14 ORGANIC COMPOUNDS: NAMING AND ISOMERISM

You have already understood that organic chemistry is the branch of chemistry dealing with compounds of carbon. You have also come across the structure and the IUPAC system of naming of a few hydrocarbons, an important class of organic compounds. The organic compounds with only single bonds between carbon atoms are known as saturated compounds. Alkanes belong to this category.

Homologous series

Examine the molecular formulae of the first five alkanes given below.

CH_4	C_2H_6	C_3H_8	C_4H_{10}	C_5H_{12}

Draw the structural formulae and write their IUPAC names in your science diary.

- What is the difference in the number of carbon atoms and hydrogen atoms between CH_4 and C_2H_6 ?

- -

- Is the difference the same in the case of all successive members among the given compounds? Examine.

- -

- Write down the molecular formulae of a few more members in the series.

- See whether it is possible to represent all these compounds using a general formula.
- If the number of carbon atoms is 'n', the general formula of the alkane is

The group of organic compounds in which the successive members differ by $-CH_2-$ and can be represented by a general formula, is regarded as a family in organic chemistry. Such a family is called a homologous series.

The members in a homologous series show similarities in their chemical properties and a gradation in their physical properties. The alkane family is an example of a homologous series.

The open chain hydrocarbons containing double bonds between carbon atoms are called alkenes.

The open chain hydrocarbons containing triple bonds between carbon atoms are called alkynes. Alkenes and alkynes are unsaturated compounds.

Examine the molecular formulae of the first five members in the alkene and alkyne families given below. Add to this list the molecular formulae of a few more members.

Alkenes

C_2H_4	C_3H_6	C_4H_8	C_5H_{10}	C_6H_{12}

Alkynes

C_2H_2	C_3H_4	C_4H_6	C_5H_8	C_6H_{10}

Examine whether alkenes and alkynes are also homologous series. What are the characteristics you considered? Record the following.

★ General formula of alkenes.

★ General formula of alkynes

★ Molecular formula of the alkene containing seven carbon atoms.

★ Molecular formula of the alkyne containing seven carbon atoms.

By classifying organic compounds into various homologous series their study can be made easy.

Naming of organic compounds

You have already studied the method of naming saturated open chain hydrocarbons with no branches. The method of naming of a few members in the alkane, alkene and alkyne families is given in Table 14.1.

What are the factors considered for their naming? Find out.

- The number of carbon atoms
-
-

Naming of alkanes with branched chains

Look at the detailed and condensed structural formulae of three hydrocarbons given in Table 14.2.

Find out the molecular formulae of these compounds and complete Table 14.3.

Hydrocarbon	Word root	suffix	name
CH_4	meth	ane	methane
$CH_3–CH_3$	eth	ane	ethane
$CH_3–CH=CH_2$	prop	ene	propene
$CH{\equiv}CH$	eth	yne	ethyne
$CH_2=CH_2$	eth	ene	ethene
$CH_3–C{\equiv}CH$	prop	yne	propyne

Table 14.1

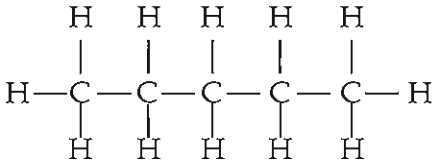
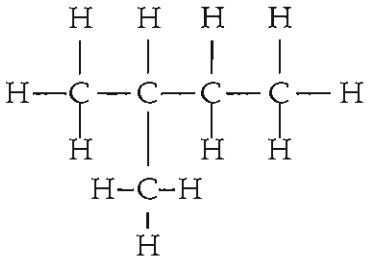
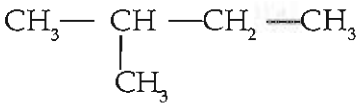
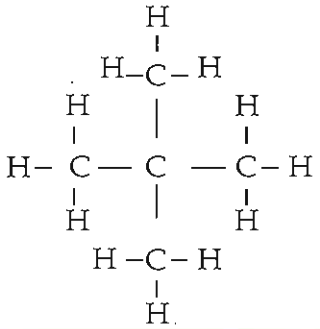
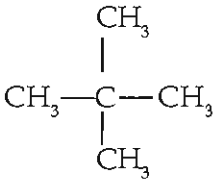
I		$CH_3-CH_2-CH_2-CH_2-CH_3$
II		
III		

Table 14.2

★ What peculiarity is noticed?

★ Are these three compounds the same?

Examine some of the characteristic properties of these compounds tabulated (Table 14.3).

★ What can be understood?

Haven't you understood that different compounds with the same molecular formula can exist? Such compounds are known as isomers.

★ Will it be enough to give the same name for all these three isomers?

★ Why?

Can you write the name of the first compound in the group?

Compound	Molecular formula	Melting point (K)	Boiling point (K)	Density in liquid state (g/L)
I	.....	143.2	309	621
II	.....	113.1	300.7	616
III	.....	256.4	282.5	586

Table 14.3

What is the difference between compounds I and II in their structures? Draw their structures showing only the carbon atoms. There is a straight chain of five carbon atoms in compound I. In compound II, the longest straight chain has only four carbon atoms. The fifth carbon atom is a branched one.

In the IUPAC system, while naming a compound the word root is fixed, based on the number of carbon atoms present in the longest chain.

★ The word root corresponding to the number of carbon atoms in the longest chain of compound II?

- -

★ The name of alkane corresponding to this longest carbon chain?

- -

★ Name of the branch?

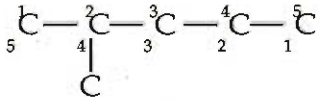
- -

★ And the position of the branch?

Isn't the numbering of carbon atoms in the longest chain necessary to decide this?

- -

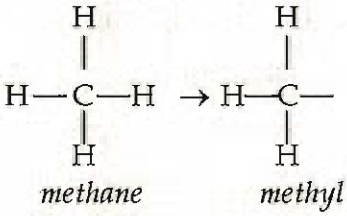
It can be done in the two ways given below.



In such instances, the compound should be named such that the carbon atom with the branch gets the lowest position number in the chain.

Alkyl radical

The CH_3- part obtained after the removal of a hydrogen atom from methane (CH_4) is called the methyl radical.



Similarly CH_3-CH_2- and CH_3-CH_2-CH_2- are respectively known as ethyl and propyl radicals. For alkyl radicals, names are given by replacing the suffix 'ane' with 'yl'.

alkane - ane + yl → alkyl

methane- ane + yl → methyl

ethane - ane + yl → ethyl

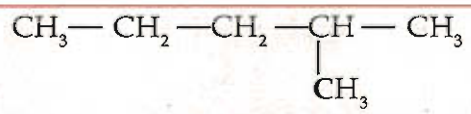
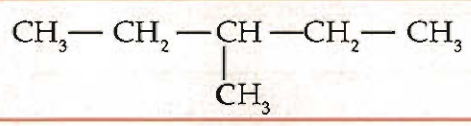
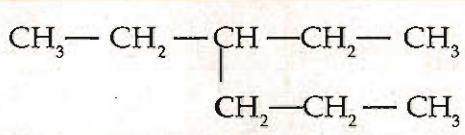
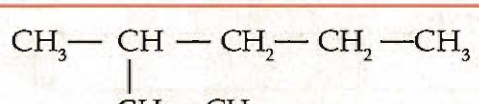
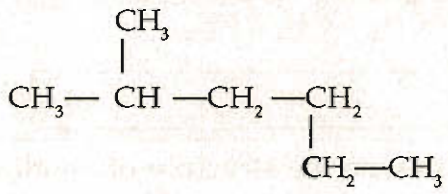
Usually alkyl radicals are represented by the symbol R-

Considering all these, compound II can be named as 2-methylbutane in the IUPAC system.

What information does the above name contain? Examine the structure of the name.

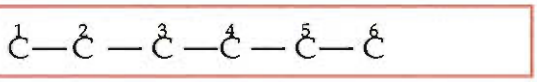
Position of branch(2) + hyphen (-) + name of branch (methyl) + word root (but) + suffix (ane)

Find the longest carbon chain in each hydrocarbon given. Number the carbon atoms of the chain properly and write down the IUPAC names.

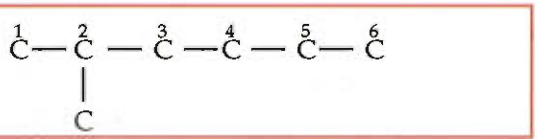
Is it possible to write the structural formula of a hydrocarbon, if its IUPAC name is given?

Suppose we want to write the structural formula of 2-methylhexane. How many carbon atoms are there in its longest chain? The carbon atoms in this chain can be represented as

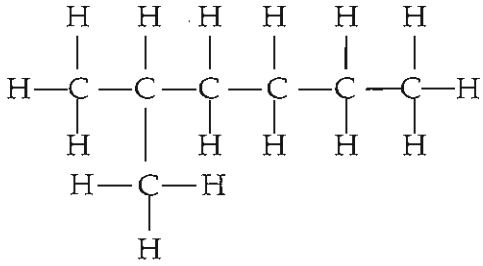


- Which is the position of the branch? .....
- What is the name of the branch? .....
- How many carbon atoms are there in the branch? .....

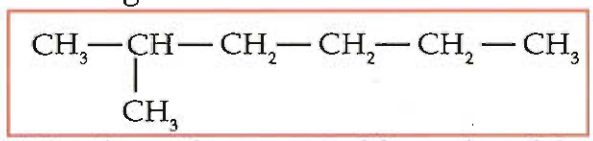
Now let's draw the carbon chain including the branch.



Now add the required number of H atoms so that the four valencies of all the carbon atoms are satisfied.



It can be represented in the condensed form as given below.



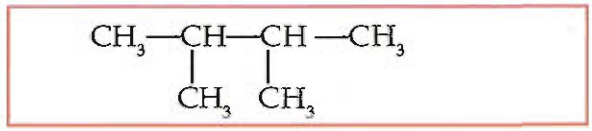
Write down the structural formulae of the alkanes given below.

2-methylpentane .....

3-ethylhexane .....

Naming of alkanes with more than one branch

Now look at the structure of another alkane.



- ✶ Number of carbon atoms in the longest chain in this alkane?

  -

- ✶ The name of the alkane based on this number?

  -

- ✶ Number of branches in the chain?

  -

- ✶ Positions of the branches?

  -

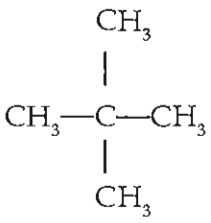
- ✶ Name of the branches?

  -

When the same alkyl group appears as branches more than once in an alkane, the prefixes di, tri, tetra etc. are used to indicate their numbers. The numbers indicating the positions of branches are shown in the name separated by commas.

According to these rules, the IUPAC name of the alkane is 2,3-dimethylbutane.

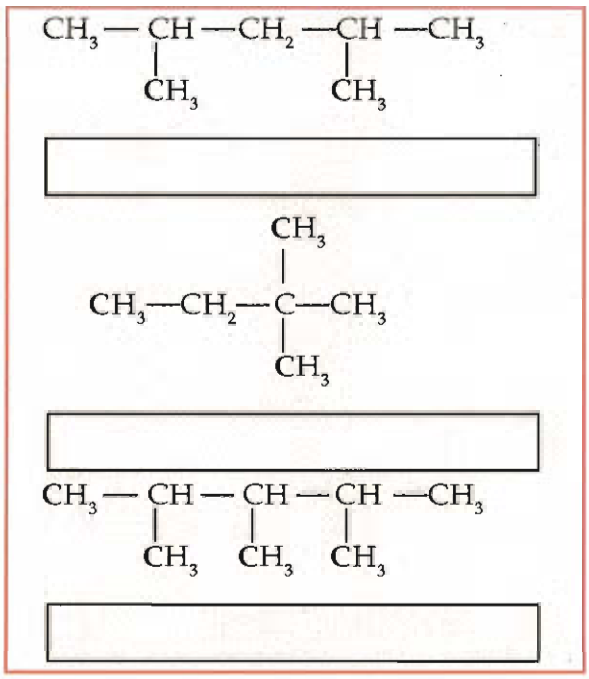
Look at the structure of another compound.



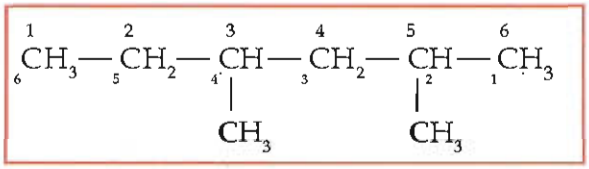
Here there are two methyl radicals as branches on the same carbon atom. When this happens, the position number of the branch should be repeated. Then the name of the compound will be

2,2-dimethylpropane.

Now name the alkanes given below.



Let us examine the structure of another alkane.



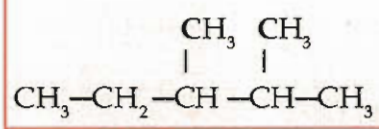
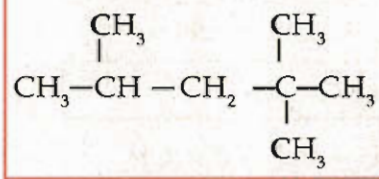
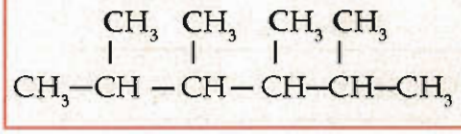
Find the following.

- The number of carbon atoms in the longest carbon chain .....
- Number of branches.....
- The positions of branches from right.....
- The sum of position numbers.....
- The positions of branches from left.....
- The sum of position numbers.....

While naming alkanes of this type, the numbering should be done in such a way that the sum of the position numbers is minimum.

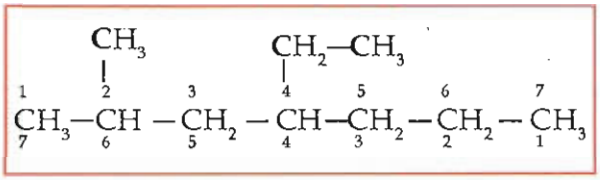
Then the name of the alkane shown above is 2,4-dimethylhexane.

Name the alkanes given below.

Naming of alkanes with different alkyl radicals as branches

Look at the structure of the alkane given below.



- ★ The longest carbon chain in this compound can be found out. The name of the alkane corresponding to this?

  -

- ★ Identify the various branches. Are both the branches the same radical?

  -

- ★ Names of the radicals?

  -

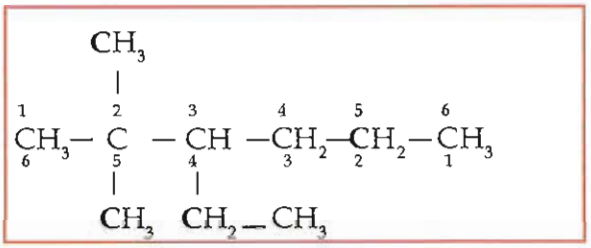
- ★ The position of each radical?

  -

While naming such alkanes, the names of the different alkyl radicals are arranged in alphabetic order. There is no change in the other rules. Thus the compound shown above can be named as:

4-ethyl-2-methylheptane.

Look at the name given, in the same manner, to another alkane.



3-ethyl-2,2-dimethylhexane

- Write the structural formula of 3-ethyl-3,4-dimethylheptane.

Naming of unsaturated hydrocarbons

Alkenes

Examine the IUPAC names given to a few alkenes.

$CH_2 = CH–CH_2 – CH_3$

but - 1 - ene

$CH_3 – CH = CH–CH_3$

but - 2 - ene

$CH_3 – CH_2–CH_2–CH = CH_2$

pent - 1 - ene

$CH_3–CH_2–CH = CH–CH_3$

pent - 2 - ene

What are the factors considered for their naming?

- Number of carbon atoms.
-

While naming alkenes the longest carbon chain carrying the double bond is considered for selecting the word root. The numbering is done in such a way that the carbon atom having the double bond gets the lowest position number. Look at the structure of the name.

Word root + hyphen + position of double bond + hyphen + suffix (ene)

Alkynes

Look at the names given to certain alkynes. Is the method of naming of alkynes similar to that of alkenes? Examine.

$CH_3–C \equiv C–CH_3$

but- 2 - yne

$CH_3–CH_2–C \equiv CH$

but- 1 - yne

$CH_3 –CH_2–CH_2 –C \equiv CH$

pent- 1 - yne

$CH_3–CH_2–C \equiv C–CH_3$

pent- 2 - yne

See the structure of the name.

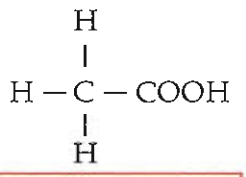
Word root + hyphen + position of triple bond + hyphen + suffix (yne)

Functional groups

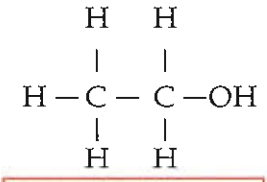
So far we have discussed organic compounds containing only carbon and hydrogen. Besides these, won't there be compounds containing other elements?

Examine the names and structures of certain organic compounds given below.

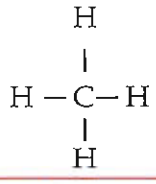
Which among these are hydrocarbons?



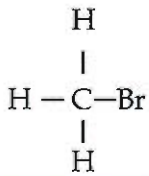
ethanoic acid



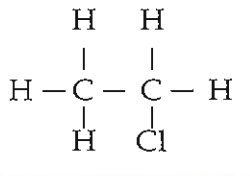
ethanol



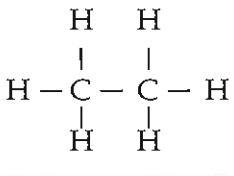
methane



bromomethane



chloroethane



ethane

What is the characteristic difference between hydrocarbons and the other compounds?

They are formed from hydrocarbons by the replacement of hydrogen atoms by other atoms or groups of atoms, aren't they?

Atoms or groups of atoms that replaced hydrogen atoms from hydrocarbons are termed as functional groups. The physical and chemical properties of a compound depend on the functional group it contains. Some important functional groups are given in Table 14.4.

Naming of compounds containing functional groups

Halogen compounds

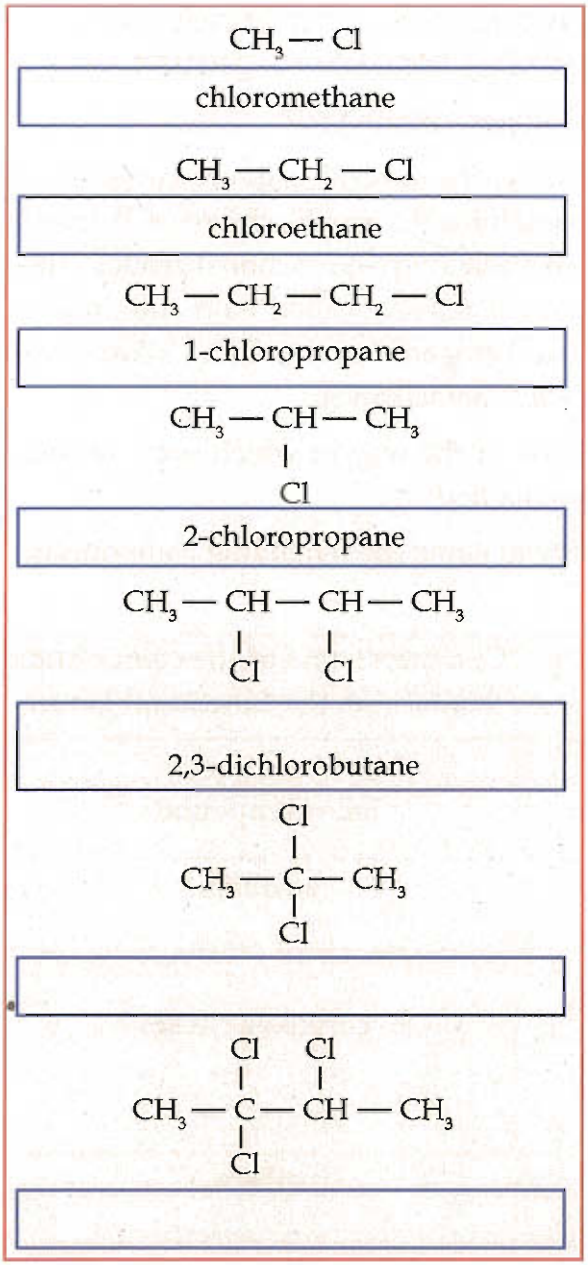
There are several organic compounds containing fluoro (-F), chloro (-Cl), bromo (-Br) and iodo (-I) functional groups. They are collectively called halo compounds. The halogen derivatives of alkanes are called haloalkanes.

Look at the way in which some of them are named.

Try to name the remaining compounds.

Functional group	Name of the functional group	Common name of the compounds containing the functional group
-F, -Cl, -Br, -I	fluoro, chloro, bromo, iodo	halo compounds
-OH	hydroxyl	alcohols
O ‖ -C-OH (-COOH)	carboxylic	carboxylic acids
R-O-	alkoxy	ethers
O ‖ -C-H (- CHO)	aldehyde	aldehydes
O ‖ -C-	carbonyl	ketones
$-NH_2$	amino	amines
$-NO_2$	nitro	nitro compounds

Table 14.4



You have understood the method of the naming of haloalkanes, haven't you?

position number of halo group + hyphen + prefix for halo group + name of alkane

Alcohols

The compounds containing -OH as functional group are called alcohols. According to the IUPAC system, alcohols are named by replacing the suffix 'e' in the name of the alkane with the same number of carbon atoms, by 'ol'.

alkane - e + ol → alkanol

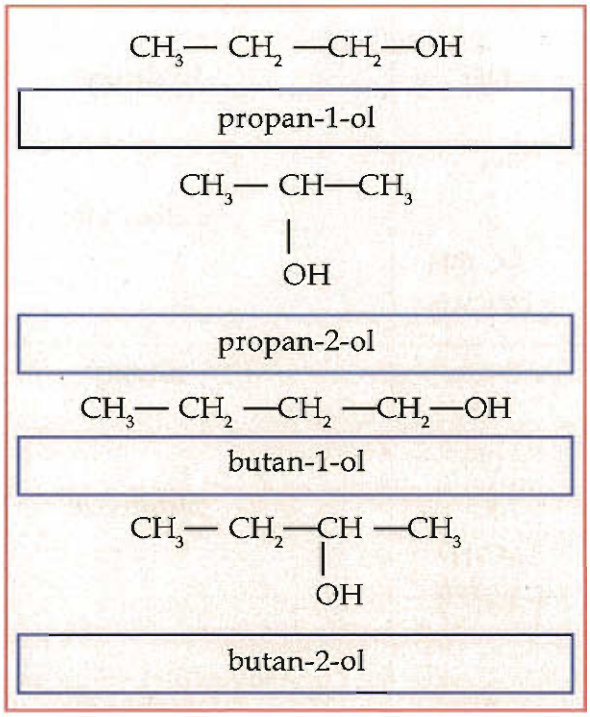
See some examples:

$CH_3 — OH$ methanol

$CH_3 — CH_2 — OH$ ethanol

If there are more than two carbon atoms in the molecule, the position of the -OH group should also be specified. For this the longest carbon chain containing the -OH group is to be considered. Numbering of carbon atoms in the chain should be done in such a way that the carbon atom containing the -OH group gets the lowest position number. Then replace 'e' in the name of the alkane with the position number of hydroxyl group followed by the suffix 'ol'.

Look at the examples:



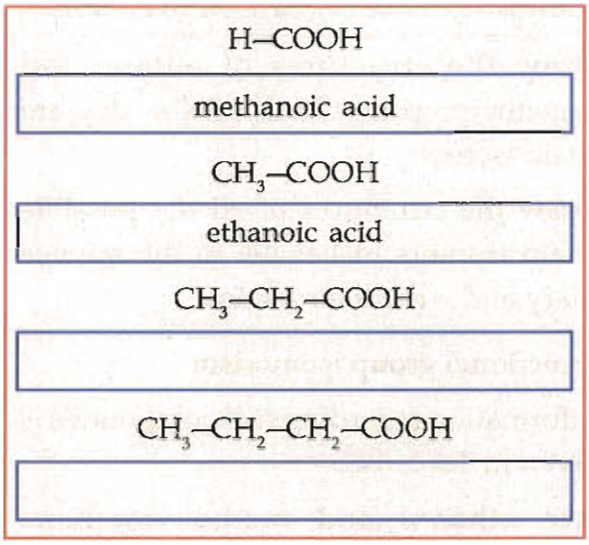
Acids

The compounds containing the functional group -COOH are organic acids. While naming acids, all carbon atoms in the main chain including the one in the carboxylic group are to be considered. The 'e' in the

name of the corresponding alkane is replaced with 'oic acid'.

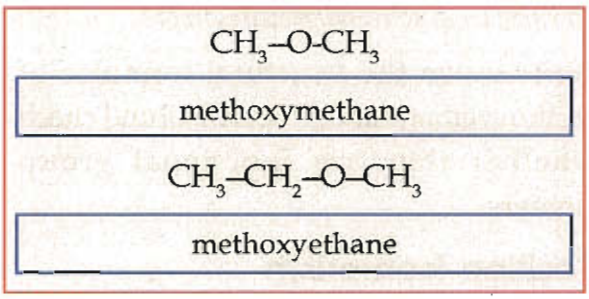
alkane - e + oic acid → alkanoic acid

Look at the examples.



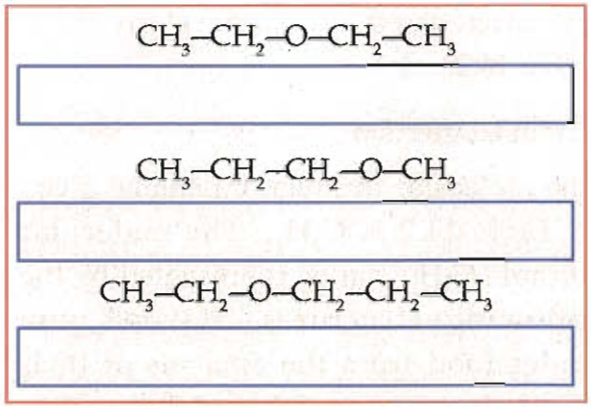
Ethers

Compounds containing the functional group R-O- are called ethers. Look at the IUPAC names of certain ethers.



Let us see how they are named. Haven't you understood that the general IUPAC name of ethers is alkoxy alkane? An ether is named by taking the longer alkyl group as the alkane and the shorter one as the alkoxy group.

Write down the names of the following ethers.



Now you have understood that IUPAC names are based on the structure of compounds. Hence it is possible to understand the name of a compound from its structural formula and the structural formula from its name. More about the naming of organic compounds can be learnt in higher classes.

Isomerism

You have understood that the abundance of organic compounds and their diversity are amazing. You have also studied the reasons for this. Note them in your science diary. Isn't the presence of various functional groups also a factor for the abundance and diversity of organic compounds?

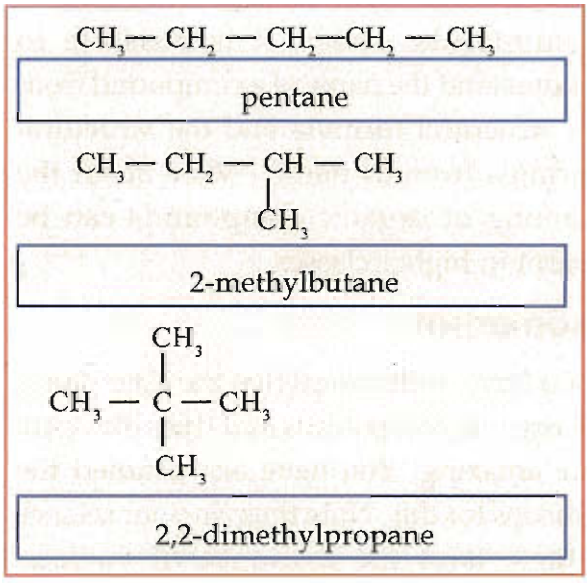
We have seen that more than one compound can have the same molecular formula. They are called isomers and the phenomenon is known as isomerism.

Isn't isomerism another reason for the diversity of organic compounds? What may be the reason for the isomers differing in their physical and chemical properties, though they have the same molecular formula? Can you find this by examining

the structures of isomers given in Table 14.2?

Chain isomerism

The molecular formula of pentane given in Table 14.2 is C_5H_{12}. The molecular formula C_5H_{12} can be represented by the following structures. Haven't you understood from the analysis of their properties given in Table 14.3, that they are entirely different compounds?



You know that they are isomers. What is the difference among the structures of these three compounds? Draw the structures of these compounds showing the carbon atoms alone. What is understood?

The isomers that differ in the structure of their carbon chains are termed as chain isomers.

Draw the structures of butane and 2- methylpropane. Check whether they are chain isomers.

Draw the structures of all the possible chain isomers of hexane in the science diary and write their names.

Functional group isomerism

Information regarding two compounds is given in Table 14.5.

Are ethanol and methoxymethane isomers? Examine.

Are the functional groups in both these isomers the same?

Isomers with different functional groups are termed as functional group isomers.

Write down the structural formulae of methoxyethane and propan-1-ol and check whether they are functional group isomers.

Position isomerism

Look at the structural formulae of two alcohols given.

Name	Ethanol	Methoxymethane
Structural formula	CH_3-CH_2-OH	CH_3-O-CH_3
Molecular formula	.....	.....
Functional group	-OH	-O-CH_3
Family	Alcohol	Ether
Melting point	159K	134.6K
Boiling point	352K	254.6K

Table 14.5

$CH_3–CH_2–CH_2–OH$

propan-1-ol

$CH_3–CH(OH)–CH_3$

propan-2-ol

Both of them are isomers. In these, is there any difference in the carbon chain? And in their functional groups? Then what difference is there in their structures?

Isomers with a difference in the positions of the functional group are known as position isomers.

- Write the structural formula of hexan-1-ol.

Write down the structures and the IUPAC names of all the position isomers possible without changing the carbon chain of the compound.

- Find out which are the position isomers among the given compounds.

$CH_3-CH_2-CH_2-OH$

$CH_3-CH_2-CH(OH)-CH_3$

$CH_3-CH_2-CH_2-CH_2-Cl$

$CH_3-CH(OH)-CH_3$

$CH_3-CH_2-CH_2-CH_2-OH$

$CH_3-CH(Cl)-CH_2-CH_3$

Follow up Activities

1. Write down the structural formulae of the compounds given below. Which among these are isomer pairs? Note down the type of isomerism each pair of compounds has.
   (a) methoxyethane
   (b) hexane
   (c) 1-chlorobutane
   (d) propan-1-ol
   (e) propan-2-ol
   (f) 2,3-dimethylbutane
   (g) 2-methylpentane
   (h) 2-chlorobutane
2. A student gave an organic compound the name 2-ethyl-3-methylpentane.
   (a) Write the structural formula of the compound and examine whether the name given by the student is correct.
   (b) If not, write the correct name of the compound.
   (c) Write the molecular formula of the compound.
   (d) Write the structural formulae of all possible isomers of the compound in your science diary and record the IUPAC name of each. What type of isomerism is this?

3. The molecular formulae of some organic compounds are given.

CH_3Cl	$C_2H_4O_2$	C_3H_8O
CH_2O_2	C_2H_6O	C_2H_5Cl
$C_3H_6O_2$	CH_4O	C_3H_7Cl

   (a) Classify the compounds into different homologous series?

   (b) Obtain the general formula for each homologous series.

4. Write the structural formulae of the compounds given below.

   (a) 3,4,4,5-tetramethylheptane

   (b) 2,5-dimethylhexane

   (c) 2- chloro-3-methylpentane

   (d) 1-chloro-2,2-dimethylpropane

5. Write the structural formulae of the compounds given below. Examine whether the names given are correct. If not write the correct names.

   (a) 2- ethylpentane

   (b) 5-ethyl,3-methylhexane

   (c) 2,5-diethylhexane

6. Write down the structural formulae and the IUPAC names of all possible isomers of the compounds given below.

   (a) pentene (C_5H_{10})

   (b) pentyne (C_5H_8)