7 ORGANIC COMPOUNDS - CHEMICAL REACTIONS

WHAT WE HAVE LEARNT

- **Alkanes are saturated hydrocarbons.**
- **The double bond in alkenes and the triple bond in alkynes makes these compounds unsaturated.**
- **Functional groups determine the properties of organic compounds.**
- **Reactions in which hydrogen is substituted by any other atom or group of atoms is called substitution reactions.**

ORGANIC COMPOUNDS - CHEMICAL REACTIONS

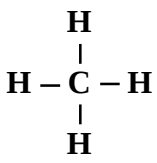
Carbon is an element which has the ability to form millions of compounds. Carbon atoms link together to form long chains and rings. When other elements are connected to this, compounds of complex structure are formed. Because of this property, there are more carbon compounds than the number of compounds of all other elements. Living cells are made of carbon compounds. Similarly, plastics, medicines, dyes, explosives and insecticides are based on carbon compounds. Each of these widely varying compounds can not be studied separately. In organic chemistry therefore, compounds are classified into different families and the general properties and reactions are studied. Element families of the periodic table are familiar to you. But families of carbon compounds contain innumerable members. Each of them exhibit the general properties of the family as well as some properties which are special to them.

The classification of organic compounds is a very complex process since these compounds can be classified in several ways - according to the structure and also according to the elements present. Each group of hydrocarbons, acids, alcohols, ethers, esters etc. belong to one's own family and they are structurally and chemically similar. We can discuss the basic structure and chemical properties of each of these family.

Hydrocarbons

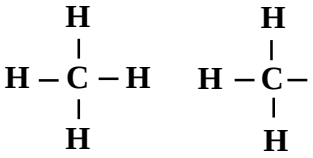
a. Substitution reactions

Examine the structure of methane given below.

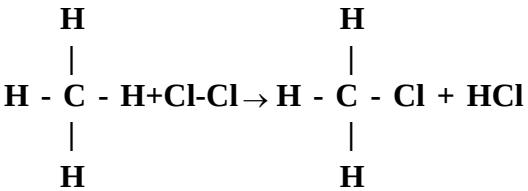


All the four valencies of carbon atom are satisfied by hydrogen atom. Can this carbon form more bonds?

Now suppose if hydrogen is removed from the CH_4 molecule.

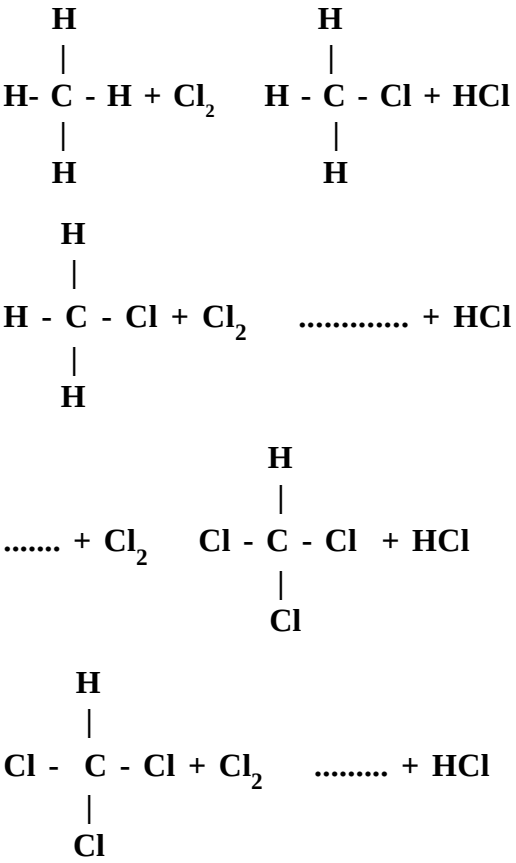


Now are the all valencies of carbon satisfied? Now it is possible to join a chlorine atom also.



Reactions in which the hydrogen atom of the hydrocarbon is substituted by other atoms or group of atoms are called substitution reactions.

Now, find out how many hydrogen atoms are there in CH_4 which can be substituted. These hydrogen atoms can be substituted step by step. Complete the equations given below.



Similarly write the substitution reaction of ethane (C_2H_6) with chlorine.

Not only chlorine but other atoms or group of atoms can enter into substitution reactions by displacing hydrogen.

b. Combustion

The burning of substances in air can be termed as combustion. The main components of cooking gas are ethane, propane, butane etc. What is the chemical reaction taking place when butane undergoes combustion.

Chemical formula of butane = C_4H_{10}

When substances are burned, they combine with oxygen in the air. The products of such reactions are oxides of component elements. Complete the following equation.

C_4H_{10} + O_2 ..... + ...

Complete the following table.

Compound	Compo-nents	Products of combustion
CH_4		
C_2H_6		
$CH_2 = CH_2$		
CH_3-CH=CH_2		
CH CH		
CH_3 - C CH		

Table 7.1

What are the components of the compounds given in the table? What products are obtained from combustion? What are the products formed due to the combustion of hydrocarbons?

Hydrocarbon + O_2 .... + ...

Write the equation for the combustion of the compounds in the table.

- **CH_4 + $2O_2$ CO_2 + $2H_2O$**
-
-

c. Thermal cracking

We know that when hydrocarbons are burned in air they give carbon dioxide and water. Now we shall see what happens to the carbon chain when saturated hydrocarbons containing more than two carbon atoms are heated in the absence of air.

CH_3-CH_2-CH_3 CH_4+CH_2=CH_2

Now discuss the reason for the formation of double bond.

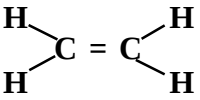
When butane is heated in the absence of air, what products are formed?

$CH_3\text{-}CH_2\text{-}CH_2\text{-}CH_3$ .....+....+....

Saturated hydrocarbons when heated in the absence of air, decompose to lower hydrocarbons. This is called thermal cracking. In certain cases catalysts are used. The products formed depend on the nature of the hydro carbon, temperature and the catalyst.

d. Addition reactions

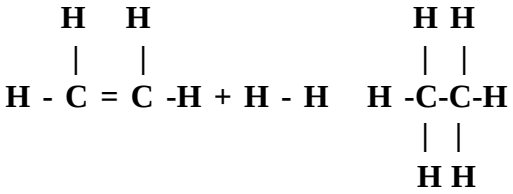
Observe the structure of ethene.



Suppose in this compound the double bond breaks up forming a single bond.

Now find out how many residual valencies are there for carbon atom to be satisfied?

Let us examine the reaction of ethene with hydrogen.

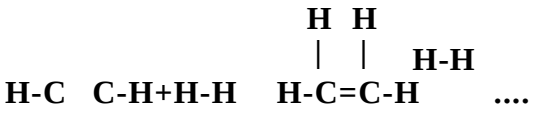


$C_2H_4 + H_2$ C_2H_6

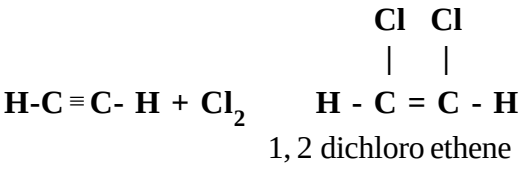
When a double bond breaks up to form a single bond how many hydrogen atoms can be joined?

Similarly when a triple bond breaks to give a double bond how many hydrogen atoms can be joined?

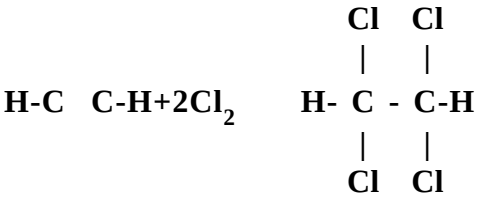
Complete the following equation of the reaction of ethyne with hydrogen.



Given below is the equation for the reaction of ethyne with chlorine.



1, 2 dichloro ethene



1,1,2,2 tetra chloro ethane

In the first reaction as there are only two chlorine atoms the only one bond in the triple bond breaks. Therefore a double bonded compound is formed.

But in the second reaction two bonds in the triple bond break to give a single bonded compound. Why?

Write the equation for the reaction of 1,2-dichloro ethene with a hydrogen molecule.

Complete the following equation.

$H_2C = CH_2 + HCl$ .....

CH CH + HCl .....

Compounds having double bond and triple bond react with H_2, Cl_2, and HCl . As a result double bonded compounds change to saturated hydrocarbons and triple bonded hydrocarbons

change to unsaturated double bonded hydrocarbons and then to saturated hydrocarbons. These reactions are called addition reactions.

Now complete the following table.

Compound	Combining molecule	Product
CH_3-CH=CH-CH_3	H-H	.....
$CH_2 = CH_2$	H-H	.....
HC $\equiv$ CH	H-Cl	.....
CH_3-C C-CH_3	Cl-Cl	

Table 7.2

e. Polymerisation

You have learnt the addition reaction of hydrocarbons. For example ethene undergoes addition reaction with hydrogen to give ethane. Suppose two ethene molecules undergo addition reaction,

$CH_2 = CH_2 + CH_2 = CH_2 \rightarrow CH_2 - CH_2 - CH_2 - CH_2$

When many ethene molecules combine,

$..... + CH_2 = CH_2 + CH_2 = CH_2 + CH_2 = CH_2 + ... \rightarrow CH_2 - CH_2 - CH_2 - CH_2 - CH_2 - CH_2$

This can be summarised as follows:

$nCH_2 = CH_2 \rightarrow CH_2 - CH_2 _n$

ethylene poly ethylene

$CH_2 - CH_2 _n$ is the familiar molecule called polythene.

In such reactions many number of lower hydrocarbons combine together. These lower hydrocarbons are called monomers. The monomers combine to give a complex molecule called polymer. From here it is evident that the molecular weight of polymers are very high. Thus the process in which monomers combine together to give polymers is called polymerisation. To get the name of the polymer we can add prefix poly to the name of the monomer.

Like polythene, many polymers are familiar to you. List them out.

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-

Name of monomer	Polymer	
	Name	Structure
$CH_2 = CH_2$ (Ethylene)	Polyethylene	.....
n $CH_2 = CH - Cl$ (Vinyl chloride)	.....	$CH_2 - CH _n$ | Cl
$CH_3 CH = CH_2$ (Propene)	.....	.....

Table 7.3

Alcohols

Earlier you have learnt that compounds with -OH functional group are alcohols. The chemical formula of some alcohols are given below. Try to write the IUPAC names for them.

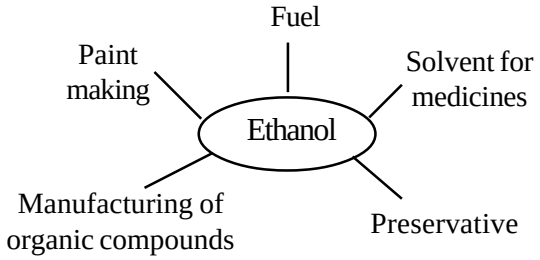
$CH_3 - CH_2 - CH_2 - OH$

$CH_3 - CH(OH) - CH_3$

$CH_3 - CH_2 - CH_2 - CH_2 - CH_2 - OH$

$CH_3 - CH_2 - OH$

The important uses of ethanol is given below. You may add more to this. Ethanol (ethyl alcohol) is the most important one among alcohols. Alcohol is manufactured by the fermentation of sugar solution.



Add yeast to 10% concentrated sugar solution. The enzymes invertase and zymase in yeast convert sugar solution to alcohol. The chemical equations are given below.

$C_{12}H_{22}O_{11} + H_2O \rightarrow \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{fructose}}{C_6H_{12}O_6}$

$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$

Here we get 8-10% alcohol. This is known as wash. On fractional distillation 95% alcohol (or rectified spirit) is obtained. The alcohol used for industrial purposes is rectified spirit. 100% alcohol is known as absolute alcohol.

The mixture of petrol and absolute alcohol is used as fuel in automobiles. This is known as power alcohol.

Denatured spirit

We have seen some of the uses of ethanol. Ethanol is used in large quantities in industries. There is a chance that this may be consumed by people as a drink. To prevent this methanol, pyridine or rubber distillate are added to the ethanol used for industrial purposes. This is called denatured spirit.

Carboxylic acids

We know that most of the natural compounds with sour taste contain organic acids. The functional group is -COOH. To get the IUPAC names of organic acids add 'oic acid' to the name of the hydrocarbon.

Consider HCOOH. Since there is only one carbon, add 'oic acid' to the name of methane . So the name becomes methanoic acid.

Methane -e+oic acid = Methanoic acid
Ethane - e+oic acid = Ethanoic acid

- **CH_3COOH - ethane + oic acid - ethanoic acid**
- **CH_3CH_2COOH -**
- **$CH_3CH_2CH_2COOH$ -**

Now we shall find out some of the chemical properties of organic acids.

- **Take some zinc granules in a test tube. Add a few drops of vinegar to it. The gas evolved is hydrogen .**

$2CH_3COOH + Zn \rightarrow \underset{\text{zinc acetate}}{(CH_3COO)_2 Zn} + H_2$

- **Repeat the experiment using magnesium, and sodium instead of zinc. Write the equation for the reaction.**

- **Now we can see what are the products obtained when organic acids and alcohols react.**

To a little acetic acid, add ethanol and a few drops of dilute sulphuric acid.

Smell the solution. The equation for the reaction can be written as follows.

$$CH_3COOH + HOC_2H_5 \rightarrow CH_3COOC_2H_5 + H_2O$$

ethyl acetate

Such products obtained by the reaction of alcohols and acids are called esters. Since these esters have the smell of fruits and flowers they are used in squashes and perfumes for flavours.

The reaction of a compound with water is called hydrolysis.

The sucrose molecule gives two molecules of carbohydrates (glucose and fructose). But these glucose and fructose do not further react with water to give lower carbohydrates. Such carbohydrates which does not undergo further decomposed into simpler carbohydrates are called monosaccharides. Disaccharides react with water to give two monosaccharide molecules.

Sucrose + Water → glucose + fructose

Smell	Ester	Molecular formula
Plantain fruit (Big variety)	Amyl acetate	$CH_3\ COO\ C_5H_{11}$
Apricot	Amyl butyrate	$CH_3\ CH_2\ CH_2\ COO\ C_5H_{11}$
Pineapple	Ethyl butyrate	$CH_3\ CH_2\ CH_2\ COO\ C_2H_5$
Orange	Octyl acetate	$CH_3\ COO\ C_8H_{17}$
Jasmine	Benzyl acetate	$CH_3\ COO\ C_6H_5$

Table 7.4

Carbohydrates

You have learnt about carbohydrates and the constituent elements which help in the production of energy in the human body. Since the amount of hydrogen and oxygen is the same as that of water we name these compounds as carbohydrates.

Carbohydrates react with acidified water giving lower carbohydrates. For example sucrose decomposes to glucose and fructose. The equation for the reaction is given below.

$$C_{12}H_{22}O_{11} + H_2O \rightarrow C_6H_{12}O_6 + C_6H_{12}O_6$$

glucose fructose

There are other compounds which have the same molecular formula as that of glucose. These are the smallest carbohydrates. But their structure is different. How do we name the compounds having the same molecular formula but different structural formula?

Lactose gives two monosaccharides on hydrolysis.

$$C_{12}H_{22}O_{11} + H_2O \rightarrow 2C_6H_{12}O_6$$

(Lactose)

Formulate definitions for trisaccharides, tetra saccharides and poly saccharides.

Write the equation of the reaction of the following compounds with water and classify them as mono, di or tri.

Maltose $(C_{12}H_{22}O_{11})$

Galactose $(C_6H_{12}O_6)$

Raffinose $(C_{18}H_{32}O_{16})$

Given is the equation of the reaction of stachyose $C_{24}H_{42}O_{28}$ with water.

$$C_{24}H_{42}O_{21} + 3H_2O \quad C_6H_{12}O_6 + C_6H_{12}O_6 + C_6H_{12}O_6 + C_6H_{12}O_6$$

Explain why stachyose is called a tetra saccharide.

What will be the equation for the hydrolysis of polysaccharides like starch, cellulose $(C_6H_{10}O_5)_n$?

$$(C_6H_{10}O_5)_n + n\ H_2O \quad nC_6H_{12}O_6$$

Glucose

Glucose is the most important one among monosaccharides. $(C_6H_{12}O_6)$

We know that glucose formed in the body by the process of metabolism gives energy for our bodily activities. But excess amount of glucose in the body leads to a disease called diabetes.

Now perform the following experiment using glucose.

- **Prepare glucose solutions of concentration 1%, 0.5%, 0.25%, 0.05%. Take four test tubes with 2 mL of Benedict solution to each. Add 8-10 mL glucose solution in each and shake well. Observe the colour change in each test tube and compare with the colour chart in the Benedict solution and note down the amount of glucose in each.**

Test tube	Colour	Percentage of glucose
1		
2		
3		
4		

Table 7.5

Alter the concentration of glucose and repeat the experiment. Note down the change in colour in your science diary. This experiment is used to determine the amount of glucose in the urine of diabetic patients.

Benedict's solution is added to the urine sample. Based on the change in colour diabetes can be confirmed.

- **Another experiment to determine the presence of glucose.**

Take some glucose solution in a test tube and add ammoniacal silver nitrate.

What is the colour of the precipitate?

Discuss and prepare notes on the functions of glucose in our body and the harmful effects of a higher than normal sugar level.

SUMMARY

- Alkanes undergo substitution reactions.
- Hydrocarbons undergo combustion in air giving carbon dioxide and water.
- The decomposition of higher level hydrocarbons to lower level hydrocarbons on strong heating is called thermal cracking.
- Unsaturated hydrocarbons undergo addition reactions.
- Many of the unsaturated hydrocarbons undergo addition reaction to give polymers.
- Compounds with -OH functional group are called alcohols.
- The functional group in organic acids is -COOH.
- Organic acids react with alcohols to give esters.
- C, H, O are the elements present in carbohydrates. The ratio of hydrogen and oxygen is 2:1.
- Carbohydrates that do not decompose into simpler carbohydrates in reacting with water are called monosaccharides.
- Depending on the number of monosaccharides formed as a result of the reaction of the carbohydrate with water, carbohydrates can be classified as disaccharides, trisaccharides, polysaccharides etc.

MORE ACTIVITIES FOR YOU

1. Write the molecular formulae of propane. What are the compounds obtained when it undergoes substitution reaction with chlorine.
2. Fill up
   a. CH_3-CH_2-CH_2 - CH_2 - CH_2 - CH_3 + ... O_2 ..... + ...
   b. CH_3 - CH_2 - CH_2 - CH = CH_2 + Br_2 .....
   c. CH_3 - CH_2 - CH_2 - CH_2 - C C - CH_3 + HCl .....
3. Write the structural formula
   a. 2, 2- dimethyl butanoic acid
   b. 2, 3, 4 - trimethyl heptanol
   c. 1, 2 - ethanediol
4. What are the harmful consequences of an increased glucose level in blood and urine.
5. Give the names of the following compounds

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

   b. $CH_3 - OH$

   c. $CH_2(OH) - CH(OH) - CH_2(OH)$

   d. $CH_3 - CH_2 - COOH$

   e. $CH_3 - CH(CH_3) - CH_2 - COOH$
6. Which among the following can make polymers?

   Butane, propane, propene, methane, butene.

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