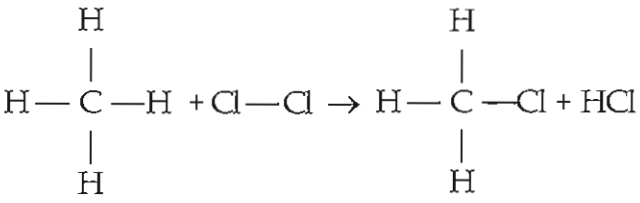
15 ORGANIC COMPOUNDS: REACTIONS

You have studied many chemical reactions. It is through chemical reactions that new products are formed.

Let us examine the different ways in which hydrocarbons undergo chemical changes.

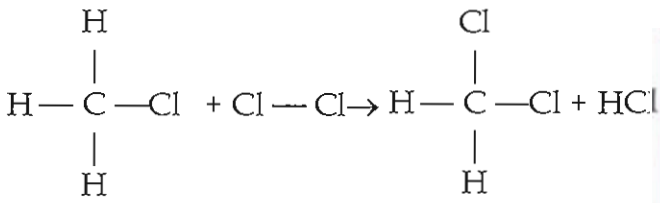
Substitution reaction

Methane (CH_4) is a saturated hydrocarbon. See what happens when methane reacts with chlorine in the presence of sun light.



methane chloromethane

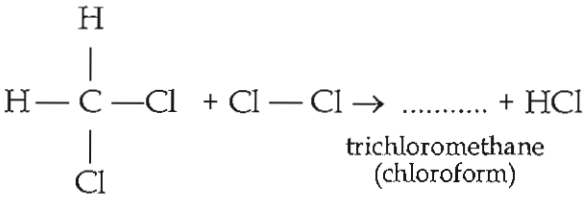
In this reaction one H atom of methane is replaced by one Cl atom, isn't it? What will be the product formed if one hydrogen atom in the above product is replaced by chlorine?



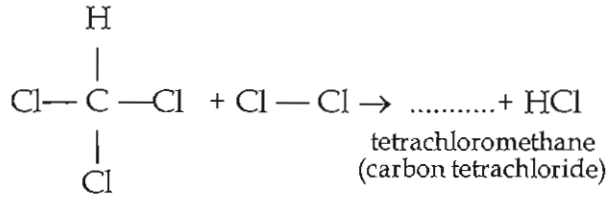
chloromethane dichloromethane

How many replaceable hydrogen atoms are left in dichloromethane molecule?

Find out how they can be replaced step by step with chlorine, and then complete the reaction.



trichloromethane (chloroform)



tetrachloromethane (carbon tetrachloride)

See the simplified representation of the different steps of the reaction.

$$CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$$

$$CH_3Cl + Cl_2 \rightarrow CH_2Cl_2 + HCl$$

$$CH_2Cl_2 + Cl_2 \rightarrow CHCl_3 + HCl$$

$$CHCl_3 + Cl_2 \rightarrow CCl_4 + HCl$$

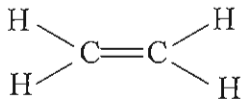
Observe the formation of HCl molecule also in each step of the reaction.

The reaction in which hydrogen atom from a hydrocarbon is replaced by another atom or a group of atoms is called substitution reaction.

Write down the various steps involved in the substitution reaction of ethane with chlorine in your science diary.

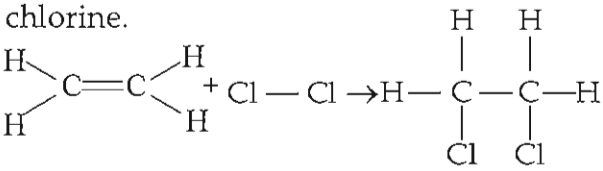
Addition reaction

Look at the structural formula of ethene.



The special feature of this compound is the double bond between the two carbon atoms.

See the reaction between ethene and chlorine.



$CH_2 = CH_2 + Cl_2 \rightarrow CH_2Cl - CH_2Cl$

Here, isn't it the addition of two molecules that happened?

★ What happened to the bonding in ethene?

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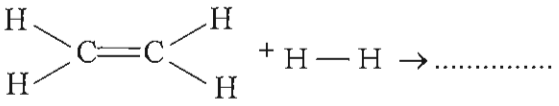
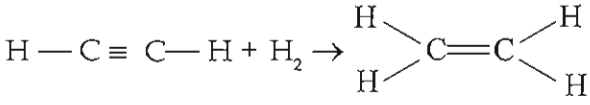
Under favourable conditions if the reaction between ethene and hydrogen is also an addition reaction like this, complete the equation.



$CH_2 = CH_2 + H_2 \rightarrow$ .....

Alkynes with triple bond also undergo addition reactions like this. See the equation for the reaction between ethyne and hydrogen:



$CH \equiv CH + H_2 \rightarrow$ .....

What will happen if the reaction continues? Write the equation.

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Similarly try to complete the equation of the reaction between ethyne and chlorine.

$CH \equiv CH + Cl_2 \rightarrow$ .....
1,2 - dichloroethene

..... + $Cl_2 \rightarrow$ .....
1,2 - dichloro ethene
1,1,2,2-tetrachloro ethane

Now can't you complete the equation given below?

$CH_2 = CH_2 + HCl \rightarrow$ .....

Now, you are convinced that unsaturated molecules with double and triple bonds can combine with molecules such as H_2, Cl_2, HCl etc. As a result of this, compounds with double bond get converted into saturated compounds and compounds with triple bond get converted first into unsaturated compounds with double bond and then to saturated compounds with single bonds. Such reactions are called addition reactions.

Polymerisation

What will happen if unsaturated hydro carbon molecules undergo addition reaction among themselves? In such situations, a large number of molecules join together to form a big molecule.

The equation for the addition reaction among a large number of ethene molecules can be simply represented as follows:

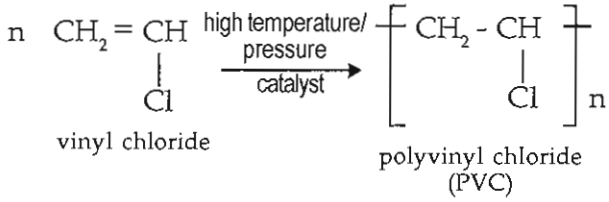
$$n\ CH_2 = CH_2 \rightarrow \left[CH_2\text{-}CH_2\right]_n$$

The formation of a gigantic molecule by the combination of a large number of simple molecules (monomers) is called polymerisation. The product of polymerisation is called a polymer.

The name of the polymer is written by prefixing 'poly' to the name of the monomer.

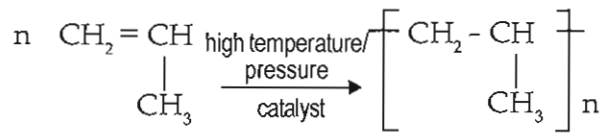
If so, the product of polymerisation of ethene can be called polyethene. This is commonly known as polythene.

Look at two more examples of polymerisation:



vinyl chloride

polyvinyl chloride (PVC)



propene

polypropene

Many industrially important products are made by polymerisation. Polythene, PVC, polypropene etc., are widely used plastics.

Combustion

Kerosene, petrol, L.P.G etc. are hydrocarbons. Heat is released as a result of their combustion. Therefore, these are used as fuels. When substances burn in air, they combine with oxygen. What are the oxides likely to be formed when hydrocarbons burn in air? Think.

Methane (CH_4) and butane (C_4H_{10}) are the chief components of natural gas and LPG. respectively. The equations for the chemical reactions when they burn in air, are given.

$$CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O$$

$$2\,C_4H_{10} + 13\,O_2 \rightarrow 8\,CO_2 + 10\,H_2O$$

Haven't you noticed the products?

Like hydrocarbons, almost all organic compounds undergo combustion.

Thermal cracking

You have understood what happens when hydrocarbons burn.

What will happen if hydrocarbons are heated in the absence of air?

When hydrocarbons of high molecular masses are heated in the absence of air they split into molecules of lower molecular masses. This process is called thermal cracking. For example, when hexane is subjected to thermal cracking at high temperature and pressure, ethane and butene are formed.

$$C_6H_{14} \rightarrow C_2H_6 + C_4H_8$$

Many products are being made by this method. The products of thermal cracking depend on the nature of the hydrocarbon, temperature, pressure and catalyst used. Thermal cracking is used to convert kerosene and diesel into petrol.

Till now we have discussed the reactions taking place in hydrocarbons. Doesn't the change occur to C - H, C - C, C = C and C ≡ C bonds in these reactions?

Haven't you become familiar with the compounds containing functional groups earlier? Don't the functional groups in them also involve in reactions?

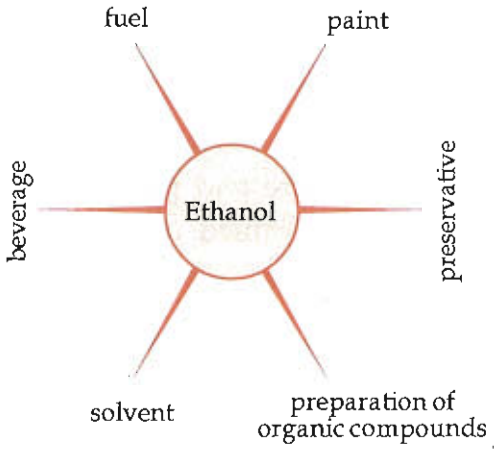
Organic compounds with functional groups undergo several reactions. The manufacture of many industrially important compounds and medicines is carried out by these reactions. The metabolic processes essential for sustaining life also involve many complex organic reactions.

You will learn more about the reactions of organic compounds and their importance in higher classes.

Some important organic compounds

Ethanol

Ethanol is a very important alcohol in industry. See the different uses of ethanol depicted.



Ethanol is made generally by the fermentation of sugar solution. Fermentation is the chemical reaction taking place in the presence of enzymes produced by micro organisms like yeast, bacteria and fungus. About 10% sugar solution is mixed with yeast and kept. Sugar is converted into ethanol in the presence of the enzymes invertase and zymase in yeast. The equations of the reactions are given.

$$\underset{\text{sugar}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow{invertase} \underset{\text{glucose}}{C_6H_{12}O_6} + \underset{\text{fructose}}{C_6H_{12}O_6}$$

$$C_6H_{12}O_6 \xrightarrow{zymase} 2\ \underset{\text{ethanol}}{C_2H_5\text{-}OH} + 2\ CO_2$$

An 8 - 10 % solution of ethanol is obtained here. This is usually called 'wash'. When wash is subjected to fractional distillation, a 95.6% ethanol solution is obtained. This is known as rectified spirit. In order to prevent the illicit consumption of ethanol supplied duty free to factories and laboratories, it is mixed with poisonous substances. This alcohol is called 'denatured spirit'. Ethanol mixed with methanol as the poisonous substance is called methylated spirit. 100% ethanol is known as absolute alcohol. Absolute alcohol mixed with petrol is used as a motor fuel. This is power alcohol.

Ethanoic acid

One of the important carboxylic acids is ethanoic acid (CH_3COOH). It is commonly known by the name acetic acid. 100% acetic acid is called glacial acetic acid. Vinegar is a 5 - 8% aqueous solution of acetic acid. You know that vinegar is used as a preservative in pickles.

Ethanoic acid can be prepared by many methods. It can be prepared by oxidising ethanol to ethanoic acid in the presence of an enzyme. The equation for the reaction is given below.

$$CH_3CH_2OH + O_2 \xrightarrow{enzyme} CH_3COOH + H_2O$$

Carboxylic acids are present in many naturally occurring substances with sour taste. For example tartaric acid in tamarind, citric acid in lemon and lactic acid in buttermilk are carboxylic acids. Carboxylic acids are also known as fatty acids. Compared to mineral acids like HCl, H_2SO_4 and HNO_3, organic acids are weak acids.

You have already learnt the general characteristics of acids in lower classes. What happens when acids react with alkalis?

See the equation of the reaction between ethanoic acid and sodium hydroxide:

$$CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$$

The salt formed here is sodium ethanoate. It is commonly known as sodium acetate.

What happens when acids react with carbonates and bicarbonates?

Prepare aqueous solutions of sodium carbonate (washing soda) and sodium bicarbonate (baking soda). Add vinegar to both the solutions and observe.

Look at the balanced chemical equations of the reactions.

$$2CH_3COOH + Na_2CO_3 \rightarrow 2CH_3COONa + H_2O + CO_2$$

$$CH_3COOH + NaHCO_3 \rightarrow CH_3COONa + H_2O + CO_2$$

Show a burning matchstick to the evolving gas. What happens?

You have studied the method of making portable fire extinguisher by using similar reactions in Standard IX.

Esters

What happens when an alcohol and a carboxylic acid react with each other?

Let us do an experiment. Take 1 mL ethanol and 1 mL glacial acetic acid in a test tube. Add a few drops of concentrated sulphuric acid into this mixture. Heat the mixture in a water bath for about 5 minutes. Take 50 mL water in a beaker and pour the hot mixture in the test tube into it. Smell the resulting solution. What have you observed?

Look at the equation of the above reaction.

$$\underset{\text{ethanoic acid}}{CH_3COOH} + \underset{\text{ethanol}}{HOCH_2CH_3} \rightarrow \underset{\text{ethyl ethanoate}}{CH_3COOCH_2CH_3} + H_2O$$

The product formed by the reaction between an alcohol and a carboxylic acid is called an ester. These reactions are called esterification reactions. Most esters have the pleasant smell of fruits and flowers. If so, what are the probable uses of esters? Think.

Soap and detergent

Oils and fats are esters of fatty acids like oleic acid, palmitic acid, stearic acid etc. Soaps are salts formed by the reaction of these esters with alkalis. Sodium hydroxide and potassium hydroxide are the alkalis generally used for making soaps. Coconut oil, palm oil, cotton seed oil, groundnut oil and animal fats are used for making soap.

Making Soap

Take 3.5 mL water in a beaker. Dissolve 10 g caustic soda (NaOH) in it. Cool the solution. Add 60 g coconut oil into the solution slowly with stirring. Observe what happens. The precipitate formed is soap. After sometime store the precipitate in small boxes. When it hardens, use it as soap.

Many other ingredients are also added to give colour, fragrance and hardness for the soaps available in the market.

Let us do an activity.

Take 10 mL of distilled water in one test tube and 10 mL of hard water in another test tube. Add a few drops of soap solution to both and shake well for the same period of time.

Is lather formed to the same extent in both the test tubes? Which has the higher amount of lather?

What is your inference?

Take 10 mL each of hard water in two test tubes. Add a few drops of soap solution to one test tube and the same quantity of detergent solution to the other.

Shake the two test tubes for the same period of time. What is your observation?

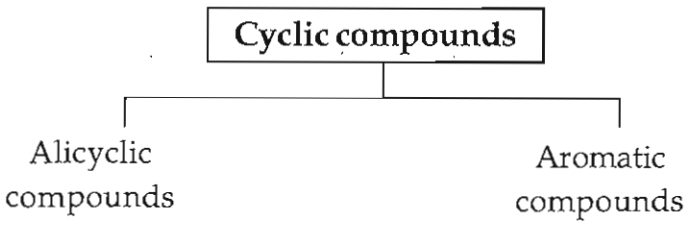
In which test tube is lather produced more?

Soap does not readily produce lather in hard water. The reason is that the calcium and magnesium salts in hard water react with soap to produce insoluble compounds. Detergents do not react like this. Therefore detergents are more effective than soap in hard water.

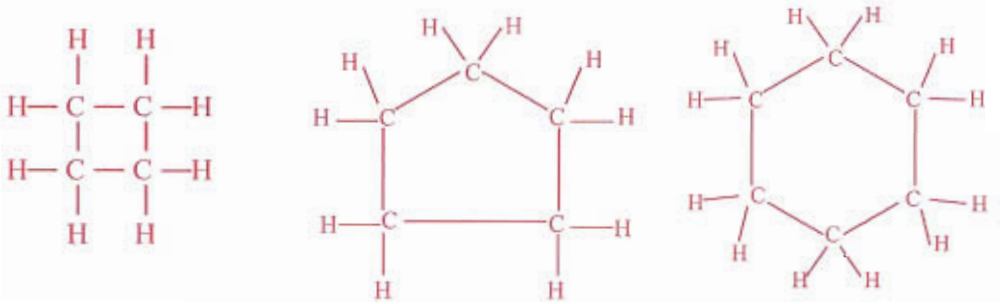
Most detergents are salts of sulphonic acids. Detergents are also used in shampoo and tooth paste.

Cyclic compounds

We have been discussing open chain compounds so far. You have learnt in Standard IX that organic compounds also include many cyclic compounds. Cyclic compounds can be classified into alicyclic compounds and aromatic compounds.



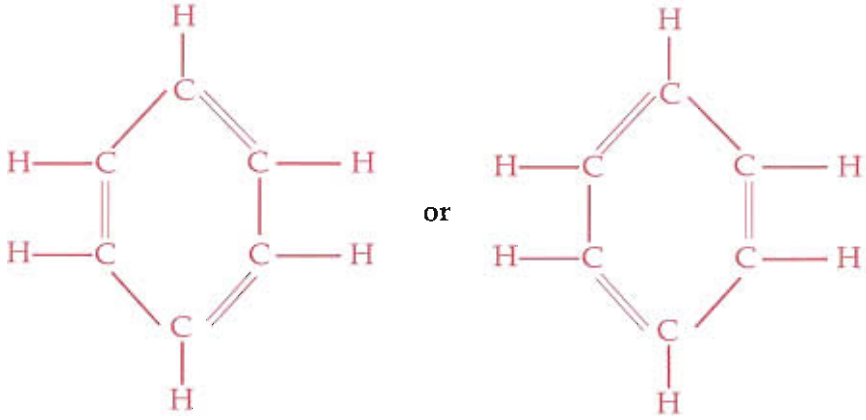
Alicyclic compounds are cyclic compounds showing the characteristics of open chain compounds. Cyclobutane, cyclopentane, cyclohexane etc. are examples.



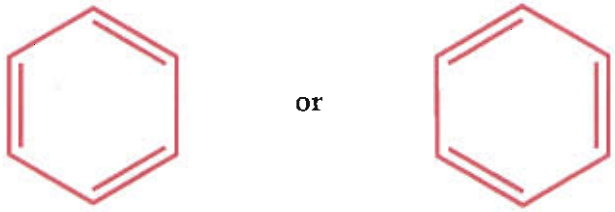
cyclobutane cyclopentane cyclohexane

Aromatic compounds are a class of cyclic organic compounds showing properties entirely different from those of open chain compounds and alicyclic compounds. One of the most important aromatic compounds is benzene with the molecular formula C_6H_6.

See the structure of benzene molecule.

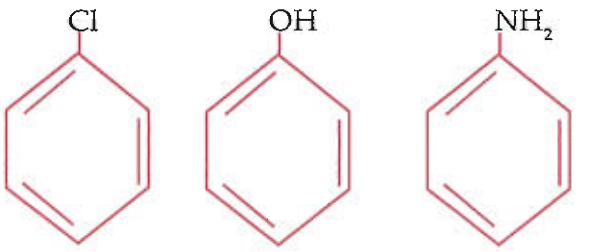


The structure of benzene molecule can be represented in a simple manner as follows.



You have noticed how the four valencies of carbon atoms in benzene get satisfied? Though benzene has alternate double bonds in its molecule it shows chemical properties different from those of unsaturated compounds.

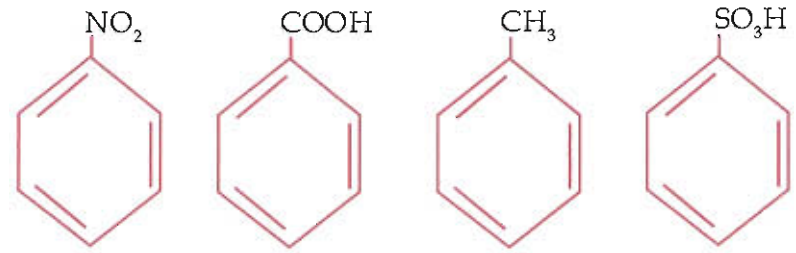
We have familiarised ourselves with substitution reactions. When the hydrogen atom of benzene is substituted by other functional groups, different aromatic compounds are obtained. Look at the structures of a few of such compounds.



chloro benzene

hydroxy benzene (phenol)

aminobenzene (aniline)



nitrobenzene | benzoic acid | methyl benzene (toluene) | benzene sulphonic acid

All these are industrially important compounds. Draw the structural formulae of the above compounds showing all the carbon and hydrogen atoms in your science diary.

The world of organic compounds is vast. You will learn more details about organic compounds in higher classes.

Follow up Activities

1. Write the structural formulae of the following compounds.

C_2H_4	CH_3Cl	$C_2H_2Cl_2$	C_2H_2
C_3H_8	C_3H_6	C_3H_4	C_2H_3Cl

   Classify them as follows.
   (a) Molecules that undergo substitution reactions.
   (b) Molecules that undergo addition reactions.
   (c) Molecules that can polymerise.
2. Ethyne (CH ≡ CH) under favourable conditions combines with hydrogen to form a compound A. A continues to combine with hydrogen to form B. B reacts with chlorine in the presence of sunlight to form C.
   (a) Write down the equations of the above reactions. Identify the compounds A, B and C and give their IUPAC names.
   (b) Write the name of the type of reaction to which each of the above reactions belongs.
3. When water is mixed with calcium carbide a gas P, used for welding, is obtained. Given is the equation of the reaction.

$$CaC_2 + 2H_2O \rightarrow Ca(OH)_2 + P$$

Compound P undergoes addition reaction with HCl to form the compound Q. When Q is subjected to polymerisation, an industrially important plastic R is obtained. Write the equations of the reactions and identify P, Q and R.

4. Esters are formed by the reaction between alcohols and carboxylic acids. What are the compounds needed to prepare the following esters? Write equations for the reactions.

   (a) ethyl propanoate.

   (b) propyl ethanoate

5. Ethene and propyne combine with bromine to form addition products. Write equations for the reactions and the IUPAC names of the products.

6. Under favourable conditions, benzene undergoes addition reaction with hydrogen and chlorine to form cyclohexane and benzene hexachloride respectively. Represent the structural formulae of these compounds.