

# **6. Alkanoic Acids and Derivatives; Giant Molecules**

## **6.1 Introduction**

Carbon forms a large number of compounds. The hydrocarbons and alkanols were studied in Book 2. Many more homologous series exist. Alkanoic acids, esters, alkanamides, amino acids, carbohydrates will be studied in this chapter. They are all homologous series, and each comprises of a large number of compounds.

Some compounds of these homologous series are capable of linking up to form giant molecules. Apart from the naturally occurring giant molecules such as proteins, and polysacharoses, man has ingeniously made many more for various uses and for which this age has been described as a polymer age!!

## **6.2 Alkanoic Acids**

In Book I, acids were defined as substances which produce hydroxonium ions in aqueous solution. They were also classified into strong and weak acids. Organic acids are weak acids because they do not ionize completely in aqueous solution. Only a few hydroxonium ions are formed when they are dissolved in water.

Many organic acids are found in living organism. Table 6.1 lists some common organic acids and their sources.

**TABLE 6.1: Common organic acids and the sources**

Common name	Formula	IUPAC name	Sources
Formic Acid	HCOOH	Methanoic acid	Sting of ants and insects
Acetic acid	CH <sub>3</sub> COOH	Ethanoic acid	Vinegar (stale wine)
Lactic acid	CH <sub>3</sub> CH(OH)COOH	2-hydroxypropanoic acid	Sour milk and grape fruit
Tartaric acid	HOOC(CHOH) <sub>2</sub> CO <sub>2</sub> H	2,3 dihydroxybutanedioic acid	Grapes
Citric acid	CH <sub>2</sub> —COH—C=O CO <sub>2</sub> H CO <sub>2</sub> H CO <sub>2</sub> H	2-hydroxypropanone-1,2,3-tricarboxylic acid	Citrus fruits and vegetables
Oxalic acid	HOOC—COOH	Ethanedioic acid	Tomato fruits, spinach and cabbages
Butyric acid	CH <sub>3</sub> (CH <sub>2</sub> )CO <sub>2</sub> H	Butanoic acid	Rancid butter
Vitamin C (Ascorbic acid)	CH <sub>2</sub> OHCO(CHOH) <sub>3</sub> CO <sub>2</sub> H	2-ketogluconic acid	Fruits and fresh vegetables

*Experiment 6.1: Preparation of Ethanoic Acid, CH<sub>3</sub>COOH*

Put 10 cm<sup>3</sup> of water into a round-bottomed flask. Add 9 cm<sup>3</sup> of concentrated tetraoxosulphate(VI) acid to it, a little at a time while swirling the flask. Add 11 g of sodium heptaoxodichromate(VI) to the resulting acidic solution. Connect a liebig condenser vertically to the flask, and immerse the flask in a beaker.

Dilute 4 cm<sup>3</sup> of ethanol (95%) with 8 cm<sup>3</sup> of water. Put this into a dropping funnel connected to the condenser as shown in Figure 6.1. Drop about 1 cm<sup>3</sup> of the ethanol solution into the flask, through the condenser.

Heat the water bath. While the solution in the flask is boiling, add the rest of the ethanol solution in 1 cm<sup>3</sup> portions at 1 minute intervals. Continue heating for 15 minutes after adding all the ethanol.

Allow the apparatus to cool down a bit, then reconnect the condenser for simple distillation, Figure 6.2. Distill the mixture in the round-bottomed flask and collect the ethanoic acid that comes over as distillate. Use portions of it to test for the properties of ethanoic acid. Use glacial ethanoic acid to test for the physical properties.



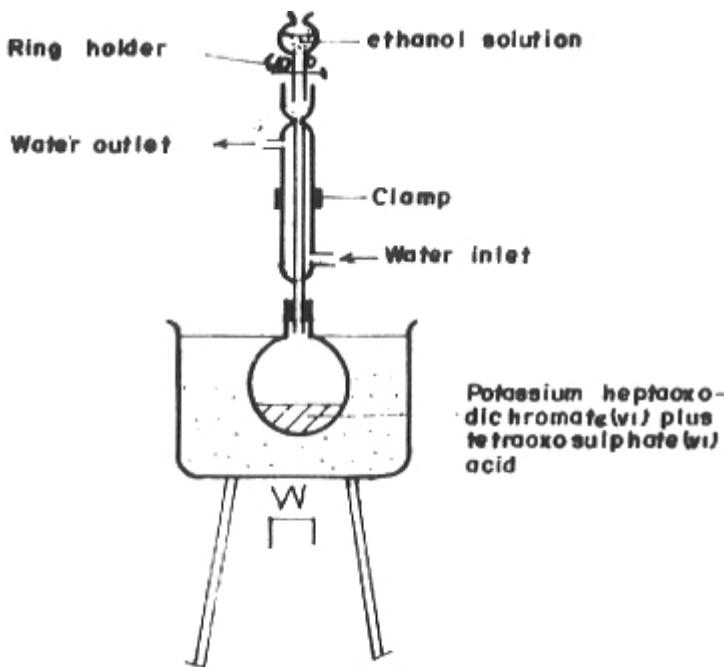


Figure 6.1: Oxidation of ethanol to ethanoic acid.

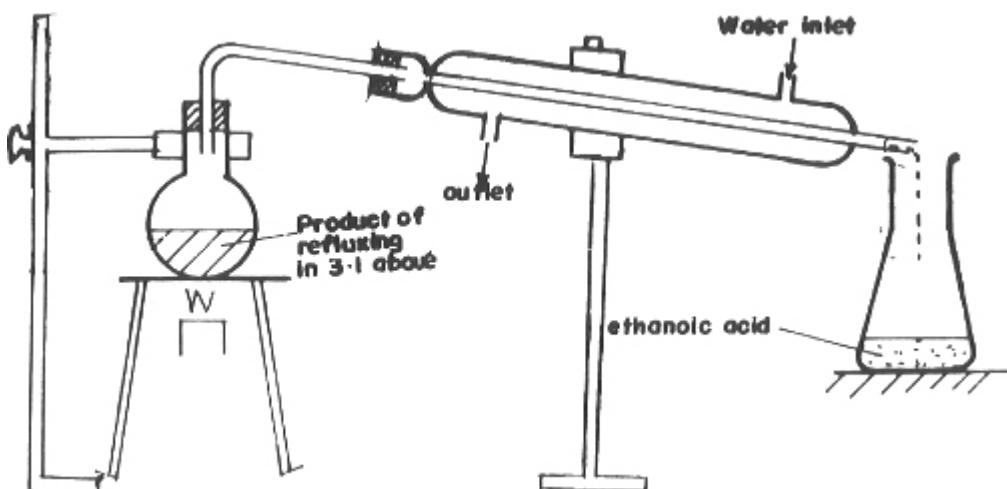


Figure 6.2: Distillation to separate ethanoic acid from the reaction

#### Experiment 6.2: Investigating the Properties of Ethanoic Acid

- Observe the colour of the distillate, and of the glacial acid. Ethanoic acid is a colourless liquid at room temperature and pressure. It is slightly denser than water.
- Boiling point:** Heat about 1cm<sup>3</sup> of glacial ethanoic acid in a test-tube with a thermometer dipping into it (Figure 6.3). Note the thermometer reading when the acid boils and there is no further rise in temperature. It should be 118°C at atmospheric pressure. The relatively high boiling point is due to inter-molecular hydrogen bonding between the molecules, which leads to

dimerisation.

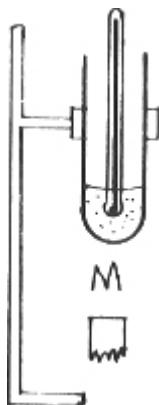
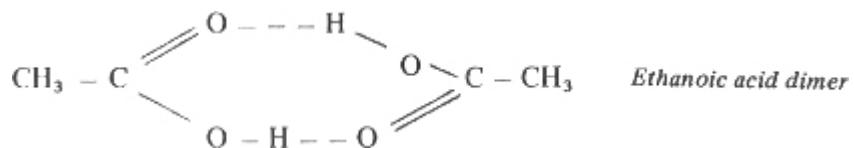


Figure 6.3: Boiling point determination

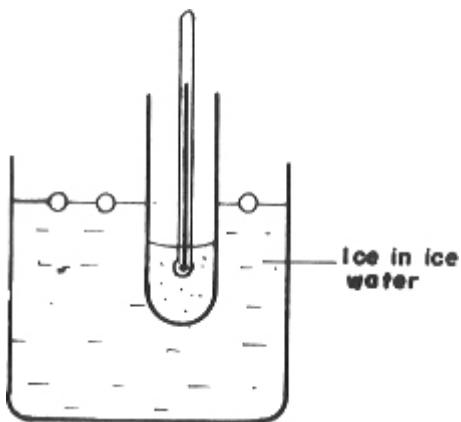
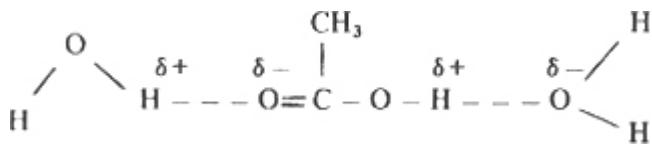
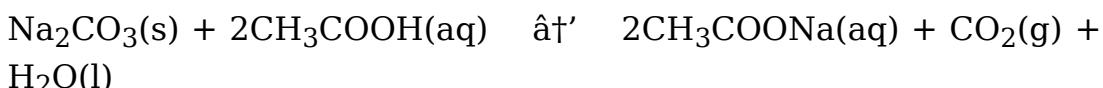


Figure 6.4: Freezing point determination.

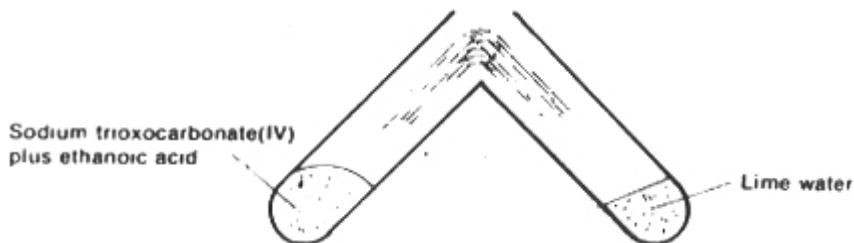
- (iii) **Melting point:** Put a little glacial ethanoic acid into a test-tube. Insert a thermometer into it and immerse the test-tube in a beaker of ice water. Watch the thermometer reading as it falls to a constant temperature of 17°C. This is the freezing point (or melting point) of ethanoic acid.
- (iv) **Solubility in water:** Put about 1 cm<sup>3</sup> of ethanoic acid (glacial) into a test-tube. Add water to it dropwise, with constant shaking. Continue, until 1 cm<sup>3</sup> of water has been added. Note that the two liquids are miscible in all proportions. Hydrogen bonding between ethanoic acid and water molecules accounts for the high miscibility.



- (v) Put a drop of the distillate (ethanoic acid) on to blue litmus paper. The paper turns scarlet, showing that ethanoic acid is weakly acidic.
- (vi) Add sodium trioxocarbonate(IV) powder to a little of the acid in a test-tube. A brisk effervescence occurs. Pass the gas liberated into another test-tube containing lime water and shake this second tube. The limewater turns milky, showing that ethanoic acid liberates carbon(IV) oxide from sodium trioxocarbonate(IV).

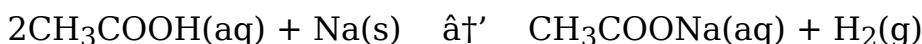


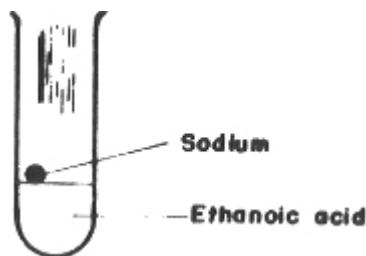
- (vii) Repeat experiment (VI) with sodium hydrogen trioxocarbonate(IV) instead of the trioxocarbonate (IV). A similar observation is noticed. This shows that ethanoic acid, though a weak acid, can react with the weakly basic hydrogen trioxocarbonate(IV), whereas phenol cannot. This means that ethanoic acid is stronger than phenol. Figure 6.5 shows the technique of passing carbon(IV) oxide from its source into another test tube containing limewater.



*Figure 6.5: Passing carbon(IV) oxide into limewater*

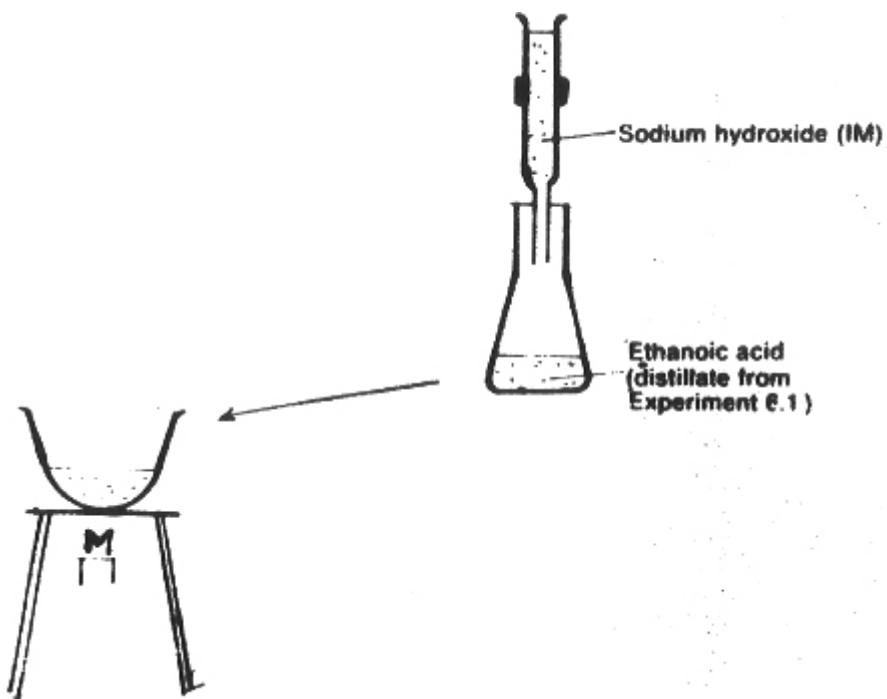
- (viii) Drop a pellet of sodium into a test-tube containing about  $1 \text{ cm}^3$  of ethanoic acid (Figure 6.6). A brisk effervescence occurs along with a hissing sound. Bring a lighted taper near the mouth of the test-tube. A pop sound indicates that the gas liberated is hydrogen. Active metals (Na, K, Mg, etc) liberate hydrogen from ethanoic acid.





*Figure 6.6: Action of sodium on ethanoic acid.*

(ix) Put  $5\text{ cm}^3$  of the distillate from Experiment 6.1 into a conical flask. Add a drop of phenolphthalein to it, then run 1M sodium hydroxide from a burette into the conical flask, swirling the flask. A colour change soon takes places, indicating the complete neutralisation of the acid by the alkaline solution. Stop the addition when the colour change just occurs. Concentrate the resulting solution by evaporation. While evaporating the solution, occasionally withdraw samples with a dropper pipette and test for saturation. When crystallization occurs with the test sample, cool the rest of the solution. Colourless crystals of sodium ethanoate are formed. Filter the solution and dry the crystals.

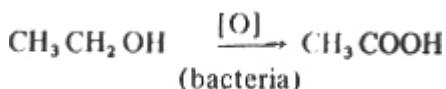


*Figure 6.7: Preparation of sodium ethanoate.*

(x) To  $1\text{ cm}^3$  of the distillate from Experiment 6.1, add  $1\text{ cm}^3$  of ethanol, then a drop of concentrated tetraoxosulphate(VI) acid. Warm the mixture, then pour the contents of the test-tube into a beaker of cold water. Note the sweet-smelling odour of the ester formed.

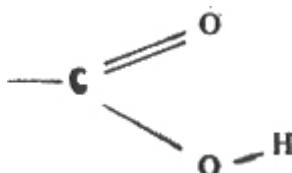


In Experiment 6.1, ethanoic acid has been prepared by oxidation of ethanol to ethanoic acid. The same reaction can take place in air in the presence of bacteria, when wines, including palm wine, go stale on standing in air. The bacteria is *Mycoderma aceti*.

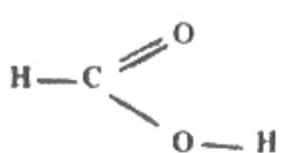


### Nomenclature of Alkanoic Acids

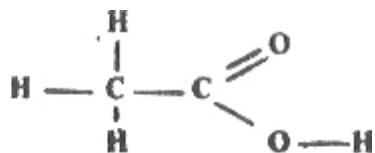
Alkanoic acids form a homologous series with the general formula  $\text{C}_n\text{H}_{2n+1}\text{COOH}$  (or  $\text{RCOOH}$  where R is an alkyl group, or H for the first member of the series). The functional group of the alkanoic acid homologous series is the carboxyl group—COOH:



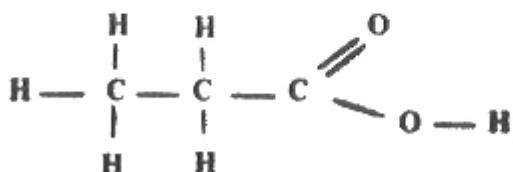
The alkanoic acids are named by replacing the last “e” in the name of the corresponding alkane with the suffix “oic acid”. The first three members of the group are:



**methanoic acid,  $\text{HCOOH}$ .**



**ethanoic acid,  $\text{CH}_3\text{COOH}$ .**



**propanoic acid,  $\text{CH}_3\text{CH}_2\text{COOH}$**

The parent alkane is that which has the same number of carbon atoms as the longest chain containing the —COOH group. The positions and names of any substituents are indicated in the name. Numbering begins from the —COOH end of the chain. Examples are:

$\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$  butanoic acid  
 $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{COOH}$  pentanoic acid  
 $\text{CH}_3-\text{CH}-\text{CH}_2-\text{COOH}$  3-methylbutanoic acid

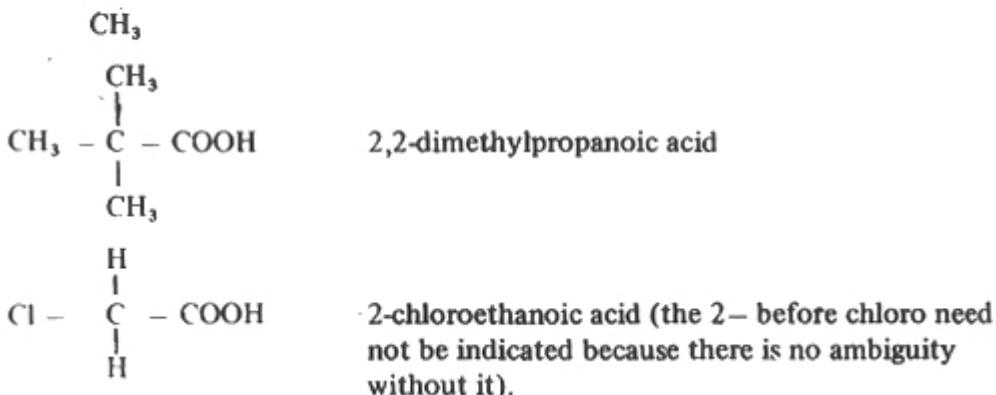


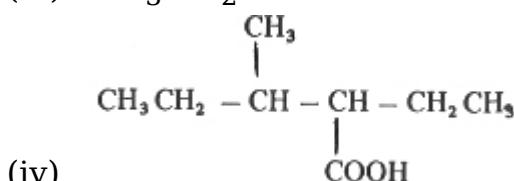
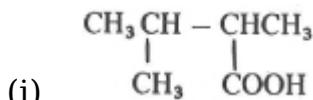
Table 6.2 lists the names and physical properties of the first six members of the alkanoic acid homologous series.

**TABLE 6.2: Physical properties of some alkanoic acids**

n	Formula	IUPAC name	M.p. ( $^{\circ}\text{C}$ )	B.p. ( $^{\circ}\text{C}$ )	Density ( $\text{g cm}^{-3}$ )
1	HCOOH	Methanoic acid	8	101	1.22
2	$\text{CH}_3\text{COOH}$	Ethanoic acid	17	118	1.05
3	$\text{CH}_3\text{CH}_2\text{COOH}$	Propanoic acid	-21	141	0.99
4	$\text{CH}_3(\text{CH}_2)_2\text{COOH}$	Butanoic acid	-7	164	0.96
5	$\text{CH}_3(\text{CH}_2)_3\text{COOH}$	Pentanoic acid	-35	186	0.94
6	$\text{CH}_3(\text{CH}_2)_4\text{COOH}$	Hexanoic acid	-1.1	265	0.93

### Exercise 6.1

(1) Name the following alkanoic acids:



(2) Write the structures of:

- (i) 2-ethyl-3-methylpentanoic acid,
- (ii) hexanoic acid,
- (iii) 2-chloro-2-methylpropanoic acid,
- (iv) 2,3-dihydroxy butanoic acid.

## Aromatic Monocarboxylic Acids

Replacement of the alkyl group with an aromatic group (benzene ring) gives rise to aromatic carboxylic acids. Table 6.3 lists a few of these.

**TABLE 6.3 : Some aromatic carboxylic acids**

Aryl group	Formula	Name
C <sub>6</sub> H <sub>5</sub> -	C <sub>6</sub> H <sub>5</sub> COOH	Benzoic acid
C <sub>6</sub> H <sub>5</sub> CH <sub>2</sub> -	C <sub>6</sub> H <sub>5</sub> CH <sub>2</sub> COOH	Phenylethanoic acid
C <sub>6</sub> H <sub>5</sub> CH <sub>2</sub> CH <sub>2</sub> -	C <sub>6</sub> H <sub>5</sub> CH <sub>2</sub> CH <sub>2</sub> COOH	3-phenylpropanoic acid

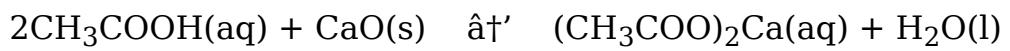
The phenyl group is regarded as a substituent, and its position in the chain is indicated by numbers.

## Dicarboxylic Acids

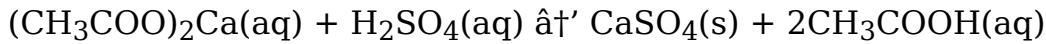
Some carboxylic acids have two "COOH groups. They are known as dicarboxylic acids (dioic acids). A common example is ethanedioic acid, HOOC.COOH.

## Manufacture of Ethanoic Acid

Ethanoic acid used to be manufactured from the products of the destructive distillation of wood (heating wood in the absence of air). The "pyrolygneous acid" which distills over contains ethanoic acid, methanol and water. Lime is added to the solution and it combines with the ethanoic acid. On distillation, methanol and water distill off, leaving calcium ethanoate behind. Acidification yields ethanoic acid.



(in pyrolygenous  
acid)



Nowadays, ethanoic acid is obtained from C<sub>5</sub> " C<sub>7</sub> alkanes by liquid phase air oxidation at high temperature and pressure.

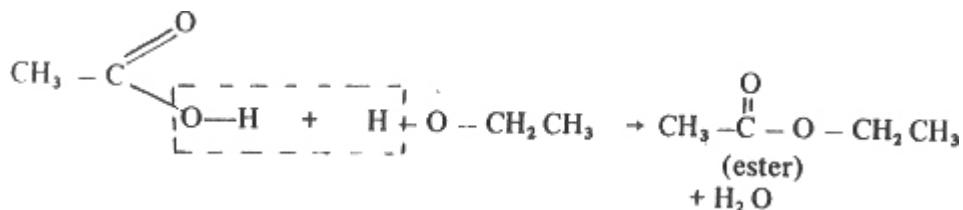
## Uses of Ethanoic Acid

- (i) Glacial ethanoic acid is used as a solvent.
- (ii) As a component of vinegar, it is used for food preservation.
- (iii) It is used industrially in the manufacture of cellulose ethanoate for photographic and motion picture films, rayon, etc.
- (iv) It is used in making vinyl ethanoate for the manufacture of emulsion paints; adhesives for wood and paper; for coagulating rubber latex; and for making inks and metal polishes for dyeing and printing cloth.

(v) It is used as an acid where mineral acids would be too strong.

## 6.3 ESTERS

In studying the properties of ethanoic acid (Experiment 6.2), we prepared an ester, ethyl ethanoate, by reacting an organic acid with an alkanol: ethanoic acid and ethanol. That compound was, however, not isolated from the reaction mixture. The reaction is an example of esterification. It is the reaction of an organic acid and an alkanol to form an ester. A water molecule is eliminated. Studies with isotopic oxygen indicate that the ‘OH group of the alkanoic acid and a hydrogen atom of the ‘OH group of the alkanol are eliminated as water.

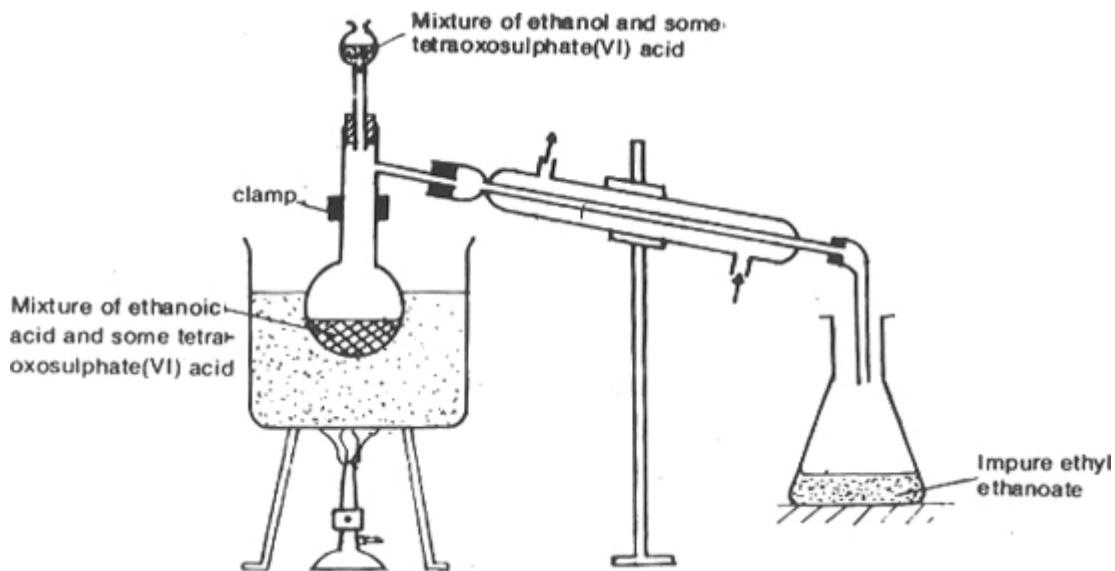


### Experiment 6.3: Preparation of Ethyl Ethanoate.

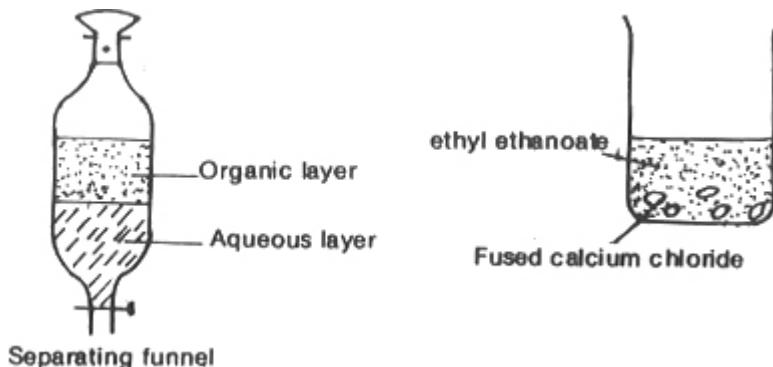
Mix equal amounts of ethanol and concentrated tetraoxosulphate(VI) acid by adding the acid, in small amounts to the alkanol. Put this mixture into a round-bottomed flask. Next, mix equal amounts of ethanoic acid and concentrated tetraoxosulphate(VI) acid. Put this mixture into a dropping funnel. Set up the apparatus shown in Figure 6.8(a). Add pieces of anti-bumping granules to the flask. Heat the flask in an oil bath.

While the mixture is boiling, add the ethanol-tetraoxosulphate(VI) acid mixture from a dropping funnel at the same rate as the ethyl ethanoate distills over. Stop distillation when all the mixture in the funnel has been exhausted. The distillate is impure ethyl ethanoate.

To purify the ester, shake the distillate with sodium trioxocarbonate(IV) solution in a separating funnel. This neutralizes any ethanoic acid in the distillate. Run off the lower aqueous layer. Again, shake the upper organic layer with calcium chloride solution. This removes the ethanol in the distillate. Run off the lower aqueous layer once more. Transfer the upper organic layer into a beaker and add fused calcium chloride to it, to dry it. Allow the solution to stand for some time, then filter off the solid calcium chloride. Finally, distill the organic reaction product and collect the pure ethyl ethanoate distilling over between 75 °C – 80°C.



(a) Distilling off ethyl ethanoate as it forms



*Figure 6.8: Preparation of ethyl ethanoate*

*Experiment 6.4: Investigating the Properties of Ethyl Ethanoate:*

- Smell the liquid and note its pleasant fruity odour.
- Boiling point:** Determine the boiling point of the liquid as was done for ethanoic acid. Ethyl ethanoate boils at  $77\text{ }^\circ\text{C}$  at atmospheric pressure.
- Hydrolysis:** Boil a mixture of about  $20\text{ cm}^3$  of ethyl ethanoate and  $100\text{ cm}^3$  of 10% sodium hydroxide solution in a  $250\text{ cm}^3$  round-bottomed flask fitted with a reflux condenser (Figure 6.9(a)). The ester will be hydrolysed into its constituents—ethanoic acid and ethanol; and the acid forms sodium ethanoate with the alkaline sodium hydroxide solution. After 30 minutes of boiling, allow the mixture to cool a little. Then connect a condenser to the flask for distillation. Distil the mixture (see Figure 6.9(b)) and collect the fraction distilling over between  $75$ – $80\text{ }^\circ\text{C}$ . This is the ethanol component.

When the distillate stops coming over and the temperature rises above  $80\text{ }^\circ\text{C}$ , stop heating. Acidify the residual solution with

dilute tetraoxosulphate(VI) acid. This frees ethanoic acid from the sodium ethanoate.

Continue the distillation, and collect the fraction distilling over between 115 °C – 120°C, as ethanoic acid.

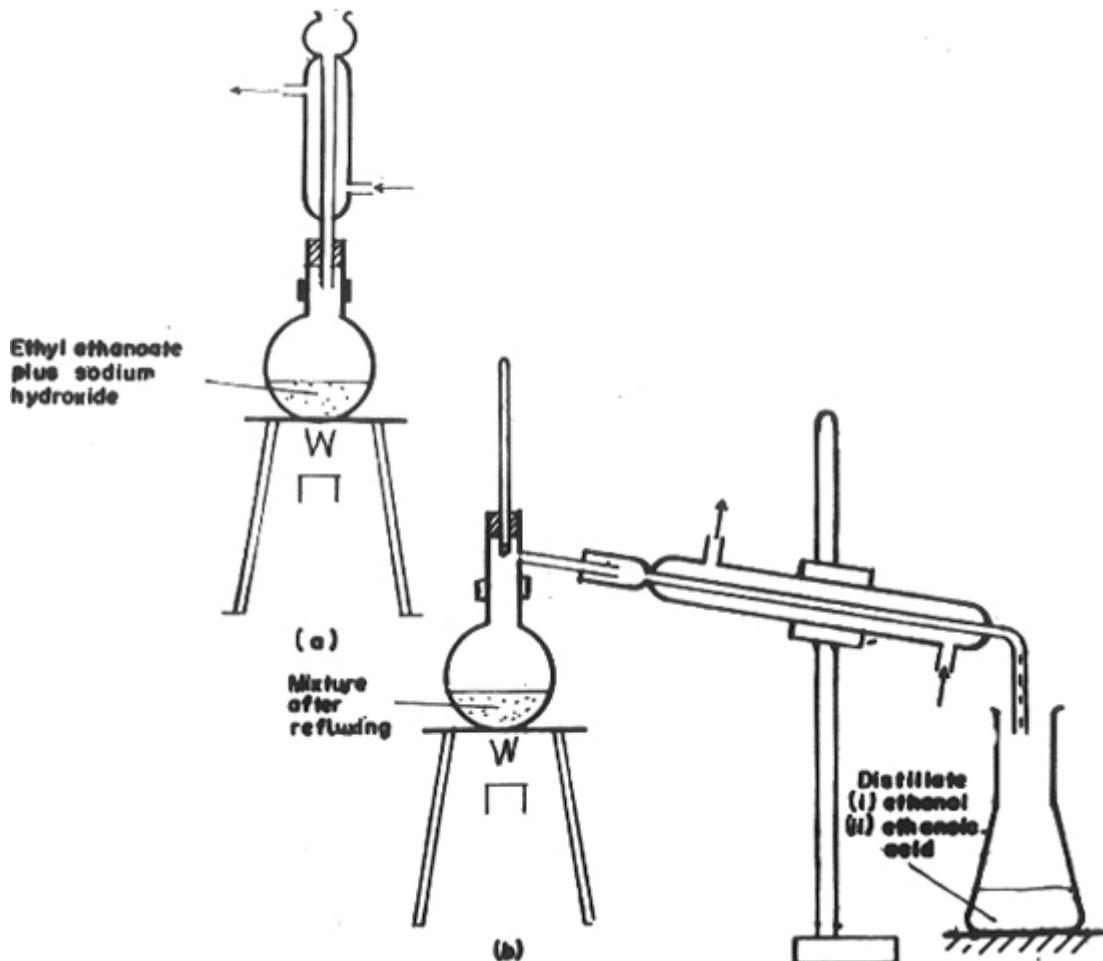
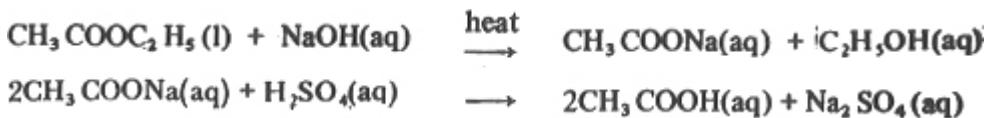


Figure 6.9: Alkaline hydrolysis of ethyl ethanoate.



The acid-catalysed hydrolysis is reversible and presents a separation problem.



### Uses of Ethyl Ethanoate:

- (i) It is used as a solvent for paints and varnish, to hasten drying.
- (ii) In making perfumes.

### Nomenclature of Esters

Esters are named by indicating the alkyl group of the parent alkanol as a prefix, then changing the suffix “oic acid, of the parent alkanoic

acid to ‘oate. For example,  $\text{HCOOCH}_3$  is methyl methanoate, indicating that it is derived from methanol and methanoic acid. More examples are given in Table 6.4.

**TABLE 6.4: Nomenclature of esters**

Alkanol	Alkanoic acid	Ester	Name of ester
$\text{CH}_3\text{OH}$	$\text{CH}_3\text{COOH}$	$\text{CH}_3\text{COOCH}_3$	Methyl ethanoate
$\text{CH}_3\text{OH}$	$\text{CH}_3\text{CH}_2\text{COOH}$	$\text{CH}_3\text{CH}_2\text{COOCH}_3$	Methyl propanoate
$\text{CH}_2\text{H}_5\text{OH}$	$\text{CH}_3\text{CH}_2\text{COOH}$	$\text{CH}_3\text{CH}_2\text{COOC}_2\text{H}_5$	Ethyl propanoate
$\text{C}_3\text{H}_7\text{OH}$	$\text{CH}_3\text{COOH}$	$\text{CH}_3\text{COOC}_3\text{H}_7$	Propyl ethanoate
$\begin{array}{c} \text{CH}_3\text{CHOH} \\   \\ \text{CH}_3 \end{array}$	$\text{CH}_3\text{COOH}$	$\begin{array}{c} \text{CH}_3\text{COOCHCH}_3 \\   \\ \text{CH}_3 \end{array}$	2-propyl ethanoate
$\text{C}_2\text{H}_5\text{OH}$	$\begin{array}{c} \text{CH}_3-\text{CHCOOH} \\   \\ \text{CH}_3-\end{array}$	$\begin{array}{c} \text{CH}_3\text{CHCOOC}_2\text{H}_5 \\   \\ \text{CH}_3 \end{array}$	Ethyl-2-methyl propanoate

### Properties of Esters

- (a) Esters are sweet-smelling liquids or solids.
- (b) They are usually soluble in ethanol.
- (c) They are generally unreactive.
- (d) Their only important reaction is hydrolysis which can be acid or base catalysed.

The general formula for esters is  $\text{RCOOR}'$  where R and R' may be the same or different alkyl, or aryl groups. Hence, the hydrolysis reaction may be represented as:



## 6.4 FATS AND OILS

Animal fats and vegetable oils are esters of long-chain alkanoic acids (called fatty acids) and propan ‘1,2,3’ triol (a trihydric alcohol). Table 6.5 lists the common fats/oils and the fatty acids from which they are formed.

**TABLE 6.5: Common glycerides and their fatty acids**

Fatty acids	Glyceride (Fat/Oil)
$\text{CH}_3(\text{CH}_2)_{14}\text{COOH}$  Hexadecanoic acid (Palmitic acid)	$\begin{array}{c} \text{CH}_2-\text{OOC}(\text{CH}_2)_{14}\text{CH}_3 \\   \\ \text{CH}-\text{OOC}(\text{CH}_2)_{14}\text{CH}_3 \\   \\ \text{CH}_2-\text{OOC}(\text{CH}_2)_{14}\text{CH}_3 \end{array}$ Propan-1,2,3-trihexadecanoate (Propan-1,2,3-tripalmitate)
$\text{CH}_3(\text{CH}_2)_{16}\text{COOH}$  Octadecanoic acid (Stearic acid)	$\begin{array}{c} \text{CH}_2\text{OOC}(\text{CH}_2)_{16}\text{CH}_3 \\   \\ \text{CH OOC}(\text{CH}_2)_{16}\text{CH}_3 \\   \\ \text{CH}_2\text{OOC}(\text{CH}_2)_{16}\text{CH}_3 \end{array}$ Propan-1,2,3-trioctadecanoate (Propan-1,2,3-tristearate)
$\text{CH}_3(\text{CH}_2)_7\text{CH}=\text{CH}(\text{CH}_2)_7\text{COOH}$ Octadec-9-enoic acid [Oleic acid (unsaturated)]	$\begin{array}{c} \text{CH}_2\text{OOC}(\text{CH}_2)_7\text{CH}=\text{CH}(\text{CH}_2)_7\text{CH}_3 \\   \\ \text{CHOOC}(\text{CH}_2)_7\text{CH}=\text{CH}(\text{CH}_2)_7\text{CH}_3 \\   \\ \text{CH}_2\text{OOC}(\text{CH}_2)_7\text{CH}=\text{CH}(\text{CH}_2)_7\text{CH}_3 \end{array}$ Propan-1,2,3-trioctadeo-9-enoate (Propan-1,2,3-trioleate)

Esters of saturated fatty acids are solids or semi-solids (fat) at room temperature, while esters of unsaturated fatty acids such as oleic acid, are liquid (olis) at room temperature. Fats and oils contain mixtures of these glycerides.

## Manufacture of Margarine

The catalytic hydrogenation of vegetable oils at  $200^\circ\text{C}$  and  $2\times 10^5$  atmosphere pressure converts the oils to solid fat. Addition of vitamins A and D plus milk improves the nutritional value of the solid which is then called margarine.

## Soap:

The alkaline hydrolysis of fats and oils is termed saponification. The sodium or potassium salts which are formed are known as soaps. Sodium salts of fatty acids are hard soaps, but the potassium salts are soft soaps.

### Experiment 6.5: Laboratory Preparation of Soap:

Boil about  $5\text{ cm}^3$ , of palm oil in a beaker. Add  $25\text{ cm}^3$  of 2 M sodium hydroxide to it, stirring during the addition. Continue to boil and stir until the oil layer disappears. Allow to cool. Add about  $25\text{ cm}^3$  of brine (saturated sodium chloride solution) to it. Soap, sodium hexadecanoate (sodium palmitate), separates out from solution as a

white solid. Decant the liquid and wash the solid with more brine, then with a little water. Test a little of it for lathering property by shaking with water.

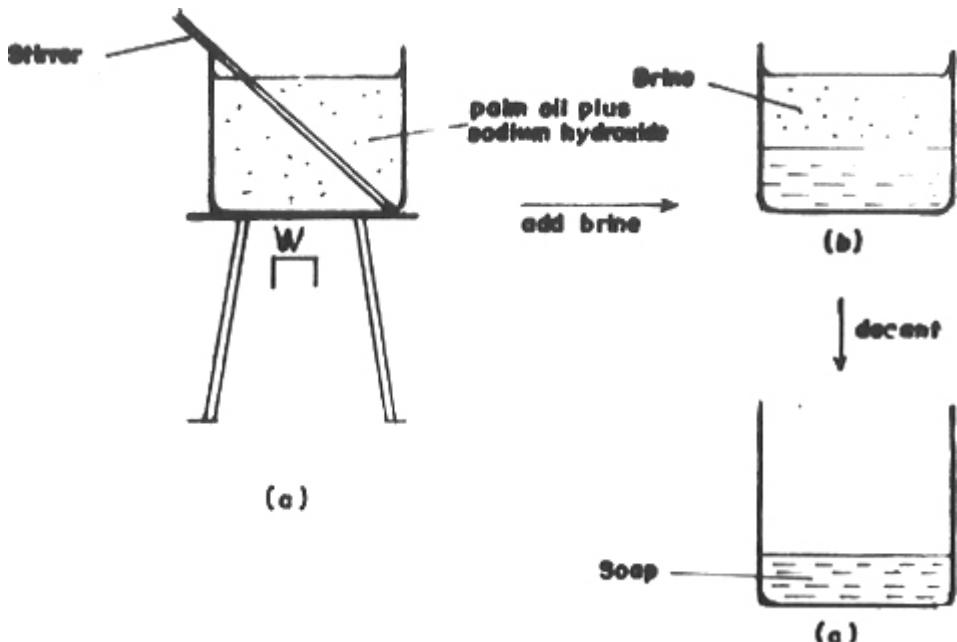
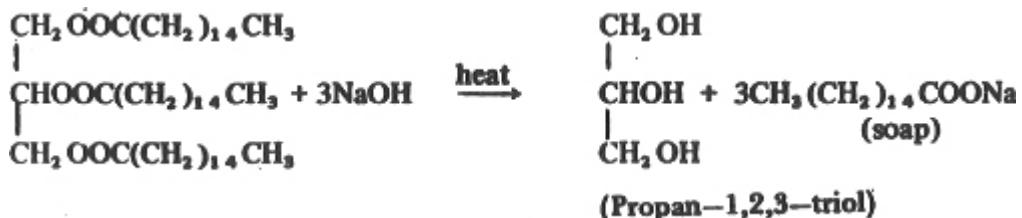


Figure 6.10: Laboratory preparation of soap



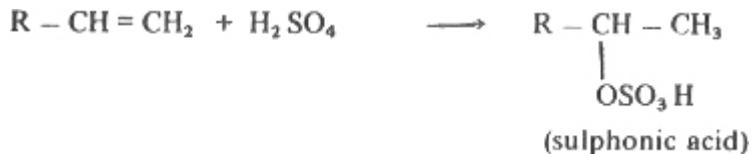
**Local soap making:** Local soap is made from potash got from ash. Dry palm husks are burnt and the ash collected. Water is added to it and the mixture stirred, then filtered. The filtrate is added to boiling palm oil. While heating the mixture, it is stirred continuously till it becomes viscous. A brownish-black soap is formed on cooling the hot mixture. This is really an impure soft soap. It contains both solid impurities from the ash, and glycerol (propan-1,2,3-triol), the by-product of saponification.

**Industrial manufacture of soap:** In industry, soap is made by passing calculated quantities of vegetable oil and caustic soda (sodium hydroxide) through a mixer, into an open tank. Here, the mixture is boiled with steam, then brine is added to the resulting viscous liquid and boiling is continued for some time. Soap precipitates out as a curd. The process of precipitating out soap from the product of saponification is termed **â€œsalting outâ€**.

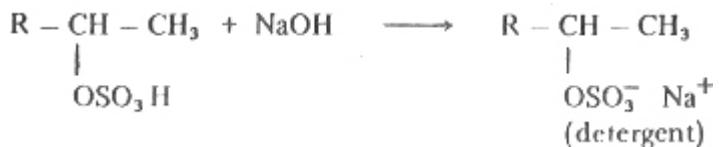
Liquid glycerol (propan-1,2,3-triol) dissolved in brine, is poured off and the curd boiled with water to remove excess salt from the soap. Soap settles out on standing for about four days. It floats on

the water containing a small amount of salt. The water is pumped out, and perfumes and colouring matter are added to the soap. It is then pressed into bars, cut into tablets, stamped with trade marks, and wrapped.

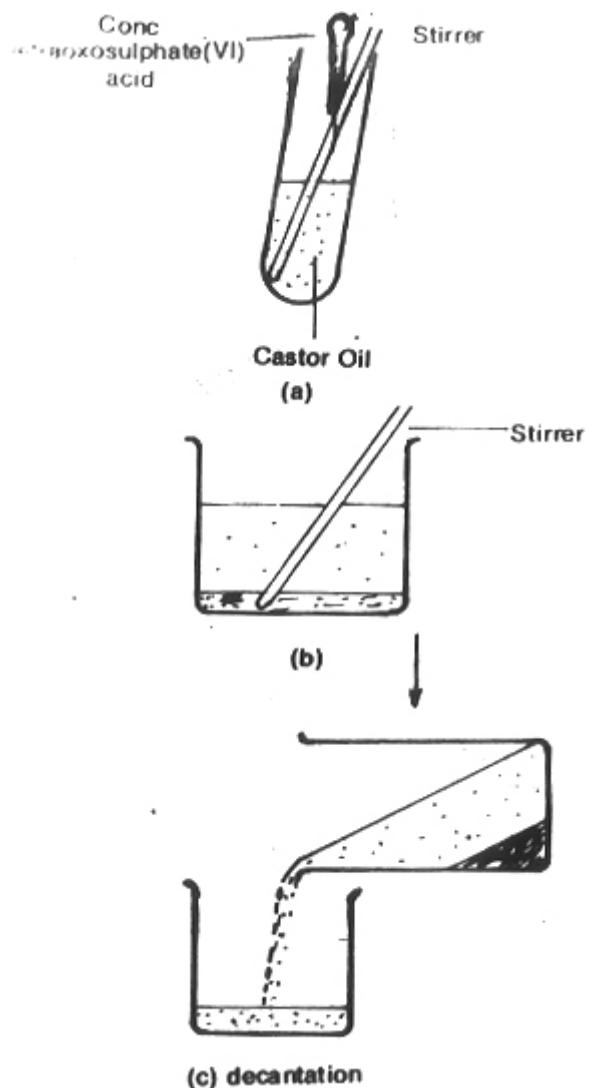
**Detergents:** Detergents are made from alkenes containing 13-18 carbon atoms in the chain by treating it with 90% tetraoxosulphate(VI) acid, in the presence of hydrogen chloride gas as catalyst. The reaction occurring is known as sulphonation. It can be represented by the equation.



The sulphonic acid formed is then treated with sodium hydroxide to yield its sodium salt.



This sodium salt of sulphonic acid is a detergent.

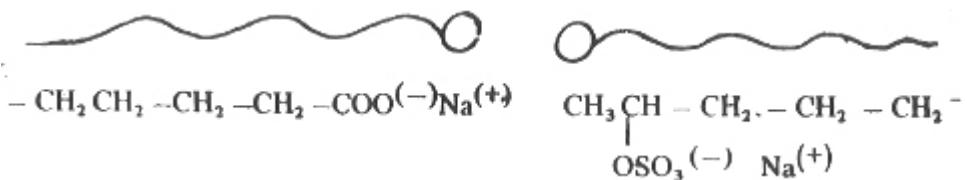


*Figure 6.11: Making of a detergent from castor oil*

#### *Experiment 6.6: To make a Detergent from Castor Oil*

Pour 1 cm<sup>3</sup> of castor oil into a test-tube. With a dropping pipette, add 2 cm<sup>3</sup> of concentrated tetraoxosulphate(VI) acid to it. Stir the mixture with a glass rod. Note that the test-tube becomes hot and that the mixture darkens due to charring. Pour this mixture into 10 cm<sup>3</sup> of cold water contained in a beaker, and stir. Decant the liquid. The solid remaining is a detergent. Test its lathering property by shaking a little of it with water.

**Cleansing action of soaps and detergents:** Soaps and detergents have polar ends and long non-polar tails. The polar ends (heads), are soluble in water while the non-polar tails are soluble in oil. Dirts adhere to fabrics through oil films.



*Figure 6.12: Structures of soap and detergent showing heads and non-polar tails.*

When soaps and detergents are used for washing, the polar head dissolves in water while the non-polar tail dissolves in the oil. Thus the oil film is dislodged along with the dirt.

Water containing  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$  or  $\text{Fe}^{2+}$  is said to be “hard” because it does not lather easily with soap. This is so because the fatty acid salts of these ions are insoluble in water. A lather forms only when these ions are completely precipitated out of solution. The sulphonates of these ions, on the other hand, are soluble in water. As a result, detergents easily form lather in both hard and soft water.

## 6.5 Amides

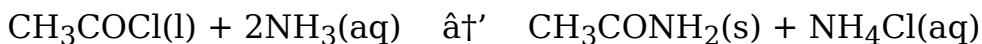
Various derivatives of alkanoic acids may be formed when the “OH group in  $\text{C}-\text{OH}$  is replaced. The replacement of this “OH group by an amino group, “ $\text{NH}_2$ , gives an amide.

### *Experiment 6.7: Preparation and study of the Properties of Ethanamide*

Place 1 cm<sup>3</sup> of glacial ethanoic acid into a round-bottomed flask. Add 5 cm<sup>3</sup> of thionyl chloride to it and reflux for 30 minutes (Figure 6.13). (Thionyl chloride is used instead of phosphorus(V) chloride because all other products are gaseous and escape during the reaction).

After refluxing, transfer the product into a distillation flask. Distil off excess thionyl chloride at 78°C, (Figure 6.13(b)), then cautiously add concentrated ammonia solution (20 times the volume of the residue). Warm for a few minutes, then cool. Filter off any solid formed. If no solid forms on cooling, evaporate to dryness on a water bath. (Figure 6.13(c)).

A white crystalline solid is left. The solid is impure ethanamide. To purify, redissolve it in just enough hot ethanol to make a saturated solution. Filter the hot solution, then cool the filtrate. Pure crystals of ethanamide separate out of solution. Filter, and dry the crystals in a dessicator.



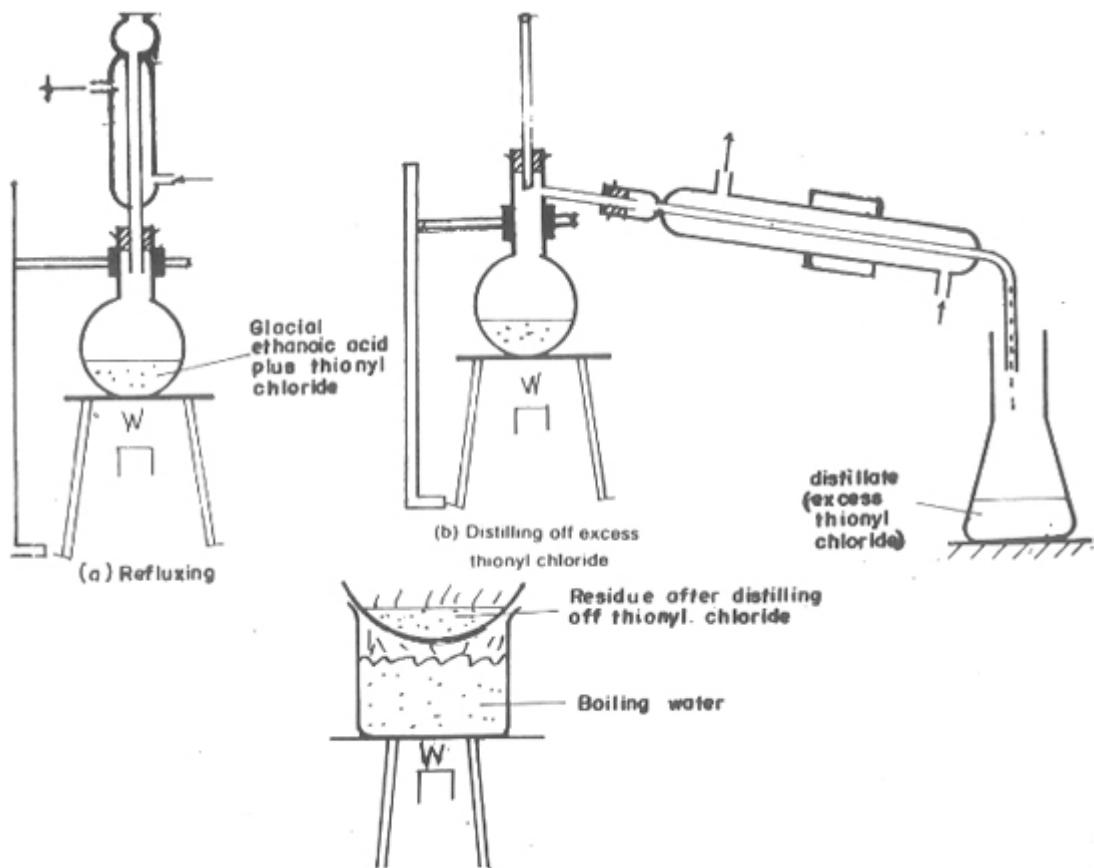
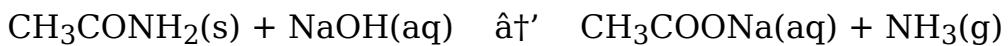


Figure 6.13: Preparation of ethanamide.

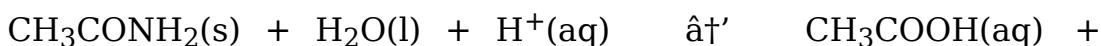
### Properties of Ethanamide:

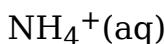
- Melting point:** Determine the melting point of the pure ethanamide after drying it. Note that it melts at  $82\text{A}^{\circ}\text{C}$ .
- Solubility in water:** Shake a little ethanamide in water. Note that the solid dissolves readily.
- Acidic/basic behaviour:** Test the resulting solution from (ii) above with litmus paper (blue and red). There is no effect on either, showing that ethanamide is neutral.
- Hydrolysis:** Take 0.5 g of ethanamide into a test-tube and add about  $5\text{ cm}^3$  2 M sodium hydroxide to it. Warm the mixture. A colourless pungent gas is evolved. Test the gas with moist red litmus. The litmus turns blue, showing that the gas is ammonia.

Ammonium salts liberate ammonia on treating with sodium hydroxide, without warming. Amides have to be warmed before ammonia is given off. The reaction is a hydrolysis, similar to the hydrolysis of esters.

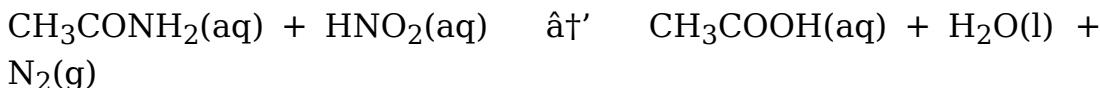


The hydrolysis can also occur in acid medium.





- (v) **Action of dioxonitrate(III) acid:** Dissolve about 1 g of sodium dioxonitrate(III) in water in a test-tube. Cool the solution in ice. Also cool 1 cm<sup>3</sup> of dilute hydrochloric acid in another test-tube. Add the 1 cm<sup>3</sup> cold hydrochloric acid to the sodium dioxonitrate(III) solution. When the initial reaction has subsided, add a cold solution of ethanamide. Effervescence occurs as nitrogen gas is evolved.

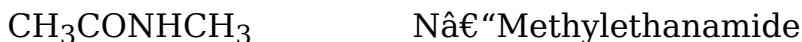


## Nomenclature of Amides

Primary Amides are named by changing the suffix “oic acid of the acid to “amide. Examples are:



Secondary and tertiary amides are named by indicating the alkyl group(s) on nitrogen with the letter N.



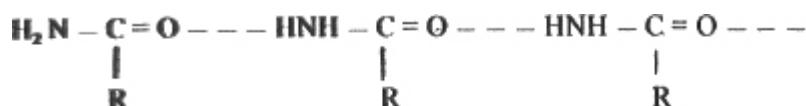
## Properties of Amides

Amides show a gradation in physical properties as illustrated in Table 6.6.

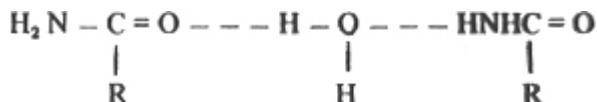
**Table 6.6: Physical properties of primary amides**

Name of amide	Formula	M.P.(°C)	B.P.(°C)
Methanamide	HCONH <sub>2</sub>	3	193
Ethanamide	CH <sub>3</sub> CONH <sub>2</sub>	82	221
Propanamide	CH <sub>3</sub> CH <sub>2</sub> CONH <sub>2</sub>	81	213
Butanamide	CH <sub>3</sub> CH <sub>2</sub> CH <sub>2</sub> CONH <sub>2</sub>	116	216
Benzamide	C <sub>6</sub> H <sub>5</sub> CONH <sub>2</sub>	182	290

- (a) With the exception of methanamide, all other primary amides (general formula: RCONH<sub>2</sub>) are crystalline solids, due to hydrogen bonding.



- (b) The lowest molar mass members, methanamide and ethanamide, are soluble in water, due to hydrogen bonding.

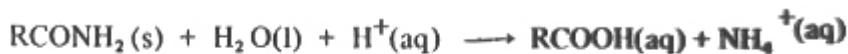


- (c) Primary amides are neutral because the electron pair on nitrogen is not made available to protons due to the electron-withdrawing effect of the carbonyl bond.

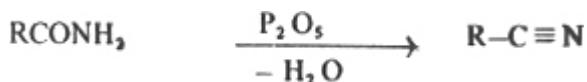


N,N-dialkyl amides are, however, basic because the electron withdrawing effect of the carbonyl bond is counterbalanced by electron donating alkyl groups.

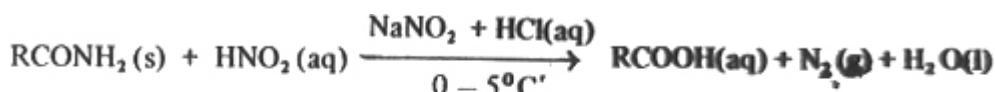
- (d) **Hydrolysis:** Amides undergo hydrolysis in acid and in basic media, like esters.



- (e) **Dehydration:** Strong dehydrating agents such as phosphorus(V) oxide eliminate water from amides, forming nitrites.



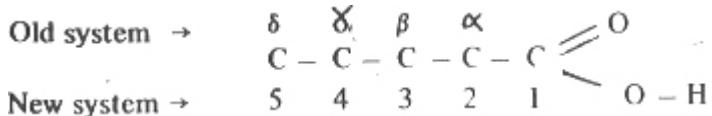
- (f) **Reaction with dioxonitrate(III) acid:** With dioxonitrate(III) acid at low temperatures, amides liberate nitrogen. Dioxonitrate(III) acid is unstable. It is generated in situ by the reaction between sodium dioxonitrate(III) and hydrogen chloride acid (hydrochloric acid).



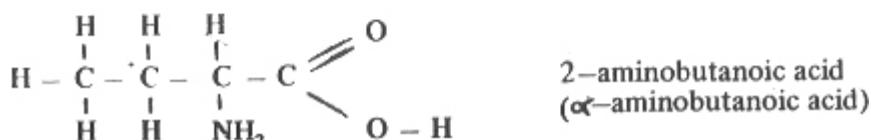
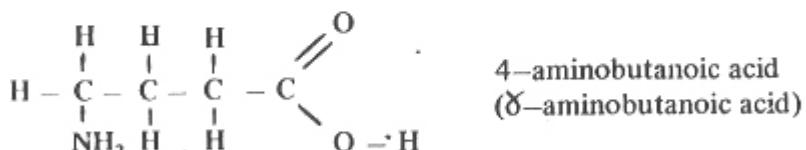
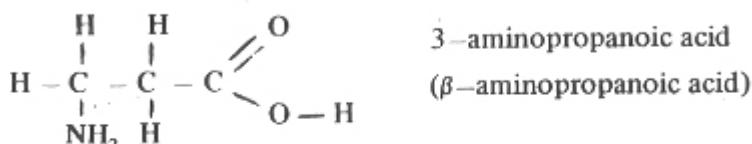
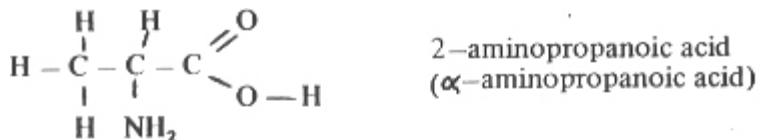
## 6.6 Amino Acids

Amino acids are organic compounds containing two types of functional groups, the  $\text{COOH}$  (carboxylic acid), and the  $\text{NH}_2$  (amine) groups. The  $\text{COOH}$  group must necessarily be at the end of a carbon chain. The  $\text{NH}_2$  group, on the other hand, may be on the second, third, fourth (etc, other than the first) carbon atom of the chain. In the old naming system, the carbon chain of the amino acid

was numbered with Greek letters. The IUPAC system of naming involves numbering the carbon atoms in a chain with numerals, starting from the  $\text{COOH}$  carbon atom. The position of the amine group is indicated by the numeral of the carbon atom to which it is attached. The two systems of identification are illustrated below:



Examples of the naming systems are as follows:

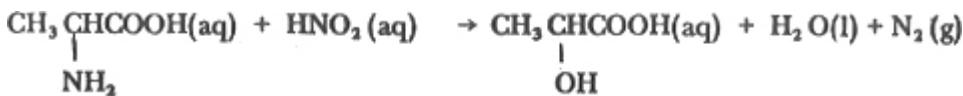


## Properties of Amino Acids

- (a) Amino acids are usually white crystalline compounds.
- (b) They have high melting points and are often soluble in water, due to hydrogen-bonding.
- (c) They show the reactions of both carboxylic acids and amines as illustrated in Experiment 6.6.

### Experiment 6.8: Investigating the Reactions of Amino Acids.

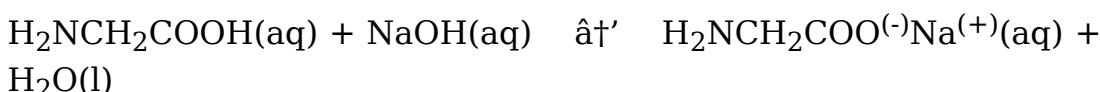
- (i) Dissolve about 0.2 g of aminoethanoic acid (glycine) in 2 cm<sup>3</sup> of water. Cool the solution in ice water. Also cool about 2 cm<sup>3</sup> of aqueous solution of sodium dioxonitrate(III) in ice water. Mix both solutions. Then add dilute hydrochloric acid to the mixture. Effervescence occurs as nitrogen gas is liberated, indicating the presence of the amine group Nitrogen is evolved when amino acids react with dioxonitrate(III) acid generated by the action of hydrochloric acid or sodium dioxonitrate(III).



- (ii) Add about 0.5 g of 3-aminopropanoic acid to dilute hydrogen chloride acid (hydrochloric acid). A clear solution results due to the formation of a soluble salt between the amino group and the inorganic acid.

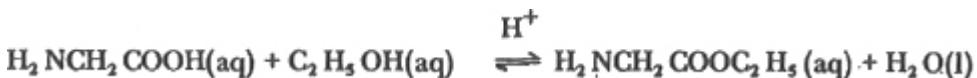


- (iii) Add about 0.5 g of aminoethanoic acid to 2 cm<sup>3</sup> of dilute sodium hydroxide solution. A clear solution also results. The carboxyl group forms a salt with the alkali.



- (iv) Dissolve about 0.1 g of aminoethanoic acid in 2 cm<sup>3</sup> of water. Add a drop of concentrated tetraoxosulphate(VI) acid, then 2 cm<sup>3</sup> of ethanol. Warm the mixture and pour it into 5 cm<sup>3</sup> of cold water in a beaker. A sweet smelling odour is produced.

The sweet-smell noticed indicates the formation of an ester between the "COOH group of the amino acid and ethanol, in the presence of tetraoxosulphate(VI) acid as catalyst.



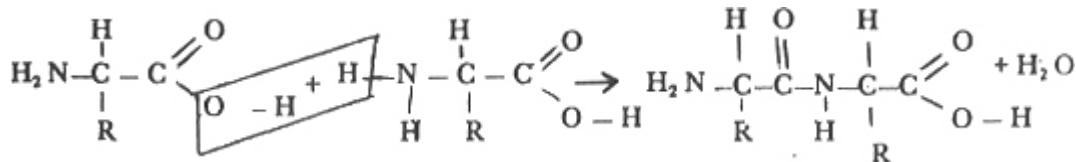
Reactions (i) and (ii) indicate the properties of the amino group while reactions (iii) and (iv) indicate the reactions of the carboxyl group present in amino acid. Aqueous solutions of aminoethanoic acid and 3-aminopropanoic acid are neutral due to the formation of a dipolar ion (zwitterion), with a zero net charge.



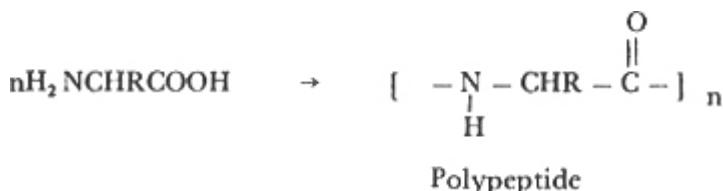
In acid medium the dipolar ion exists as H<sub>3</sub><sup>(+)</sup>NCH<sub>2</sub>COOH. while in alkaline medium it exists as H<sub>2</sub>NCH<sub>2</sub>COO"

## The Peptide Link

Recall that condensation polymerization occurs by the elimination of small molecules such as water, hydrogen chloride and ammonia, when bifunctional (or polyfunctional) molecules polymerize. When the "COOH group of one amino acid molecule reacts with the "NH<sub>2</sub> of another molecule, a water molecule is eliminated and an amide link results.



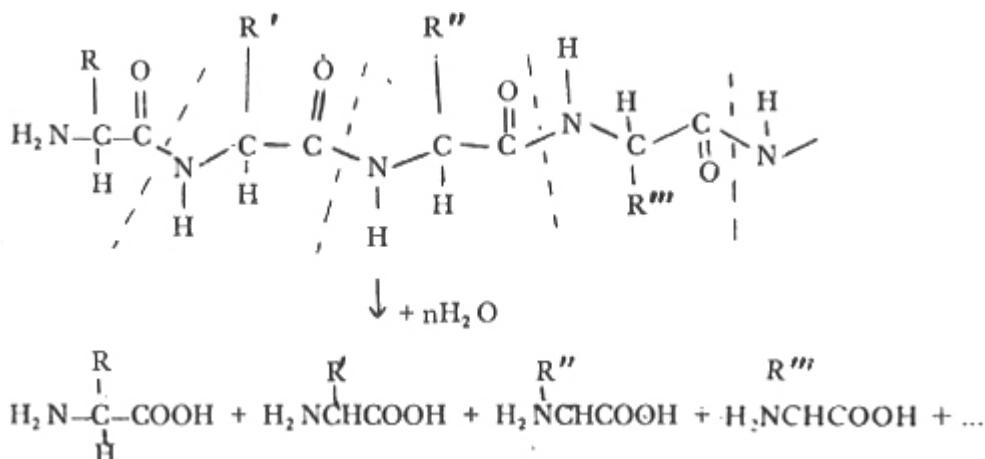
Repetition of this condensation reaction many times, results in the formation of a polypeptide.



**Proteins:** Proteins are products of condensation polymerization of 2-amino acids ( $\text{I}\pm$ -amino acids). They contain between 100 and 50,000 individual amino acid molecules per molecule of protein. Their molar masses are therefore very large.

Proteins are constituents of all living tissues. Body-building foods such as lean meat, eggs and beans contain large percentages of proteins. Haemoglobin which is present in blood is a form of protein. Many enzymes are also proteins.

**Hydrolysis of proteins:** This involves treating proteins with mineral acids which leads to the rupture of the peptide link. The constituent amino acids are thereby proteins. Hydrolysis of proteins can also occur with strong bases and with enzymes.

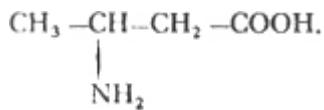


### *Experiment 6.9: Denaturing Protein:*

Shake the white of a raw egg with 20% aqueous sodium chloride solution. Filter the albumen solution through a clean piece of filter paper. Boil the filtrate. A white precipitate of denatured protein is formed.

### **Exercise 6.2:**

Name the amino acid:



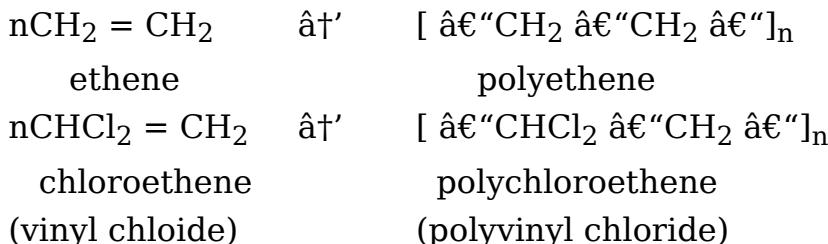
Why is it soluble in both sodium hydroxide solution and dilute hydrochloric acid solution?

## 6.7 Giant Molecules and Polymerization

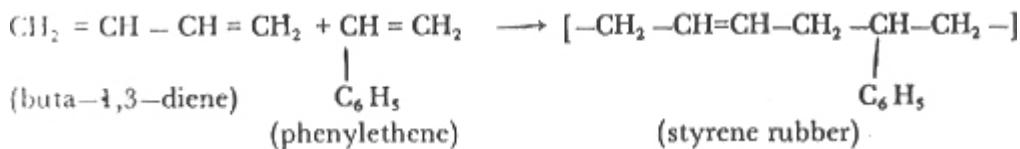
Giant molecules are the products of polymerization. We defined polymerization in Book 2 as the combination of a large number of small molecules (monomers) to form a large molecule (polymer). Polymers have high molar masses. Two types of polymerization were identified: addition and condensation polymerization.

### Addition Polymerization

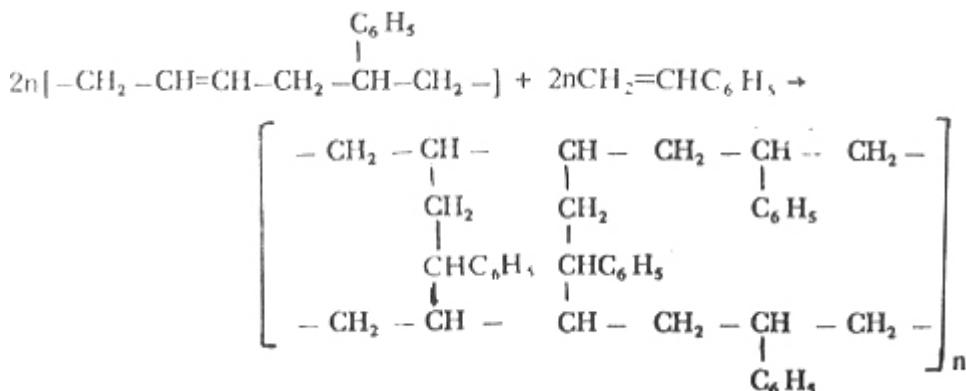
This occurs between molecules with multiple bonds. If it is between molecules of the same compound, a homopolymer results. Examples are:



If addition polymerization occurs between two or more different alkenes (or alkynes), a copolymer results. For example,



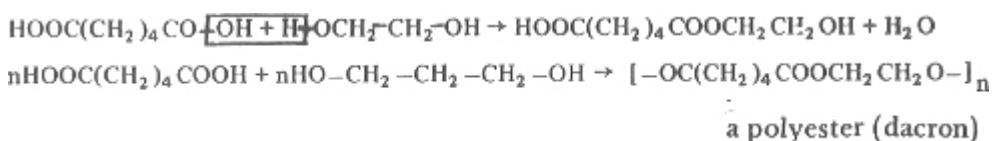
In these two cases, the polymers are straight-chain macromolecules. When the copolymer contains a double bond as in styrene rubber, cross-linking between chains of macromolecules may occur, leading to formation of a harder polymer.



## Condensation Polymerization

This is polymerization between two bifunctional (or polyfunctional) molecules with the elimination of small molecules such as water hydrogen chloride or ammonia. If the monomer(s) is/are bifunctional, a linear polymer is formed.

Example:



The polyester appears in the form of a thread which can be woven into fabric. The polymerization of a trifunctional compound and a difunctional one (or another trifunctional compound) results in the formation of a cross-linked polymer.

## 6.8 Plastics

Plastics are made from organic polymers by pouring the molten forms of the polymers into a mould where they set, on cooling. Fillers, such as saw dust, are added to the molten polymer to increase the strength of the plastic and to reduce cost. Plasticizers and pigments are also added to increase flexibility, and to give desired colours respectively.

There are two classes of plastics: thermosoftening and thermosetting plastics.

*Experiment. 6.10: Investigating the behaviour of Thermosoftening Plastics:*

Heat an old nylon comb, or a piece from an old plastic bucket, till it melts. Pour the molten form into a small tin can and allow it to cool. It takes the shape of the can on resolidifying. This shows that the nylon comb or bucket is made of a thermosoftening plastic material. Thermosoftening plastics are softened by heat and can be remoulded. They harden again on cooling. All alkene-based polymers, such as nylon and terylene are thermosoftening plastics. Cross-linked polymers such as epoxy resins and bakelite, cannot be softened and remoulded because they are thermosetting plastics.

Thermosetting plastics cannot be softened by heat.

## 6.9 Polyamides

The peptide linkage which results from the condensation reaction between a "COOH group of one amino acid molecule and the "NH<sub>2</sub> group of another molecule gives rise to a giant molecule such as a protein. Hydrogen-bonding between the residual "NH and "C = O groups in the giant molecule holds the protein chains in coils

called helix.

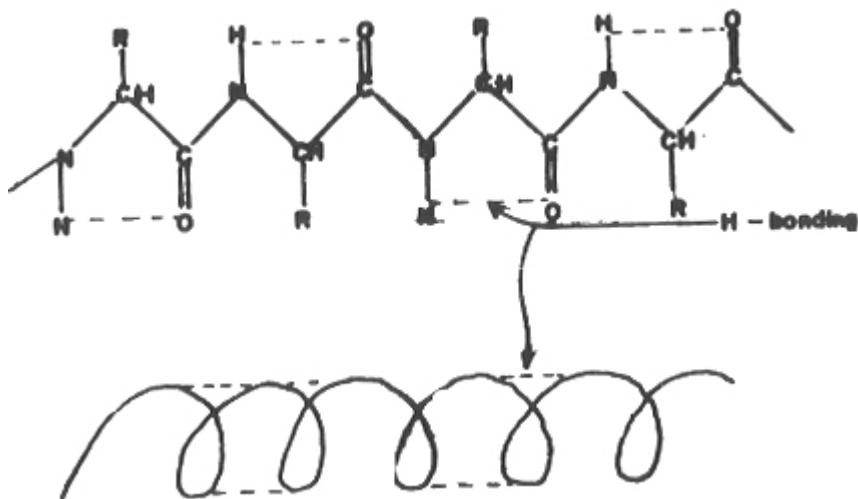
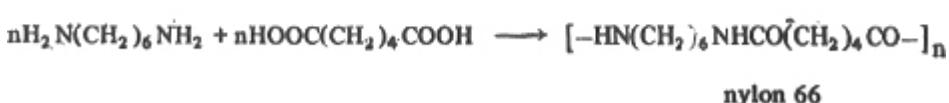
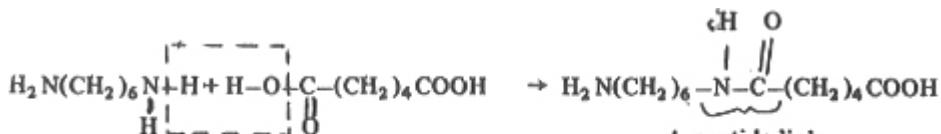


Figure 6.14: An  $\hat{I}\pm$ -helix

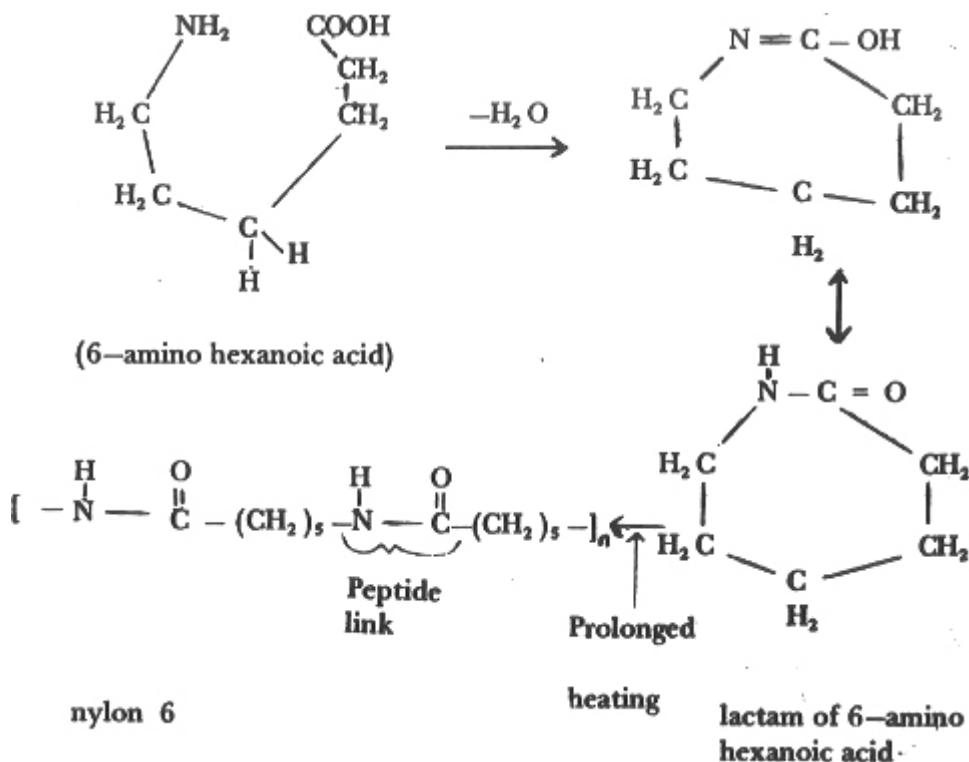
### Polyamide Fibres

Nylon is a man-made polyamide. Nylon-66 was the first synthetic fibre to be made commercially. It is crystallized out of a mixture of hexane-1,6-dioic acid solution in tetrachloromethane and hexane-1,6-diamine solution in water.



The linear polymer is called nylon 66 because its two monomers contain chains of six carbon atoms each. It is woven into the popular fabric called nylon.

Nylon 6 is a polyamide fibre made by prolonged heating of the lactam, cyclic amide, of 6-amino hexanoic acid (coprolactam).



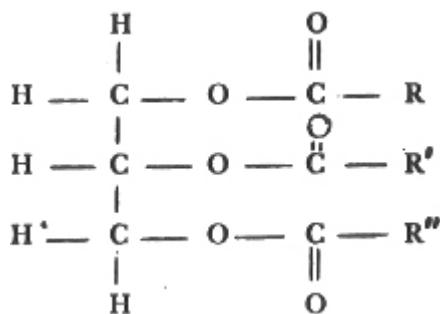
## 6.10 Basic Classes of Giant Molecules in Living Things

Many of the things needed to sustain life are giant molecules made by the repetition of simple units. They fall under the following classes: "fats, proteins, carbohydrates and enzymes.

### Fats

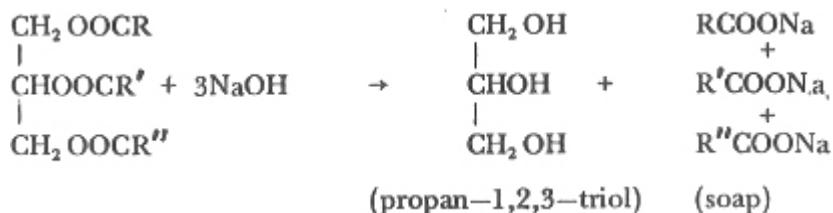
These are the glyceryl esters of fatty acids (long chain alkanoic acids). The common fatty acids which form oils with propanetriol include hexadecanoic acid (palmitic acid),  $\text{CH}_3(\text{CH}_2)_{14}\text{COOH}$ ; octadecanoic acid (stearic acid),  $\text{CH}_3(\text{CH}_2)_{16}\text{COOH}$ ; octadecenoic acid (oleic acid),  $\text{CH}_3(\text{CH}_2)_{7}\text{CH}=\text{CH}(\text{CH}_2)_{7}\text{COOH}$ ; and tetradecanoic acid (myristic acid),  $\text{CH}_3(\text{CH}_2)_{12}\text{COOH}$ . The unsaturated acids tend to form liquid esters (oils), while the saturated ones form solid or semi-solid esters. Hence in the manufacture of margarine, hydrogen is added to a liquid ester (oil) to harden it.

The general structure of fats is:



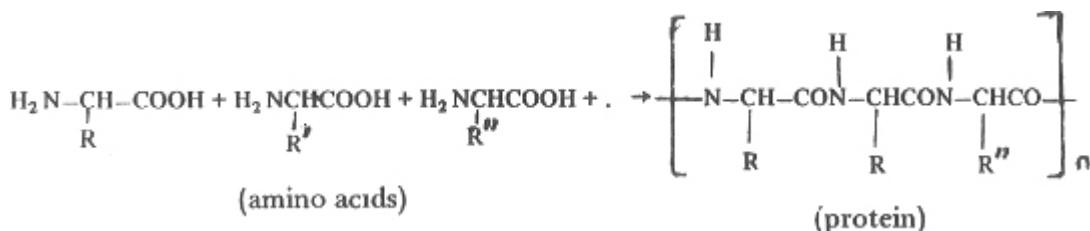
Where R, R' may be the same or different alkyl groups. Palm oil contains palmitic acid, oleic acid and small quantities of linoleic and stearic acids components in the ester.

Fats are essential to living things because they are taken as food. Their metabolism liberates heat energy. Alkaline hydrolysis of fats yields soap which is a sodium/potassium salt of the fatty acid, and also yields propanetriol (glycerol). The manufacture of soap has been discussed in an earlier section.

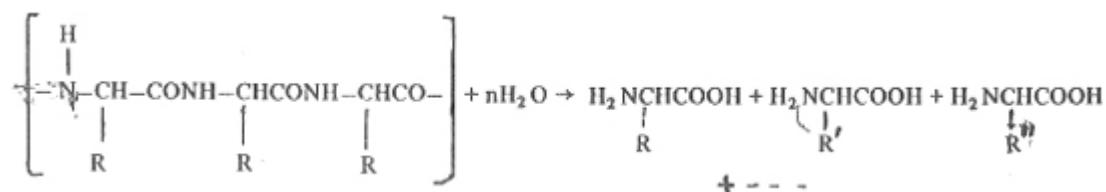


Proteins

These are the products of the condensation polymerization of amino acids.



Hydrogen-bonding between the hydrogen atoms of the residual  $\text{NH}$  and the carbonyl groups of the peptide link holds the protein chains in a helix structure. The hydrolysis of proteins produces the composite amino acids.



## *Experiment 6.11: Test for Proteins (and for the Polypeptide link):*

Shake the white of raw egg with six times its volume of 20% sodium chloride solution, then filter the mixture through a clean piece of cloth. Use portions of the filtrate for the following tests:

- (i) To  $1\text{ cm}^3$  of the filtrate add  $1\text{ cm}^3$  of concentrated trioxonitrate(V) acid. A yellow colour is formed. Add excess ammonia solution to the mixture. The colour changes to orange. This is the xanthoproteic test for protein.
  - (ii) To another  $1\text{ cm}^3$  portion of the filtrate, add 2 drops of copper(II) tetraoxosulphate(IV) solution, then  $2\text{ cm}^3$  of 2 M sodium hydroxide

solution. A violet or pink colour forms indicating the presence of a peptide link. This is the **Biuret test**.

- (iii) To 2 cm<sup>3</sup> of the filtrate, add 3 drops of ninhydrin solution, then warm. A blue colour develops to show the presence of amino acids and polypeptides.
- (iv) Add 2 drops of mercury(II) trioxonitrate(V) solution and a drop of dilute tetraoxosulphate(VI) acid to 1 cm<sup>3</sup> of the protein solution. Boil the mixture, then cool. Add a drop of sodium dioxonitrate(III) solution. A red colour develops, indicating the presence of tyrosine in the protein. This is the **Millonâ€™s test**.

## Carbohydrates

Carbohydrates are naturally occurring compounds containing carbon, hydrogen and oxygen with the general formula: C<sub>n</sub>(H<sub>2</sub>O)<sub>y</sub>. The ratio of hydrogen to oxygen is 2:1 as in water.

### *Experiment 6.12: Investigating some Properties of Carbohydrates:*

- (i) Heat a little of each of the following carbohydrates with copper(II) oxide in dry test-tubes: cane sugar, glucose, starch and cotton wool. Pass the gas evolved in each case into lime water, and test the liquid condensate near the mouth of the test-tube with anhydrous copper(II) tetraoxosulphate(VI).

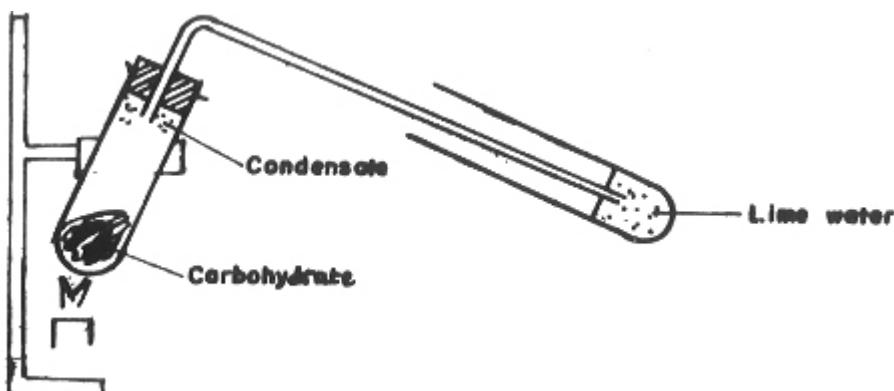


Figure 6.15: Action of heat on carbohydrates.

The gas evolved turns lime water milky, showing that it is carbon(IV) oxide. The condensate turns anhydrous copper(II) tetraoxosulphate(VI) from white to blue because it is water. Therefore, carbohydrates contain carbon and hydrogen.

The demonstration does not show the presence of oxygen. To show the presence of oxygen, and to determine the empirical formula of the carbohydrate, a quantitative experiment needs to be performed to find out how much water and carbon(IV) oxide are produced from a known mass of carbohydrate, and the mass of residue left out of a known mass of the copper(II) oxide used.

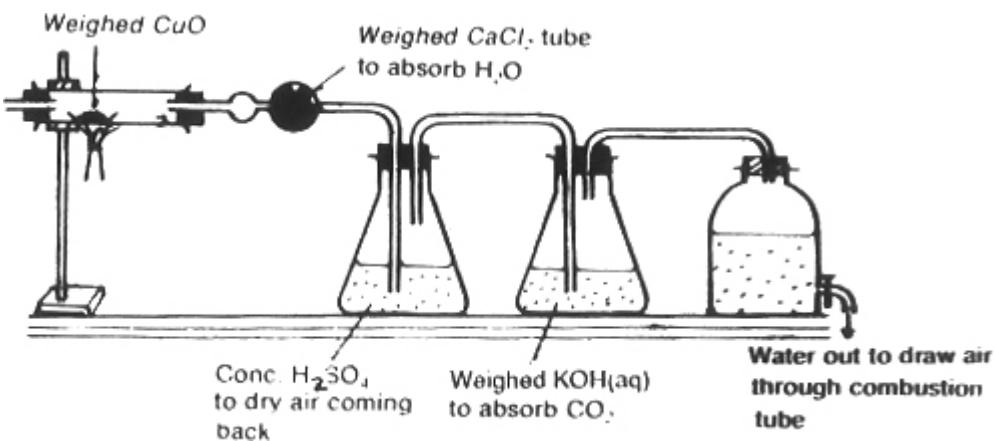


Figure 6.16: Oxidation of carbohydrate.

**Example:-** Suppose in the experiment, 0.9 g of glucose gives an increase of 1.32 g in the mass of the potassium hydroxide. 0.54 g in the mass of the calcium chloride tube, and a loss of 0.96 g in the mass of the copper(II) oxide. Then,

$$\text{Mass of carbon(IV) oxide formed} = \mathbf{1.32 \text{ g}}$$

$$\text{Mass of water vapour formed} = \mathbf{0.54 \text{ g}}$$

$$\text{Mass of oxygen added from CuO} = \mathbf{0.96 \text{ g}}$$

$$\therefore \text{Mass of C in CO}_2 \text{ formed} = \frac{12}{44} \times 1.32 \text{ g} = \mathbf{0.36 \text{ g}}$$

$$\text{Mass of O}_2 \text{ in CO}_2 \text{ formed} = \frac{32}{44} \times 1.32 \text{ g} = \mathbf{0.96 \text{ g}}$$

$$\text{Mass of O in H}_2\text{O formed} = \frac{16}{18} \times 0.54 \text{ g} = \mathbf{0.48 \text{ g}}$$

$$\text{Mass of H in H}_2\text{O formed} = \frac{2}{18} \times 0.54 \text{ g} = \mathbf{0.06 \text{ g}}$$

$$\text{Mass of O from CuO} = \mathbf{0.96 \text{ g}}$$

$$\begin{aligned} \text{Mass of O in CO}_2 + \text{H}_2\text{O formed} &= (0.96 + \\ &\quad 0.48) \text{ g} \end{aligned}$$

$$= \mathbf{1.42 \text{ g}}$$

$$\therefore \text{Mass of O in glucose} = (1.42 - 0.96) \text{ g} = \mathbf{0.48 \text{ g}}$$

### Empirical formula:

	C	H	O
Mass of element (g)	0.36	0.06	0.48
Number of mole	0.36	0.06	0.48
	12	1	16
Ratio	= 0.03 : 0.06 : 0.03		
	= 1 : 2 : 1		
$\therefore$ Empirical formula	<u>CH<sub>2</sub>O</u>		

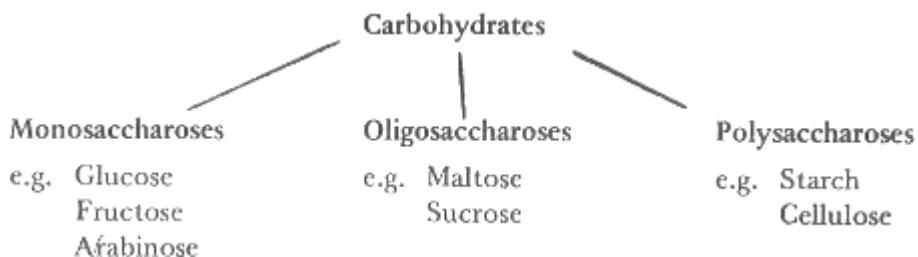
(ii) Treat a little of each of the carbohydrates with concentrated

tetraoxosulphate(VI) acid in an evaporating dish. A black mass of carbon is left as concentrated tetraoxosulphate(VI) acid dehydrates each of the carbohydrates.



**Nomenclature of carbohydrates:** The group names of simple carbohydrates end in **ose**. Aldoses are sugars with the aldehydic structure, while ketoses are those with a ketonic structure. Pentoses are simple sugars with five carbon atoms per molecule. Examples are arabinose and xylose. Hexoses contain six carbon atoms per molecule, e.g. glucose and fructose.

## **Classification of carbohydrates:**



Monosaccharoses cannot be hydrolysed to simpler sugars. They have the general formula:  $C_nH_{2n}O_n$

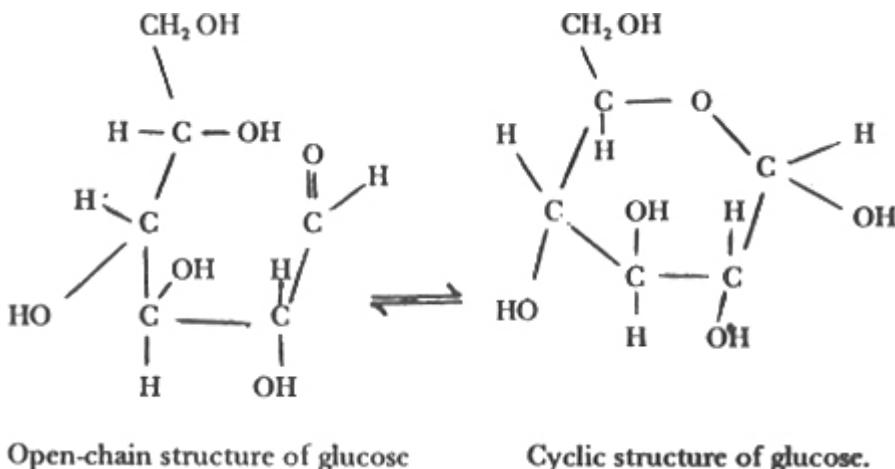
Oligosaccharoses can be hydrolysed to between two and nine monosaccharoses. Disaccharoses are those that are hydrolysed to two monosaccharoses.



The monosaccharoses which result from the hydrolysis may be the same or be different.

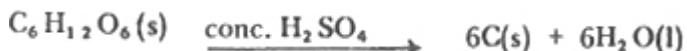
Polysaccharoses are hydrolysed to many monosaccharose units.

**Structure of carbohydrates:** Glucose, C<sub>6</sub>H<sub>12</sub>O<sub>6</sub>, has an open chain and a cyclic structure, with the cyclic structure predominating.



**Properties of glucose:** Glucose is a white crystalline solid. It is very soluble in water due to hydrogen-bonding between its many  $\text{--OH}$  groups and water molecules. It has a sweet taste.

Glucose is dehydrated to carbon by concentrated tetraoxosulphate(VI) acid.



#### Experiment 6.13: Tests for Glucose:

- Dissolve about 1 g of glucose in 5 cm<sup>3</sup> of water. To 2 cm<sup>3</sup> of the solution, add Fehling's solutions A and B, then warm in a beaker of water. A reddish-brown precipitate of copper(I) oxide is formed, showing the reduction of Cu<sup>2+</sup> ion in Fehling's solution to Cu<sup>+</sup> by the alkanal group in glucose.

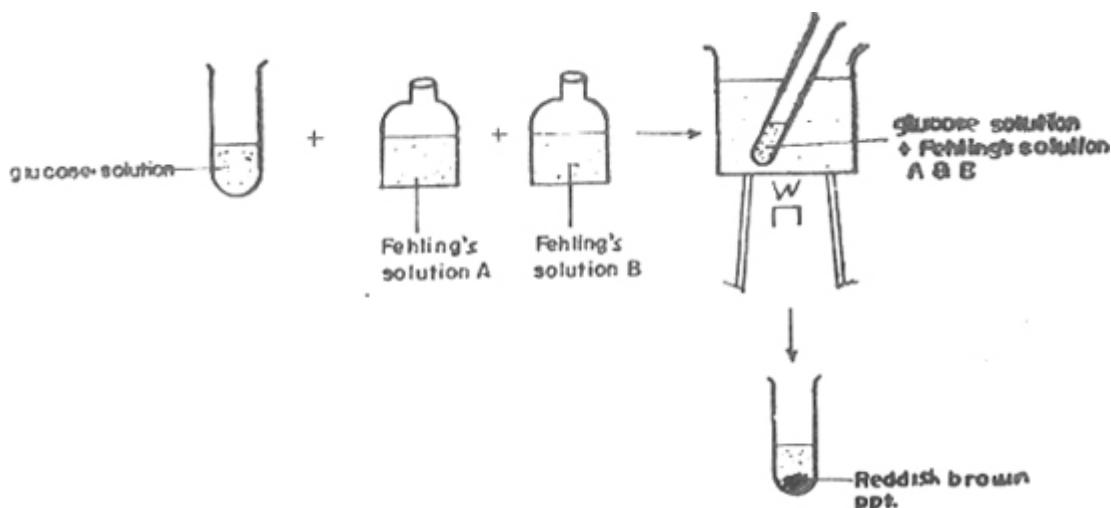
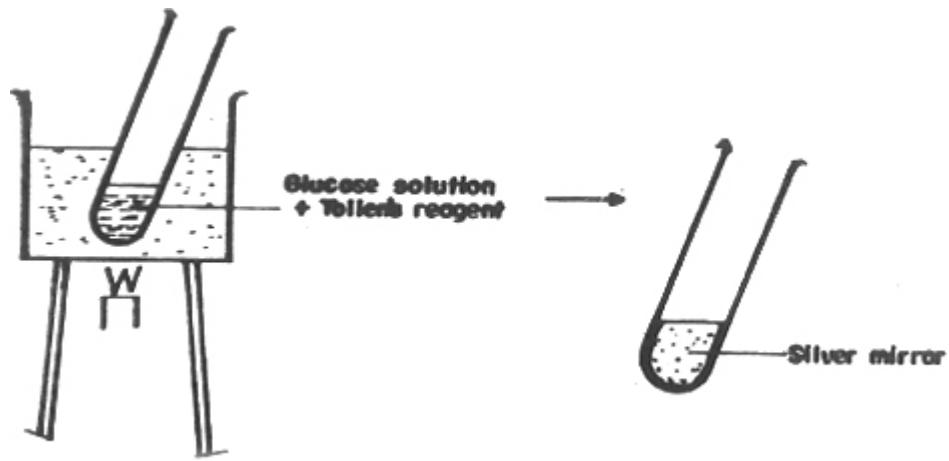


Figure 6.17 Reduction of Fehling's solution by glucose.

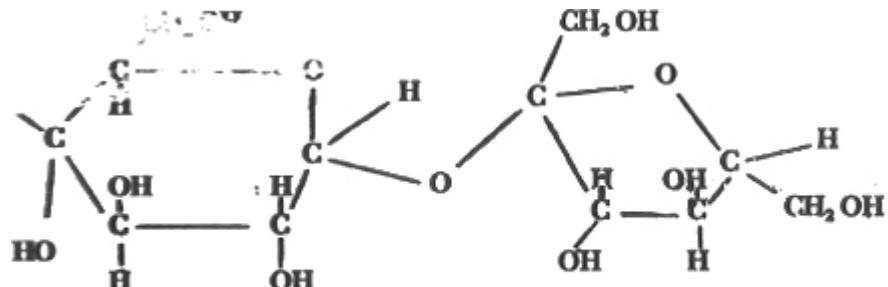
- To another 2 cm<sup>3</sup> of the glucose solution in a test-tube, add Tollen's reagent, (ammoniacal silver trioxonitrate(V) solution), made by adding a drop of sodium hydroxide solution to silver trioxonitrate (V) solution in a test-tube filtering off the aqueous layer

and then to the precipitate, add aqueous ammonia solution drop wise till the precipitate redissolves. Warm the mixture in a water bath. A  $\text{\u00e2}$ silver mirror $\text{\u2122}$  is formed on the walls of the test-tube. Glucose reduces  $\text{Ag}^+$  in the silver trioxonitrate(V) to metallic silver. The metallic silver forms a mirror on the wall of the test-tube.



*Figure 6.18: Reduction of  $\text{Ag}^+$  to  $\text{Ag}$  by glucose*

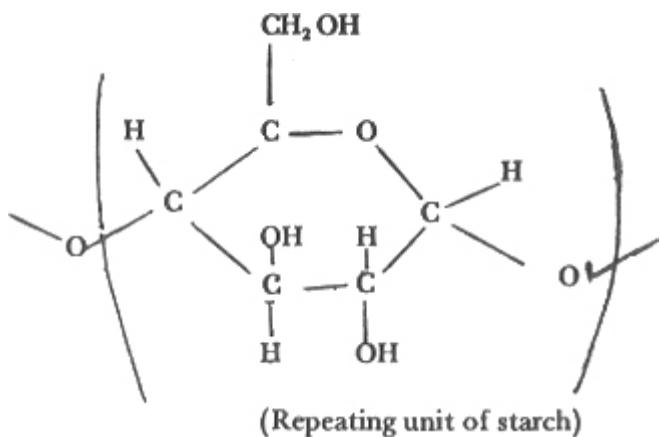
Sucrose is a product of condensation reaction between a glucose molecule and Sucrose molecule. Its structure is:



(Sucrose,  $\text{C}_{12}\text{H}_{22}\text{O}_{11}$ )

Sucrose is a white crystalline solid. It is very soluble in water, and has a very sweet taste. Like glucose and other carbohydrates, it is dehydrated by concentrated teraoxosulphate(VI) acid, but it does not reduce either Fehling $\text{\u2122}$ 's solution or Tollen $\text{\u2122}$ 's reagent.

**Starch:** is a polysaccharose with the repeating unit shown below.



Starch is insoluble in water. It is dehydrated to carbon by concentrated tetra-oxosulphate(VI) acid. It reduces neither Fehling's solution nor Tollen's reagent, but forms a blue colour with iodine. On heating, the blue colour disappears, and reappears on cooling.

### **Uses of carbohydrates:**

- (i) Most of our foods contain starch whose end product of digestion is glucose. Glucose is absorbed into the blood stream of man and other higher animals. Its oxidation in the tissues releases energy with which we do work.
- (ii) Glucose is used in making confectioneries.
- (iii) It is given to patients to generate instant energy.
- (iv) Sucrose is used for sweetening food.
- (v) Fermentation of sucrose yields ethanol for making alcoholic drinks (beer, gins, etc.).
- (vi) Starch is used in industry for making adhesives.
- (vii) Starch is used in laundry for stiffening clothes.

### **Enzymes**

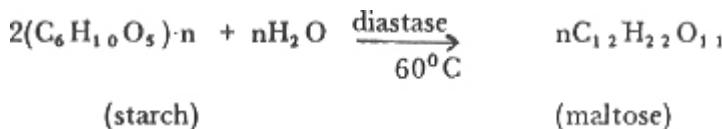
Enzymes are biological catalysts produced in small amounts by the organisms needing them. They are specific in their actions, that is, each enzyme only catalyzes a particular reaction.

**Nomenclature:** The suffix **"ase** is added to the name of the substance which the enzyme acts on. Those that act on starch are called amylases (amylum = starch). Those that act on proteins are proteases, while those that act on fats are lipases. Many enzymes, however, retain their historical names; examples are pepsin, emulsin, trypsin, etc.

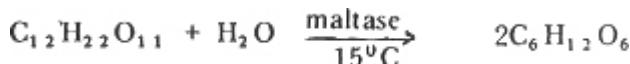
**Classification:** Enzymes are further classified according to their mode of action. Hydrolytic enzymes hydrolyse proteins and fats. Oxidative enzymes act by oxidation. If they oxidize by removal of

hydrogen from the substance they act on, they are known as dehydrogenases. Those that oxidize by donating oxygen are oxidases. Decarboxylases catalyze by decarboxylation. Transaminases act by transfer of amino group of amino acids to keto group of keto acids.

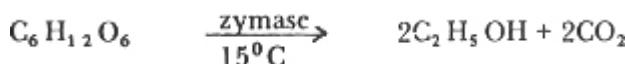
Some specific enzymes were earlier mentioned in connection with fermentation. Diastase hydrolyzes starch into disaccharoses.



Maltase further hydrolyzes maltose:



Then, zymase decarboxylates simple sugars to ethanol.



## **CHAPTER SUMMARY**

Monohydric alkanoic acids have the general formula: RCOOH, where R is an alkyl or aryl group. They are weak acids on account of the slight ionization of the hydrogen atom.



As acids, alkanoic acids liberate hydrogen with active metals, and carbon(IV) oxide from trioxocarbonates(IV).

With alkanols, the acids form esters, with halogens, they form acyl halides. The acyl halides form amides with ammonia.

Primary amides are neutral, but N,N-dialkyl amides are basic.

Amides undergo hydrolysis in acid media to form alkanoic acids and ammonium salts, and in alkaline media to form salts of alkanoic acids and ammonia.

Strong dehydrating agents such as  $P_2O_5$  eliminate water from amides, forming nitriles.

With dioxonitrate(III) acid at low temperature, amides liberate nitrogen gas.

Hydrolysis of esters yields alkanoic acids and alkanols.

Fats and oils are esters of long-chain alkanoic acids (fatty acids) and propan-1,2,3-triol (glycerol). Their hydrolysis with alkalis, known as saponification, yields soap and propan-1,2,3-triol.

The propan-1,2,3-triol esters of unsaturated fatty acids

are liquids at room temperature. They are hardened by hydrogenation, yielding margarine.

â€¢ Amino acids have two functional groups: the â€“COOH group of alkanoic acids, and the â€“NH<sub>2</sub> group of amines. They show the reactions of both homologous series.

â€¢ Amino acids react with dioxonitrate(III) acid liberating nitrogen gas. This is a reaction of the â€“NH<sub>2</sub> group.

â€¢ With dilute hydrochloric acid, amino acids form soluble salts. This is also a reaction of the â€“NH<sub>2</sub> group.

â€¢ With sodium hydroxide, amino acids form salts; a reaction of the â€“COOH group.

â€¢ With alkanols in the presence of concentrated H<sub>2</sub>SO<sub>4</sub>, amino acids produce sweet-smelling odour due to the formation of an ester; a reaction of the â€“COOH group.

â€¢ The condensation of a â€“COOH group of one amino acid molecule with the â€“NH<sub>2</sub> group of another, repeated several times, gives rise to proteins. Hydrolysis of proteins yields these amino acids. The peptide link which forms when condensation polymerization occurs in amino acids also exists in the polymeric amide fibre called nylon.

## ASSESSMENT

1. (a) Consider the following structures.

- A. CH<sub>3</sub> CH<sub>2</sub> CH<sub>2</sub> COOH
- B. CH<sub>3</sub> CH<sub>2</sub> CH<sub>2</sub> CH<sub>3</sub>
- C. CH<sub>2</sub>=CHC<sub>1</sub>
- D. CH<sub>3</sub>C%OjCH
- E.  $\begin{array}{c} \text{CH}_2\text{CH}_2\text{CH}_3 \\ | \\ \text{OH} \end{array}$

Which compound

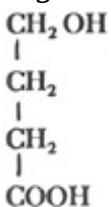
- (i) is used as a gaseous fuel? What is the main source of this fuel?
  - (ii) will react with two moles of hydrogen per mole of compound? Write an equation for the reaction.
  - (iii) will react with ethanol? State the products and write an equation for the reaction. What is the name of this type of reaction?
- (b) In the production of a detergent, C<sub>16</sub>H<sub>25</sub>SO<sub>3</sub>Na, from an acid, C<sub>16</sub>H<sub>25</sub>SO<sub>3</sub>H, 10 g of caustic soda was used. Calculate the mass of the detergent produced.

(H = 1, C = 12, O = 16, Na = 23, S = 32).

(c) Explain why butter goes rancid.

(WAEC)

2. An organic compound has the formula:

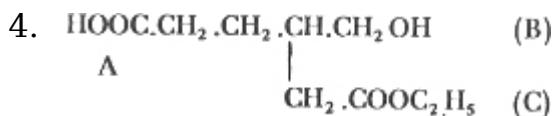


What are the names for the two functional groups present in the molecule? Would you expect the functional groups in the compound to react with each other? If so, why? Write the formula if any, for the compound formed. Suggest a name for the class of organic compound to which the compound formed, if any, belongs.

(WAEC).

3. Write one equation each to illustrate esterification and hydrolysis. What is the main difference between them? Describe a simple laboratory method for obtaining soap from palm oil.

(WAEC).



- Name the three functional groups, A,B,C in the organic molecule above.
- In a reaction of an alkali with the molecule, indicate the two functional groups that are likely to react.
- Two of the functional groups will have no effect on litmus paper if each were to occur alone in other molecules. Indicate these groups.

(WAEC).

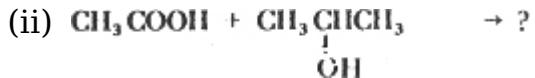
5. What are carbohydrates? What is the action of concentrated tetraoxosulphate(VI) acid on starch? What tests would you perform to distinguish between glucose and starch?

6. Explain the meaning and usefulness of each of the following:  
(i) polymerization;  
(ii) saponification.

Explain the cleaning action of soap. How do detergents differ from soap?

7. Complete the equations:





Name the products of each reaction. How would you recognise one product of each reaction?

8. Compare polypeptides with polysaccharoses. What are the products of hydrolysis of each?
9. (a) How would you distinguish between:
  - (i) glucose and starch,
  - (ii) an amino acid and a protein.  
(b) Give the unit structure of the polypeptide formed from aminoethanoic acid, 2–aminopropanoic acid, and 2–aminobutanoic acid.
10. Show that you understand the underlined words in the following sentences.

Glucose and fructose are monosaccharoses. They are reducing sugars. The condensation reaction between glucose and fructose yields the disaccharose, sucrose, which is not a reducing sugar. Many fructose units condense to the polysaccharose called starch, which is insoluble in water and is tasteless. Hydrolysis of starch gives monosaccharoses.