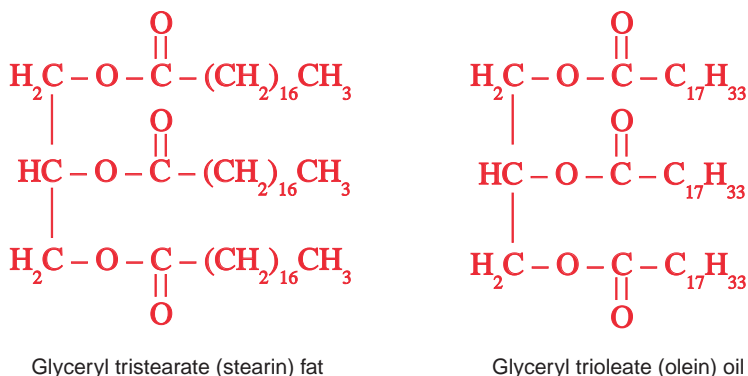
Fats and oils are represented by the following general structural formula:



Where R_1 , R_2 and R_3 may be the same or different hydrocarbon groups.

Fats are esters of glycerol and mostly saturated fatty acids and oils are liquid esters primarily derived from unsaturated fatty acids and glycerol. The acid part of fats and oils almost always contain an even number of carbon atoms.

The structures of some common triglycerides are shown below:



Exercise 6.7

Write the structure of:

- Glyceryl trimyristate
- Glyceryl palmitooleostearate

Some of the commercially available vegetable oils are shown in **Figure 6.7**.



Figure 6.7 Some vegetable oils.

6.3.2 Physical Properties of Fats and Oils

Activity 6.11



From a group and compare vegetable oils with mineral oils. Do they behave in similar fashion? Explain.

Share your ideas with the rest of the class.

The common physical properties of fats and oils are that; they are greasy to the touch, and have lubricating properties; they are not readily volatile; and may be burned without leaving any residue, that is, ash.

Fats like butter, lard and tallow are solids at room temperature. On the other hand, oils are mainly obtained from plants, e.g., corn oil, peanut oil, cotton seed oil, olive oil and soyabean oil which are liquids at room temperature. All oils and fats are colourless, odourless and

neutral substances in pure state. They are lighter than water and immiscible with it. They are soluble in organic solvents *e.g.* benzene, ether and chloroform etc.

6.3.3 Hardening of Oils

Activity 6.12



Form a group and classify the given fatty acids as saturated or unsaturated fatty acids: Myristic acid, oleic acid, linolic acid, lauric acid, palmitic acid, linolenic acid and stearic acid.

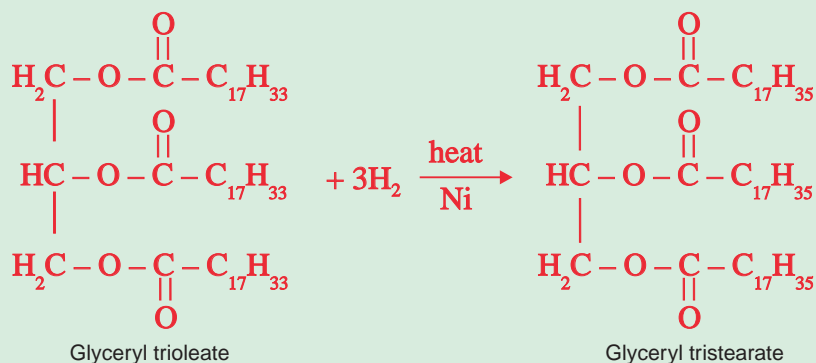
Saturated fatty acids	Unsaturated fatty acids
_____	_____
_____	_____
_____	_____

Can you suggest a method of converting unsaturated fatty acids to saturated fatty acids. Present your findings to the class.

Oils can be converted to fats by addition of hydrogen (hydrogenation) at high pressure in presence of nickel or palladium as catalyst. This process of converting oils to hard fats is known as hardening of oils. This reaction is used in the preparation of margarine.

Example 6.15

A glyceryl tristearate (found in animal fat) can be prepared by hydrogenation of glyceryl trioleate (oil found in olive oil and whole oil) is shown in the equation below



Exercise 6.8

Write the equation for the hydrogenation of:

- (a) Glyceryl palmitooleostearate, and
- (b) Glyceryl trimyristate

6.3.4 Rancidity

Activity 6.13



Form a group and perform the following activity:

Obtain two packets of fried potato chips from the market. Open one packet and smell it. Now place half the contents in a close tight container and other half in an open container. Let the second packet be kept as such. After 15 days, smell the chips kept in the open container, closed container and sealed packet. Record your observations and find out what is the best method to keep such items.

Share your findings with the class.

Fats and oils are quite reactive substances. When stored for any considerable length of time, especially when the temperature is high and the air has free access to them, they deteriorate and spoil. Among the various fats, spoilage takes the form of **rancidity**.

Fats and oils develop an unpleasant odour due to rancidity. It is caused mainly due to the hydrolysis of ester linkage and oxidation across the double bonds. In this respect, different fats differ markedly. Some spoil very much more rapidly than others. The fat acquires a peculiarly disagreeable odor and flavor.

The rancidity of a given fat is not necessarily the result of long storage under unfavorable conditions. The fat may have been spoiled and rancid from the moment of its production. This will inevitably be true when the materials from which it was produced have undergone decomposition. In other words, to obtain a sound and sweet fat, the raw material must be sound and sweet; it must be processed speedily before it gets time to decompose; and this must be done under clean and sanitary conditions. The fat thus obtained must be stored under favorable conditions and its consumption should not be delayed.

6.3.5 Soaps and Detergents

Activity 6.14



Form a group and collect the information regarding the substances which were used for cleaning before the discovery of soaps. Share the information with the class.

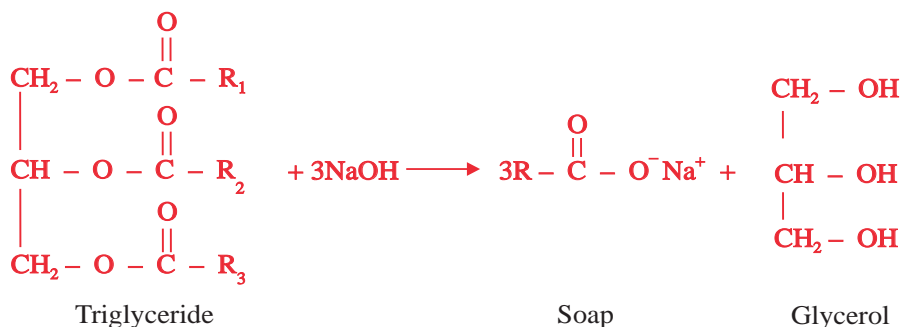
The commercially available soaps are shown in Figure 6.8.



Figure 6.8 Some commercially available soaps.

i) Soaps

Soaps are sodium or potassium salts of long chain fatty acids. These are generally obtained by alkaline hydrolysis of oils and fats. This process is called saponification. A general reaction can be written as follows:



Although chemically all soaps are salts of fatty acids but many variations are created when used for specific purposes, for example colour and perfumes are added when used as toilet soap.

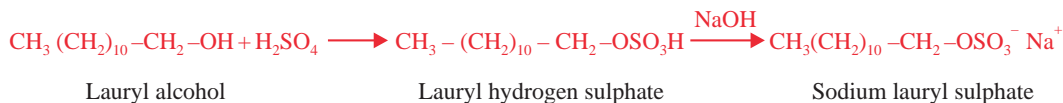
Transparent soaps are prepared by first dissolving in alcohol and then evaporating the excess alcohol. Floating soaps are prepared by beating air before it hardens during manufacture. Certain antibacterial substances are also added for making medicinal soaps. Potassium salts of fatty acids form soft soaps and are used as baby soaps.

ii) Detergents

Detergents are synthetic substances which are used as substitutes to soaps. Although synthetic detergents vary considerably in their chemical structure, the molecules of all of them have one common feature which they share with ordinary soaps. They are amphipathic, have a large non-polar hydrocarbon end that is oil-soluble and a polar end that is water-soluble.

The C_{12} - C_{18} alcohols are converted into the salts of alkyl hydrogen sulphate by treatment with H_2SO_4 . The resulting alkyl sulphates, when treated with NaOH, produce a detergent, **sodium alkyl sulphate**.

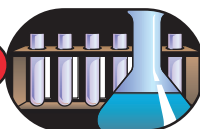
For example, sodium lauryl sulphate, a very common detergent is obtained from lauryl alcohol as shown in the following reaction.



Detergents act in essentially the same way as soap does. However, they have certain advantages over soap. For example, the sulphates retain their efficiency in hard water, since the corresponding calcium or magnesium salts are soluble. Hence detergents can be used in hard water. Detergents are neutral whereas soaps are basic. But, detergents are not without drawbacks. For example, some are not biodegradable, which makes them environmentally non-friendly. The new detergents are better in being more biodegradable than the older generation.

iii) Saponification (Soap-making)

Soap-making (saponification) is one of the oldest chemical technologies. Man first boiled goat tallow and wood ash to give a lathering and cleansing product. The goat tallow contained the needed ester, and the wood ash the necessary alkali. Chemicals with the same reactive groups are the main raw materials still used in traditional and modern soap manufacture. Remember that saponification is the chemical process of breaking down an ester in presence of alkali to form soap.

Experiment 6.2**Laboratory Preparation of Soap**

Objective: To prepare soap in the laboratory by the alkaline hydrolysis of fats and oils.

Apparatus: Water-cooled condenser, 100 mL flask, Bunsen burner, Buchner funnel, ring stand, clamp, boiling chips and 400 mL beaker.

Chemicals: Animal fat (tallow) or vegetable oil, NaOH, ethanol and table salt.

Procedure:

1. Set up a reflux apparatus as shown in **Figure 6.9**.
2. Place 3 mL of vegetable oil or 3 g of animal fat (tallow) in the 250 mL distillation flask.
3. Add about 15 mL of 20 % sodium hydroxide solution.
4. Add a few boiling chips and connect the flask to the condenser and gently reflux the mixture over a small flame. Saponification is complete when a homogeneous solution is obtained (in 30-45 minutes).
5. While the saponification is in progress, prepare a concentrated salt solution by dissolving 50 g of NaCl in a 150 mL of water in a 400 mL beaker.
6. When saponification is complete, extinguish the flame and pour the mixture quickly into the saturated NaCl solution (brine).
7. Stir the mixture thoroughly for several minutes.
8. Collect the precipitated soap on a Buchner funnel.
9. Wash the soap twice with 10 mL of ice-cold distilled water. Wait until it dries.

Observations and Analysis :

1. What happens to the animal fat (tallow) or vegetable oil in this reaction?
2. What is the role of sodium hydroxide?
3. Write the chemical reaction for this reaction.
4. What do you conclude from this activity?

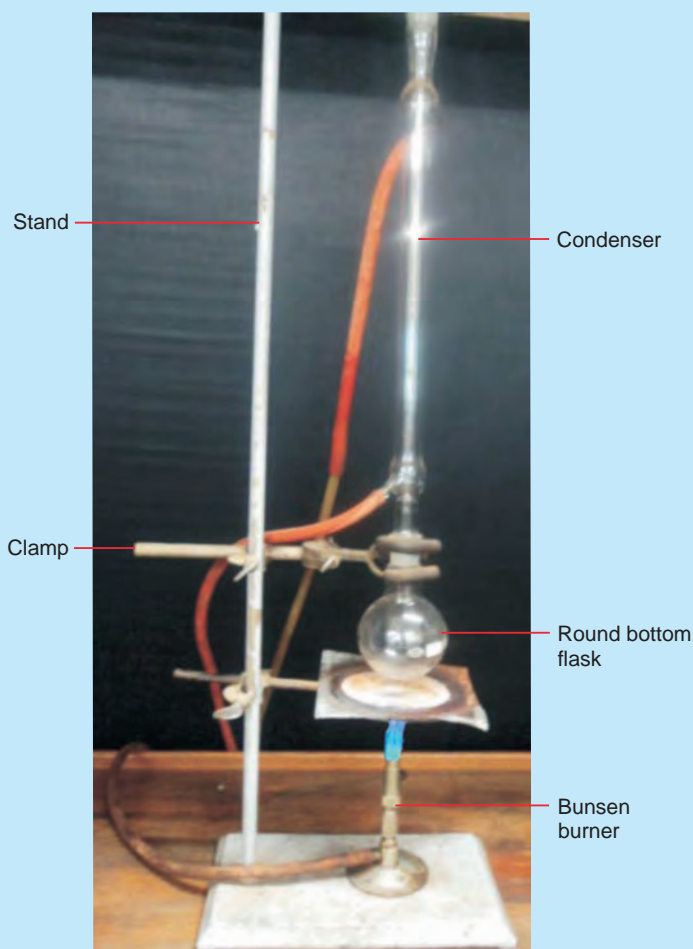


Figure 6.9 Laboratory set up for preparation of soap.

iv) Cleaning Action of Soap

Molecules of soap have two dissimilar ends. At one end is long carbon chain which is hydrophobic or water repellent. The other end has carboxylate ion which is water soluble end. So soap molecules have both polar and non-polar ends and, in addition, are big enough for each end to display its own solubility behaviour. Such molecules are called amphipathic. When they are dissolved in water, each non-polar end seeks a non-polar environment in line with rule of “like dissolves like”. Therefore, many nonpolar ends clump together to form the micelles as shown in [Figure 6.10](#).

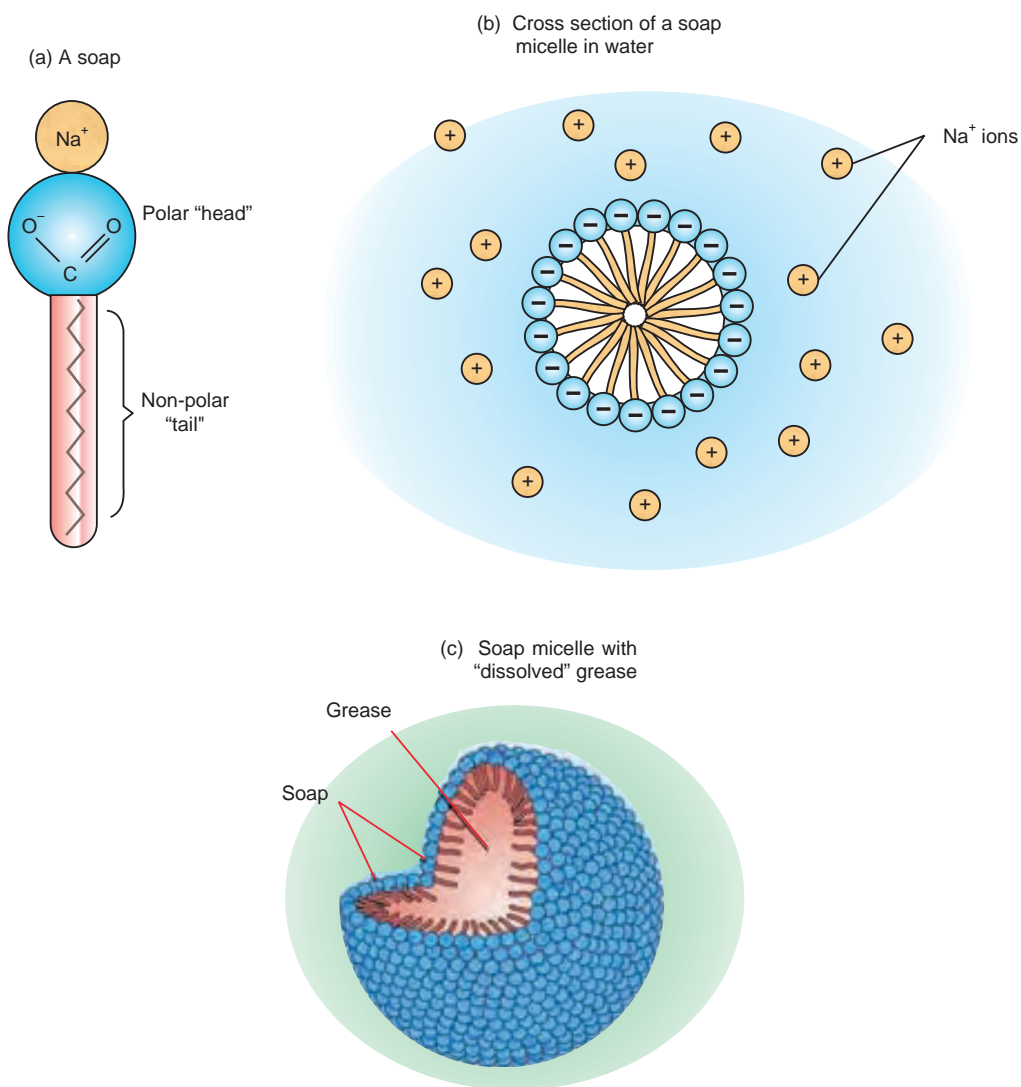


Figure 6.10 Soap molecules form micelles when "dissolved" in water.

When a cloth with spot of oil and dirt is soaked into the soap solution, the tiny droplets of oil are dissolved by the hydrocarbon end in the middle of the micelle. Due to the outwardly projected polar ends, these micelles dissolve in water and are washed away. In this way soaps act as cleaning agents.

Exercise 6.9

What saponification products would be obtained when mixing the following oils with NaOH?

1. Glyceryl trimyristate
2. Glyceryl palmitoleostearate.

Unit Summary

- Carboxylic acids are compounds with a -COOH functional group.
- Because of the -COOH functional group, carboxylic acids are polar compounds and can form hydrogen bondings with water and among themselves.
- The common names of carboxylic acids are based on their origins in nature whereas their IUPAC names are created by replacing the ending “e” of the corresponding alkane, or alkyne by “oic acid.”
- Carboxylic acids are generally prepared by the oxidation of corresponding primary alcohols.
- Esters are mildly polar compounds that are widely distributed in nature.
- Esters are named according to both the common name system and the IUPAC system.
- In a laboratory, esters can be prepared from a reaction between a carboxylic acid and an alcohol. The process requires an acid catalyst and heating.
- Fats and oils are esters of long-chain carboxylic acid with glycerol.
- Soaps are sodium or potassium salts of long-chain carboxylic acids. They can be prepared by the saponification of fats or oils, using a base (NaOH or KOH).
- One of the main difference between soaps and detergents is that the detergents can be used in hard water, whereas soaps form scum in hard water.

Check List

Key terms of the unit

- | | |
|---------------------|------------------|
| • Carboxyl group | • Lipid |
| • Carboxylic acid | • Oil |
| • Detergents | • Rancidity |
| • Ester | • Saponification |
| • Esterification | • Soaps |
| • Fat | • Triglycerides |
| • Hardening of oils | |

REVIEW EXERCISE

Match the names of the functional group in **column A** with the structure in **column B**.

Names of the functional groups A	Structures B
(i) Carboxyl group	a $\begin{array}{c} \text{O} \\ \\ -\text{C}- \end{array}$
(ii) Carbonyl group	b $\begin{array}{c} \text{O} \\ \\ -\text{C}-\text{O} \end{array}$
(iii) Ester group	c $\begin{array}{c} \text{O} \\ \\ -\text{C}-\text{OH} \end{array}$
(iv) Fats and Oils	d $\begin{array}{c} \text{O} \\ \\ \text{R}-\text{C}-\text{O}^- \text{K}^+ \end{array}$
(v) Soaps	e $\begin{array}{c} \text{O} \\ \\ \text{R}-\text{S}-\text{O}^- \text{Na}^+ \\ \\ \text{O} \end{array}$
(vi) Detergents	f $\begin{array}{c} \text{O} \\ \\ \text{R}-\text{C}-\text{CH}_2 \\ \\ \text{R}-\text{O}-\text{CH} \\ \\ \text{R}-\text{C}-\text{CH}_2 \\ \\ \text{O} \end{array}$



Part I : Multiple Choice Questions

1. Which of the following compounds reacts with sodium bicarbonate?



2. The compound 'A' when treated with methyl alcohol and few drops of H_2SO_4 gave fruity smell. The compound 'A' can be:

- a toluene c propanoic acid
b ethanol d methyl ethanoate

3. The reaction between alcohol and carboxylic acids is called:

- a esterification c hydrolysis
b saponification d dehydration

4. Conversion of ethanol into ethanoic acid is an example of:

- a reduction c addition
b oxidation d hydration

5. When 'tella' is kept for some time, it becomes sour due to the formation of:



6. Toluene can be converted into benzoic acid by its reaction with:

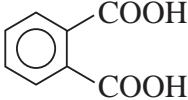
- a sodium metal c potassium permanganate
b potassium hydroxide d carbon dioxide

7. Carboxylic acids of low molecular mass are soluble in water due to:

- a hydrogen bonding c dissociation into ions
b dimer formation d hydrolysis

8. Hydrolysis reaction of fats by sodium hydroxide is known as:
 a acetylation c saponification
 b carboxylation d esterification
9. What happens when an ester is treated with LiAlH_4 ?
 a One unit of alcohol and one unit of acid is formed.
 b Two units of alcohol are formed.
 c Two units of carboxylic acid are formed.
 d No reaction occurs.
10. Detergents are better than soaps because they:
 a are naturally available.
 b are biodegradable.
 c can be used in hard water.
 d All of these.

Part II : Answer the following questions

11. Draw the structures for the following compounds:
 a 3-bromobutanoic acid
 b 2-hydroxy-2-methylpropanoic acid
 c 2-butanoic acid
 d benzoic acid
12. Name the following compounds:
- a HCOOH d 
- b $(\text{CH}_3)_2\text{CHCOOH}$ e $\text{CH}_3(\text{CH}_2)_{14}\text{COOH}$
- c $\text{HOOC}-\text{CH}_2\text{CH}_2-\text{COOH}$
13. Draw the structures of the following esters:
 a iso-butyl acetate d benzyl benzoate
 b ethyl formate e octyl ethanoate
 c iso-pentyl acetate



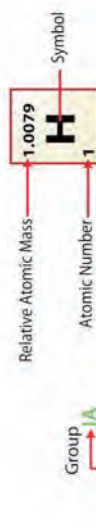
14. Name the alcohol and the acid from which each of these esters is produced.
- a isopentyl acetate
 - b benzyl benzoate
 - c octyl ethanoate
 - d isobutyl acetate
 - e ethyl formate
15. Complete the following reaction using structural formulas:



16. Define the following giving suitable examples:
- a Hydrolysis
 - b Saponification
 - c Esterification
 - d Hydrogenation
 - e Lipids
 - f Triglycerides
 - g Rancidity
 - h Hardening of oils
17. How will you carry out the following conversions?
- a Propan-1-ol into propanoic acid.
 - b Propyl propanoate into propan-1-ol.

Legend

	Alkali Metals		Nonmetals
	Alkaline Earth Metals		Noble gases
	Transition Metals		Other Metals
	Rare Earth metals		Metalloids



Group 1	H 1.0079 1											He 4.003 2		
2	Li 6.941 3	Be 9.01 4											Ne 20.18 10	
3	Na 22.990 11	Mg 24.31 12											Ar 39.95 18	
4	K 39.098 19	Ca 40.08 20											Kr 83.80 36	
5	Rb 85.458 37	Sr 87.62 38	Y 88.91 39	Zr 91.22 40	Nb 92.91 41	Mo 95.94 42	Tc (98) 43	Ru (101.07) 44	Rh 102.91 45	Pd 106.40 46	Ag 107.87 47	Cd 112.47 48	Xe 131.30 54	
6	Cs 132.91 55	Ba 137.33 56	La* 136.91 57	Hf 178.49 72	Ta 180.95 73	W 183.85 74	Re 186.21 75	Os 190.20 76	Ir 192.22 77	Pt 195.09 78	Au 196.97 79	Hg 200.59 80	Rn (222) 86	
7	Fr (223) 87	Ra 226.03 88	Ac* 227.03 89	Rf (261) 104	Ha (262) 105	Sg (266) 106	Bh (262) 107	Hs (277) 108	Mt (268) 109	Uun (281) 110	Uun (272) 111	Uub (285) 112		
			Ce 140.12 58	Pr 140.91 59	Nd 144.24 60	Pm (145) 61	Sm (145) 62	Eu 151.96 63	Gd 157.25 64	Tb 158.93 65	Dy 162.50 66	Ho 164.93 67	Er 167.26 68	Lu 174.97 71
			Th 232.04 90	Pa 231.04 91	U 238.03 92	Np 237.05 93	Pu (244) 94	Am (243) 95	Cm (247) 96	Bk (247) 97	Cf (251) 98	Es (252) 99	Fm (257) 100	Lr (262) 103
												Tm 168.93 69	Yb 168.93 70	No (259) 102

* Lanthanides

* Actinides

