Hydrocarbons and Their Derivatives

Chemistry 14

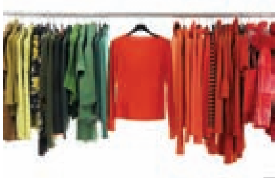
14.1 Hydrocarbons

Figure 14.1 shows some items that we use in our day to day life.


Plastic goods


Food items


Tyres


Clothes


Paints


Cosmetics


Agro-chemicals

Figure 14.1

When considering the composition of all of the above materials, presence of carbon as a component element seems to be a common feature. Carbon is also abundant in the plants and animals that we find in our environment and all the materials obtained from those sources.

Elements combine with one another in different ways to create a very large number of compounds. Quite a majority of them are compounds formed by the combination of carbon with other elements.

Because of the abundance of carbon containing compounds and the special chemical characteristics shown by those compounds, carbon chemistry (organic chemistry) is studied as a separate section under chemistry.

The compounds contaning carbon are commonly referred to as organic compounds [But, the oxides of carbon, namely carbon dioxide (CO_2) and carbon monoxide (CO) and carbonates and bicarbonates such as sodium carbonate (Na_2CO_3) and sodium bicarbonate ($NaHCO_3$) are not considered organic]. Organic compounds necessarily contain carbon and in addition, they may contain elements like hydrogen, oxygen, nitrogen, halogen, phosphorus and sulphur.

For the convenience of study, organic compounds are classified in various ways. One method is classifying on the basis of the component elements in the organic compound. On this basis, the simplest group of organic compounds are hydrocarbons which contain carbon and hydrogen only.

Assignment 14.1

List several types of fuels that are used in day to day life. Investigate into the chemical composition (the elements they contain) of those fuels.

Compare the list you prepared with the following table.

Table 14.1

Fuel	Elements present
Wax	C, H
Petrol	C, H
Methane	C, H
L.P. gas	C, H
Kerosene	C, H
Diesel	C, H
Firewood	C, H O, N

It is seen that every fuel in the above table contain carbon and hydrogen.

Let us do the following activity to examine whether wax contains carbon and hydrogen.

Activity 14.1

Confirming the pressure of carbon and hydrogen in candle wax

Materials required :- connecting tubes, beaker, aspirator, Lime water, copper sulphate, U - tube, test tube.

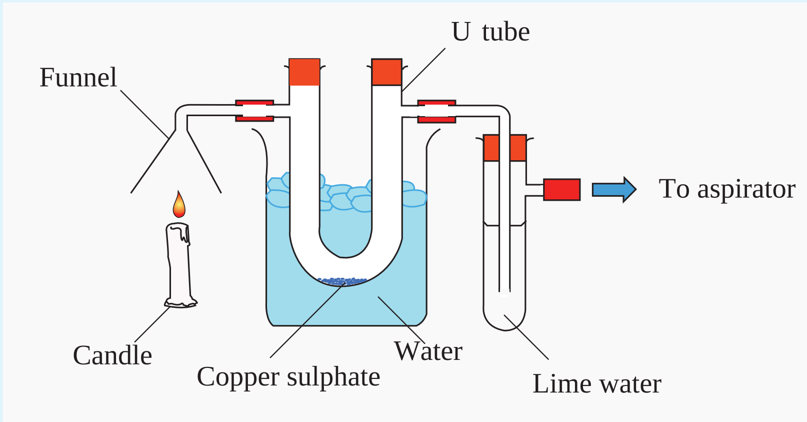


Figure 14.2

Set the apparatus as shown in figure 14.2, light the candle, connect the apparatus to the aspirator and make air pass through.

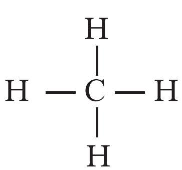
It will be seen that, the anhydrous copper sulphate contained in the U tube turns from white to blue. This change in colour was brought about by the water produced during the burning of the candle. Hydrogen required to produce that water was supplied by candle wax. This verifies the presence of hydrogen in wax.

Also, it can be observed that the limewater contained in the test tube on the right hand side turns milky. Therefore, carbon dioxide gas has been produced during the burning of the candle. The source of carbon in that carbon dioxide is wax.

This confirms the presence of carbon (C) and hydrogen (H) in candle wax.

All the countries in the world meets their energy requirements by using petroleum fuels produced by the distillation of crude oil. All compounds in those fuels are hydrocarbons. Based on the structure, hydrocarbons are classified as alkanes, alkenes and alkynes.

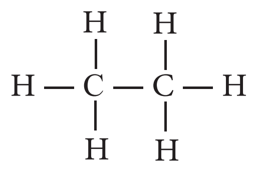
- ## Alkanes



Have you heard that bio gas produced using the waste disposed from poultry farms is used as a fuel? The main component of it which is important as a fuel is methane gas. This gas is also present in the marsh gas produced when organic matter decays in marshes.

This is the simplest hydrocarbon and has the formula CH_4. Its structure is shown in the figure.

During the mining of mineral oils, the gas ethane comes out from oil wells. Ethane is also a hydrocarbon. Its formula is C_2H_6. The structure corresponding to this formula is as follows.



Consider the methane and ethane molecules described above. Bonds between carbon atoms and hydrogen atoms (only) are present in the methane molecule. But in the ethane molecule there are bonds between carbon and carbon atoms. The hydrocarbons which have only single bonds between carbon atoms are referred to as alkanes.

Alkanes are a series of compounds. This series has several common characteristics. One of those is that all the compounds in that series can be represented by a common formula.

The common formula of the alkane set is C_nH_{2n+2}. In this, 'n' is the number of carbon atoms in a molecule of the compound. According to the above formula, the formula of the simplest alkane methane can be obtained as follows.

For methane n = 1. Hence the formula of methane is,

$$C_1H_{1 \times 2 + 2} = CH_4$$

In ethane ⟶ n = 2. Hence the formula of ethane is

$$C_2H_{2 \times 2 + 2} = C_2H_6$$

Assignment 14.2

Using the common formula, derive the formulae of alkanes that contain carbon atoms from 1 to 5.

Listed in Table 14.2 are the formulae and names of the alkanes of which the number of carbon atoms varies from 1 to 5.

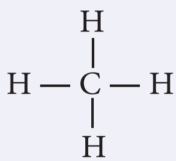
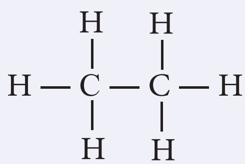
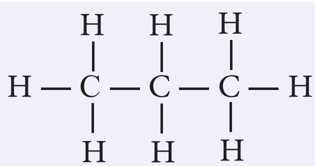
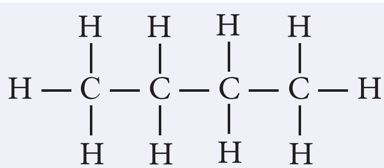
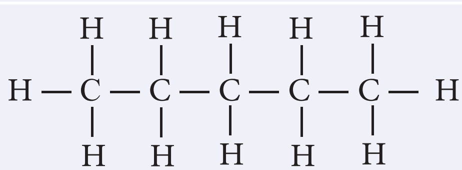
The fuel petrol (gasoline) is a mixture of alkanes. The most abundant alkane in it is octane represented by the formula C_8H_{18}. L.P. gas, another mixture of alkanes/ mainly contain alkanes propane (C_3H_8) and butane (C_4H_{10}).

Table 14.3 presents the molecular formulae and structural formulae of the alkanes with carbon atoms 1 - 5.

Table 14.2

Molecular formula	Name of the alkane
CH_4	Methane
C_2H_6	Ethane
C_3H_8	Propane
C_4H_{10}	Butane
C_5H_{12}	Pentane

Table 14.3

Molecular formula	Structural formula
CH_4	
C_2H_6	
C_3H_8	
C_4H_{10}	
C_5H_{12}	

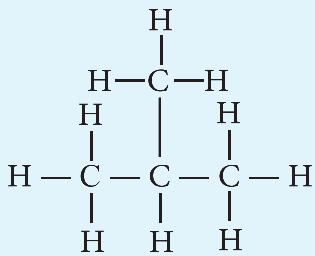
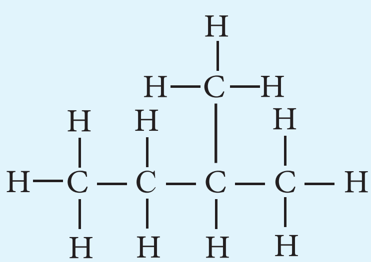
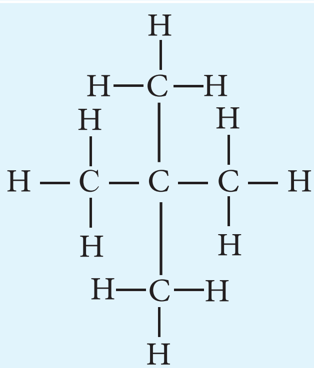
Activity 14.2

Make models of the alkanes with carbon atoms 1 - 5 with the help of your teacher, using suitable materials.

Extra knowledge

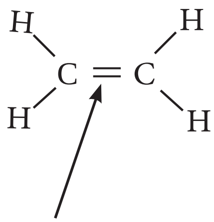
For C_4H_{10} and C_5H_{12}, the following structures are also correct in addition to the structures given in Table 14.3

Table 14.4

Molecular formula	Structural formula
C_4H_{10}	
C_5H_{12}	 

• Alkenes

In alkanes there are only single bonds between carbon - carbon atoms. Also, there are hydrocarbons having double bonds between carbon - carbon atoms. The hydrocarbons of this type with one or more double bonds between carbon - carbon atoms are classified as alkenes. The molecular formula of the simplest alkene ethene is C_2H_4. Its structural formula is given below.



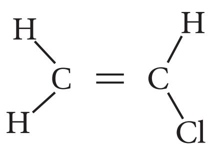
Double bond

Due to the presence of double bonds between the carbon atoms, alkenes are more reactive than alkanes.

14.2 Derivatives of ethene

• Chloroethene

The compound derived by the displacement of a hydrogen atom in ethene by a chlorine atom is called chloroethene. The formula of chloroethene is C_2H_3Cl and its structure is given below.



• Tetrafluoroethene

The compound derived by the displacement of the four hydrogen atoms in ethene by four fluorine (F) atoms is known as tetrafluoroethene. Its formula is C_2F_4 and the structure is as follows.

C_2F_4

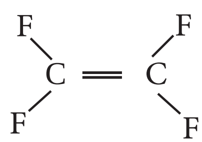
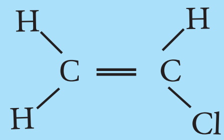
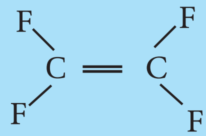


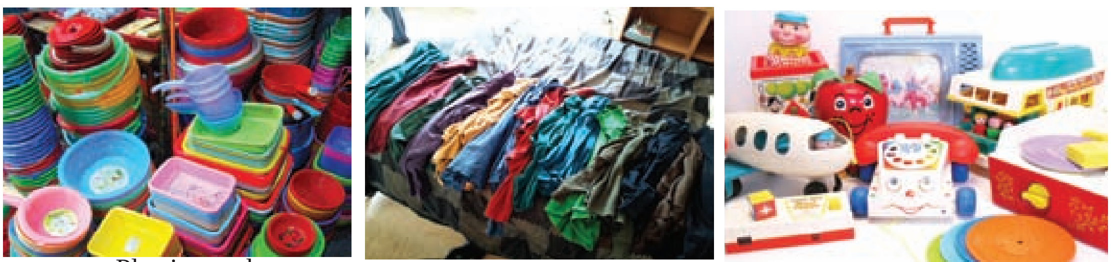
Table 14.4 - Derivatives of ethene

Chloroethene C_2H_3Cl	
Tetrafluoroethene C_2F_4	

Ethene and derivatives of ethene are used to produce the polymers that we use in our day to day life such as polythene, styrofoam and teflon

14.3 Polymers

Pay your attention to the following pictures.



Plastic goods Clothes Toys

Figure 14.3

Let us inquire into the chemical nature of the materials shown in the above pictures that we use frequently in our daily life.

At molecular level, they all have a common special feature. That is, they all are made up of large molecules arranged in the form of long chains. Another speciality is that most of those long chain molecules are composed of repeating small molecular units. Thus, the molecules from which they are made are called polymers. In this lesson, let us discuss about polymers.

Large molecules formed by the joining of a large number of small molecules with one another are known as polymers.

The process of forming polymers is called polymerization. The small molecules forming polymers are known as monomers and the large molecules formed by the polymerization of monomers are referred to as polymers. Pay your attention to the chain formed by joining some paper clips together.

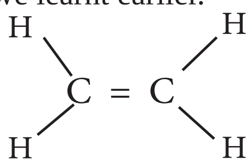
Figure 14.4

The single paper clips used to form the above chain are analogous to monomers and the chain of clips is equivalent to the polymer. The basic structural units contained in the chain after the formation of the polymer are referred to as repeating units. The molecular mass of monomers is relatively low. However, the relative molecular mass of polymers formed by the polymerization of a large numbers of monomers has a very high value.

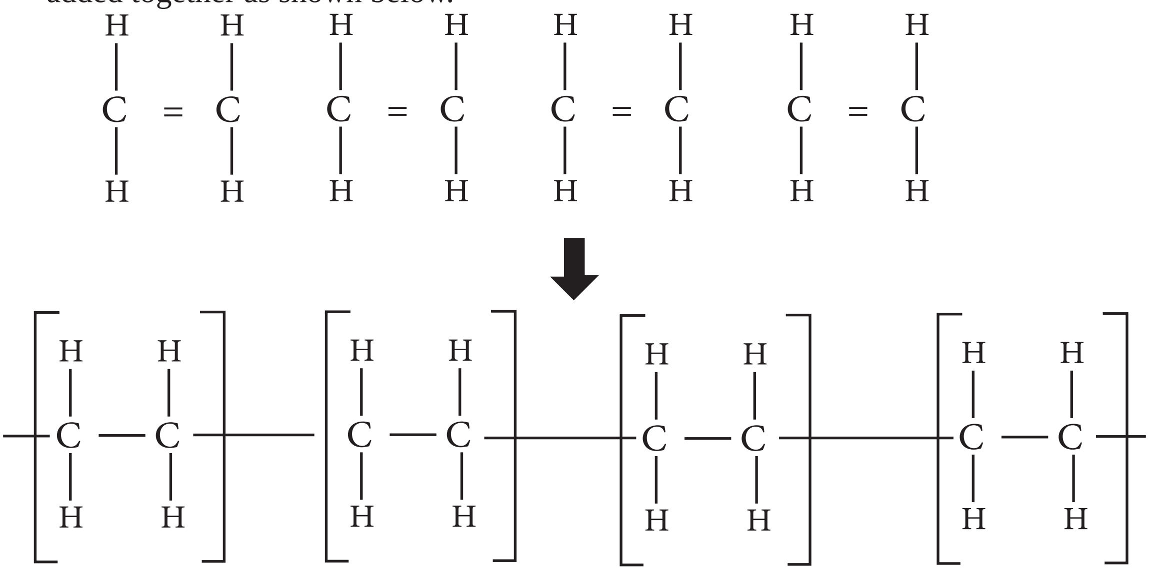
Now, let us investigate into some common polymers.

- **Polythene (Polyethene)**

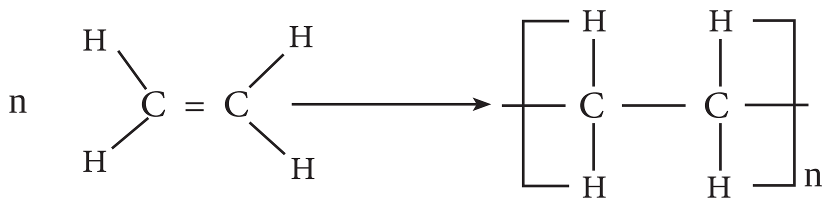
Consider the ethene molecule we learnt earlier.



Polythene is produced by the polymerization of ethene molecules. What happens here? Of the double bond, one bond breaks and thousands of ethene molecules are added together as shown below.



The above polymerization process may be summarized and indicated as follows.

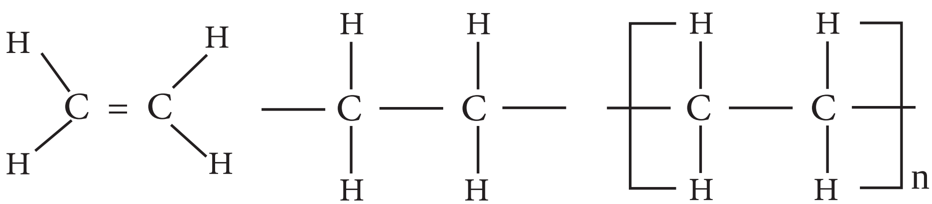


This means that 'n' number of ethene molecules link with one another and create a polythene molecule with 'n' number of $– CH_2 – CH_2 –$ repeating units.

Assignment 14.3

Make a polythene polymer molecule linking appropriately the models of the ethane molecules you have made in assignment 14.2.

Hence, it may be clear to you that polythene is a macromolecule formed by the linking of a large number of ethene molecules in a specific pattern.
The polymer, monomer and the repeating unit of polythene are given below.

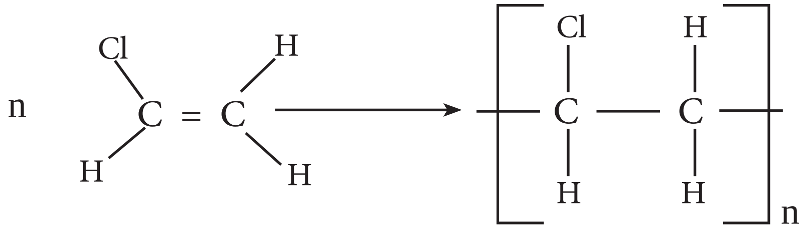


Monomer Repeating unit Polymer

Polymers - Very large molecules formed from linking together, a large number of small molecules are named polymers.
Monomers - Small molecules contributing to form polymers are called monomers.
Repeating unit - The basic structural units contained in a polymer are known as repeating units.

- **Polychloroethene (Polyvinyl chloride)**

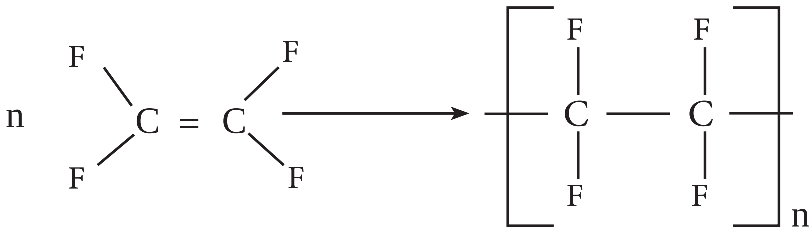
Polymerization of chloroethene gives polychloroethene. This can be summarized as follows.



Try to identify the monomer, repeating unit and the polymer of polychloroethene.

- **Polytetrafluoroethene (Teflon)**

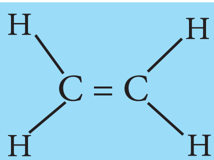
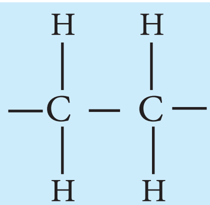
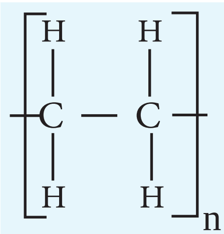
Polytetrafluoroethene is formed by the polymerization of tetrafluroethene. This can be illustrated as follows.

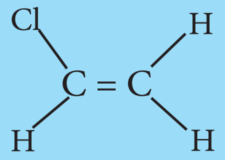
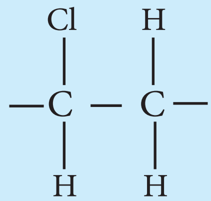
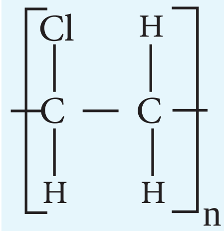
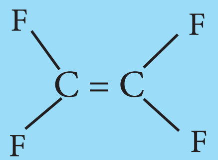
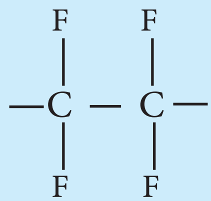
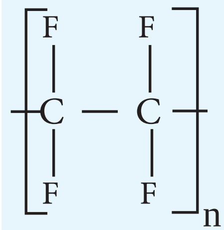


Identify the monomer, repeating unit and the polymer of tetrafluoroethene.

A summary of the polymers you studied is present in Table 14.6

Table 14.6

Polymer	Monomer	Repeating unit	Representation of the polymer
Polythene			

Polychloroethene (PVC)			
Polytetrafluoroethene			

Given in Table 14.6 are the special properties and uses of the polymers which we discussed above.

Table 14.7

Polymer	Special properties	Uses
Polyethene	Electrical insulator, impervious to water and air, light and can withstand tensions, durable	Making plastic bottles, toys, polythene tissues, polythene bags, garbage bins, hard plastic fibers
Polychloroethene (Polyvinyl chloride PVC)	Resistant to fire, electrical insulator, impervious to water, light	Making gutters, water pipes, conduits and flexible pipes
Polytetrafluoroethene (TEFLON)	resistant to heat, electrical insulator	Making non - stick cooking pans, snow shoes

- ## Classification of polymers based on origin

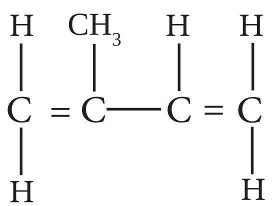
Recall the polymers you studied earlier. All of them are artificially synthesized polymers. Have you heard about natural polymers Pay attention to the bio - molecules you learnt in grade 10. Molecules like proteins, starch, cellulose and DNA are polymers. They belong to the category of natural polymers. Therefore, by origin, polymers can be classified into two types as natural and artificial. Rubber which is frequently used for technical purposes is also a natural polymer. Table 14.7 lists some examples of natural and artificial polymers.

Table 14.8

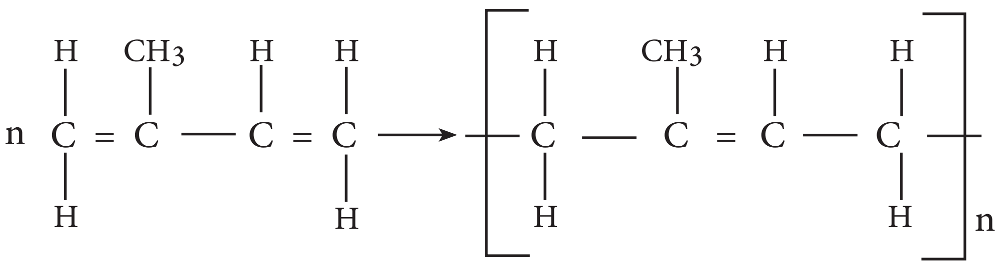
Natural polymers	Artificial polymers
Rubber	Polythene
Protein	Polychloroethene
DNA	Teflon
Starch	Polyester
Cellulose	Nylon
RNA	Terylene
	polystyrene
	Bakelite

• Rubber

Rubber is a natural polymer formed by the polymerization of a monomer called isoprene. The structure of an isoprene molecule is given below.



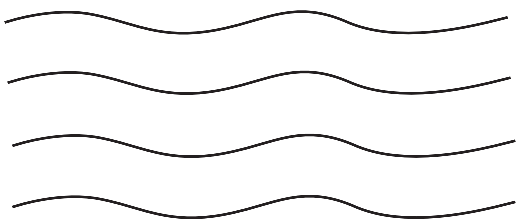
The process leading to the formation of the polymer can be illustrated as follows.



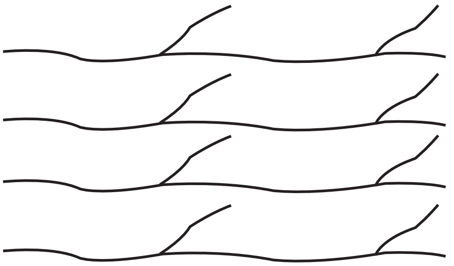
• Classification of polymers based on structure

All the polymers so far discussed are made of linear chains. However, all polymers are structurally not linear polymers. By joining polymer molecules laterally to the principle chain of the linear polymers of the type described above, branched polymers are produced.

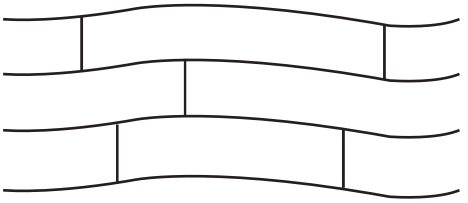
The polymers in which the linear chains are cross-linked are known as cross-linked polymers. Therefore, the polymers can be classified as follows according to the structure.



Linear polymers
Figure 14.5

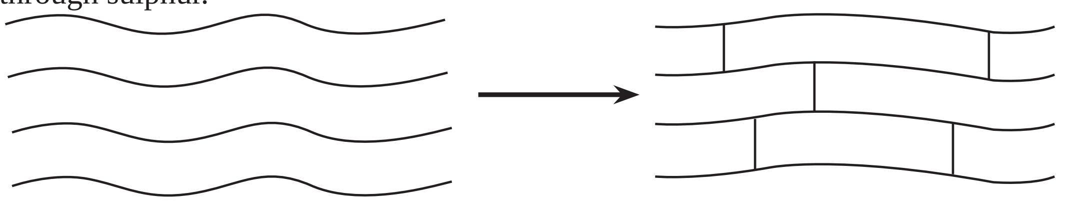


Polymers with side chains
Figure 14.6



Polymers with cross links
Figure 14.7

Have you heard about vulcanized rubber? Because of the elastic property of rubber, it is difficult to be used in some applications. By vulcanization, rubber can be made harder while decreasing its elasticity. During vulcanization natural rubber is reacted with sulphur. Then, cross links are formed among the linear chains of rubber through sulphur.



Rubber
Figure 14.8

Vulcanized rubber
Figure 14.9

Vulcanized rubber is used to make tyres, tubes and battery cases.

- ## Importance of polymers

When taking lunch away from home, natural materials such as a banana leaf or a "Kolapatha" was used for wrapping in the past. But today, what we use for this purpose is a type of polythene which is a synthetic polymer. Like this, at present, artificial polymers are being used as substitutes for materials. Properties such as the ability to synthesize with required characteristics, ease of usage, ability to produce in various shapes, ability to make colourful with any required colour and cheapness have made the items produced with polymers popular.

Assignment 14.4

List the products made of polymers that are of domestic use.

Most of the artificial polymers are not subjected to biodegradation. That is, they do not decay through biological process. Therefore they get collected in the environment. This is a big environmental problem. Since the combustion of artificial polymers release poisonous gases, burning is not suitable. Chemists are making attempts to find a solution for this problem by producing degradable polymers. At present, production of biodegradable and photodegradable polymers and water-soluble polymers are underway.

The clothes produced with artificial polymers such as nylon, terylene and polyester do not absorb sweat and cause discomfort to the body. This can be minimized by mixing natural polymers such as cotton and wool with artificial polymers.

Summary

- Organic compounds only made up of carbon and hydrogen are called hydrocarbons.
- In some hydrocarbon molecules, carbon atoms are bound only by single covalent bonds. Such hydrocarbons are named alkanes.
- Crude oil is a mixture of alkanes. The common formula of the alkane family is C_nH_{2n+2}.
- In addition to alkanes, there are hydrocarbons in nature with double or triple bonds between carbon atoms.
- Joining of other atoms or atomic groups in place of hydrogen atoms in hydrocarbons gives rise to other organic compounds.
- The macromolecules formed by linking together of a large number of simple molecules are known as polymers.
- The polymers present in natural animal parts or plant parts are called natural polymers. The artificially synthesized polymers are artificial polymers.
- Artificial polymers are generally referred to as plastics.
- The shape of some polymers can be changed by heat whereas in some the shape cannot be changed by heat.
- Since artificial polymers do not decay, there are both advantages and disadvantages in them.
- If the management of plastic wastes is not carried out properly, many environmental problems may arise

Exercises

01. L.P. gas is a mixture of propane and butane.

i. Write the molecular formulae of propane and butane.

ii. Draw the structures of propane and butane.

iii. If only carbon dioxide and water are formed during the combustion of the above compounds, write balanced chemical equations for their combustion separately.

iv. Is the use of L.P. gas as a fuel more environment friendly than using firewood? Present your ideas.

02. Octane is the most abundant alkane contained in petrol

i. What would be released if petrol completely burns in a combustion engine?

ii. State two unfavorable substances released to the environment during the incomplete combustion of petrol.

iii. How do you know that the L.P gases burn incompletely in the gas cooker used at home?

03. Polythene is a commonly used artificial polymer.

i) What is the chemical name of polythene?

ii) Draw the structure of the monomer that forms polythene and write its name

iii) State two advantages and two disadvantages of polythene.

04. It is more suitable to use PVC pipes as water pipes rather than iron pipes.

i) Give three reasons to support this statement.

What is the name of the monomer that is used to make the polymer PVC?

ii) Draw the structure of that monomer.

05. Name three natural polymers of your choice.

Technical terms

Organic compound	-	කාබනික සංයෝග	-	சேதன சேர்வைகள்
Hydrocarbon	-	හයිඩ්රොකාබන	-	ஐதரோகாபன்
Alkanes	-	ඇල්කේන	-	அற்கேன்
Alkenes	-	ඇල්කීන	-	அற்கீன்
Polymers	-	බහුඅවයවක	-	பல்பகுதியம்
Monomer	-	ඒකඅවයවකය	-	ஒருபகுதியம்
Repeating unit	-	පුනරාවර්තන ඒකකය	-	மீண்டுவரும் அலகு