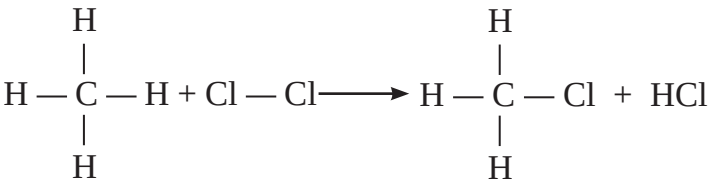
2 CHEMICAL REACTIONS OF ORGANIC COMPOUNDS

We use many substances like drugs, polymers, fuels, plastics, paints, clothing etc., which are the contribution of organic chemistry. Various organic compounds of these types are formed by organic reactions. Organic reactions are chemical reactions involving carbon compounds. Major organic reactions are substitution reactions, addition reactions, combustion, thermal cracking, polymerisation etc. Let us examine these types of chemical reactions.

Substitution reactions

Examine the given chemical equation of the reaction of methane with chlorine in the presence of sunlight.

Step (1)



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

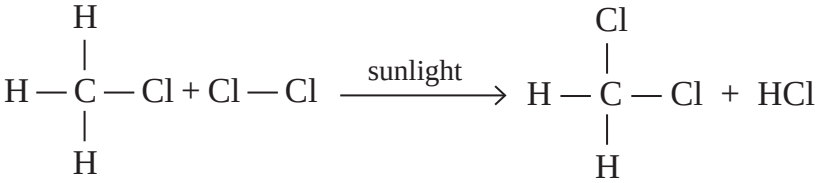
- Which hydrocarbon is given here?
- Which atom replaces hydrogen in the hydrocarbon?
- Write the IUPAC name of the product.

Such chemical reactions are called substitution reactions.

Substitution reactions are chemical reactions in which an atom or group of atoms is replaced with another atom or group of atoms in a compound.

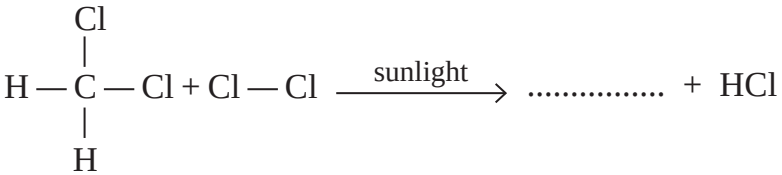
The products formed when CH_3Cl reacts further with chlorine in the presence of sunlight are given.

Step (2)

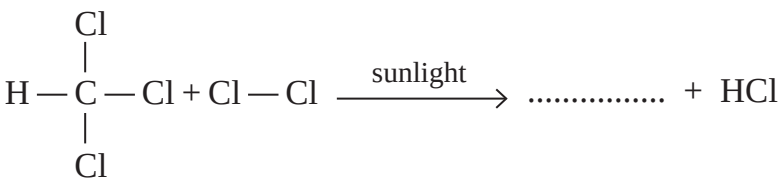


Complete the steps (3) and (4) and write the IUPAC name of the products.

Step (3)



Step (4)



- What are the products formed when ethane ($CH_3 - CH_3$ or C_2H_6) reacts with chlorine? Write the equations.

Addition reactions

CH_4 , $CH_2 = CH_2$, $CH \equiv CH$

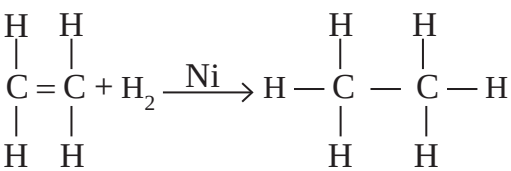
- Which among these are unsaturated hydrocarbons?

Write their IUPAC names.

.....

.....

The chemical equation of the reaction between ethene (C_2H_4) and hydrogen, in the presence of nickel (Ni) as catalyst at high temperature, is given.



$$CH_2 = CH_2 + H_2 \xrightarrow{Ni} CH_3 - CH_3$$

- What change takes place to the carbon-carbon double bond in ethene?
- What is the product formed?
- Is this product saturated or unsaturated?

Such chemical reactions are called addition reactions.

Addition reactions are reactions in which unsaturated organic compounds with double or triple bonds combine with certain molecules to form saturated compounds. The reactions in which triple bonded organic compounds partially combine with small molecules to form double bonded compounds are also addition reactions.

Complete the chemical equations of the addition reactions of ethyne and ethene.

$$H-C \equiv C-H + H_2 \rightarrow .....$$

$$CH_2=CH_2 + Cl_2 \rightarrow .....$$

Complete the Table 2.1 given below.

Chemical reaction	Product	IUPAC name
$CH_3-CH=CH_2+H_2$		
$CH_2=CH_2+HCl$		
$CH_3-CH=CH-CH_3+HBr$		

Table 2.1

Polymerisation

Polymerisation is the process by which simple molecules join together to form large complex molecules.

The simple molecules are called monomers and the large complex molecules formed as a result of polymerisation are called polymers.

(Polymers: poly - many, mer - unit/part)

Based on the method of polymerisation, polymers are classified into addition polymers and condensation polymers.

Addition polymers

Addition polymers are obtained by the repeated addition reaction of monomers.

Have a look at the addition polymerisation between ethene molecules under high pressure and temperature in the presence of a catalyst.

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

ethene polyethene (polythene)

In this chemical reaction,

What is the monomer? .....

What is the polymer? .....

Polyvinyl chloride (PVC) is a polymer used for the manufacture of plastic pipes. Its monomer is vinyl chloride.

Complete the equation given below.

$$n CH_2 = \underset{\underset{Cl}{|}}{CH} \longrightarrow .....$$

Vinyl chloride

Polytetrafluoroethene (Teflon), a polymer manufactured from tetrafluoroethene, is used to coat the inner surface of non stick cookware. Teflon is a polymer that can withstand high temperature.

$$n CF_2 = CF_2 \rightarrow \left[CF_2 - CF_2 \right]_n$$

Tetrafluoroethene Polytetrafluoroethene (Teflon)

Polythene, polyvinyl chloride, teflon, etc. are addition polymers.

Monomer	Polymer	Uses
Vinyl chloride	PVC	Manufacture of pipes, plastic furniture, coating of electric conductors etc.
Ethene	Polythene	Manufacture of tarpaulin sheets, carry bags etc.
Isoprene	Natural rubber	Manufacture of tyres.
Tetrafluoroethene	Teflon	Coating of the inner surface of non stick cookware.
Acrylonitrile (Vinyl cyanide)	Orlon	Manufacture of synthetic fibres.

Table 2.2

Condensation polymers

Nylon 66 is a condensation polymer. Let us examine how it is manufactured.

Nylon 66 is obtained by the condensation polymerisation of adipic acid and hexamethylenediamine at high temperature and pressure. Here a small molecule, H_2O is removed.

$$nHOOC-(CH_2)_4-COOH + nNH_2-(CH_2)_6-NH_2 \rightarrow$$

Adipic acid — Hexamethylenediamine

$$\left[CO-(CH_2)_4-CO-NH-(CH_2)_6-NH\right]_n + nH_2O$$

Nylon 66

Condensation polymerisation is the process in which different monomers combine together to form larger compounds accompanied by the removal of simple molecules.

Examine the Table 2.3 and answer the following questions.

Monomer	Polymer	Use
• Adipic acid • Hexamethylenediamine	Nylon 66	Manufacture of fabrics, combs, bristles of brushes etc.
• Phenol • Formaldehyde	Phenol formaldehyde resin (bakelite)	Manufacture of switches, plugs, handles of pressure cookers etc.
• Ethylene glycol • Terephthalic acid	Polyethylene terephthalate (polyester)	Manufacture of tarpaulin, bottles, fabrics etc.

Table 2.3

- What are the monomers of nylon 66?
- What polymer is obtained when phenol and formaldehyde undergo condensation polymerisation?
- What are the monomers of polyester?

Thermal cracking

The chemical equation involved in the heating of propane in the absence of air is given.

$$CH_3-CH_2-CH_3 \xrightarrow{\text{heat}} CH_4 + CH_2 = CH_2$$

- What are the products obtained?
- Which is the unsaturated compound formed?

When heated in the absence of air, some hydrocarbons with high molecular weight decompose into hydrocarbons with lower molecular weight. This process is called thermal cracking.

Let us look at more examples.

Complete the chemical equations.

$CH_3 - CH_2 - CH_2 - CH_3 \rightarrow CH_3 - CH = CH_2 + ...$

$CH_3 - CH_2 - CH_2 - CH_2 - CH_3 \rightarrow ..... + CH_2 = CH_2$

When hydrocarbons containing more carbon atoms are subjected to thermal cracking, the carbon chain is likely to break up in several ways. The products obtained as a result of thermal cracking depend on the temperature, pressure and nature of the hydrocarbons undergoing cracking. When saturated hydrocarbons undergo thermal cracking, the products include saturated and unsaturated hydrocarbons.

Certain plastic wastes can be broken down into lighter molecules by thermal cracking. This helps to control pollution to some extent.

Combustion of hydrocarbon

The chemical equation of burning of methane in air is given.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O + \text{Heat}$$

What are the products obtained in this process?

.....

Heat and light are also produced along with this process.

What are the products obtained when butane burns in air?

$$2C_4H_{10} + 13O_2 \rightarrow ..... + ... + \text{Heat}$$

On burning, all hydrocarbons give the same products.

When hydrocarbons burn, they combine with oxygen in air to form CO_2 and H_2O along with heat and light. This process is called combustion.

Complete Table 2.4 related to the chemical reactions of hydrocarbons. Write the name of the type of each chemical reaction.

No.	Chemical equation	Name of the chemical reaction
1.	$CH \equiv CH + 2H_2 \xrightarrow{Ni}$	.....
2.	$CH_2Cl_2 + Cl_2 \xrightarrow{sunlight}$ ..... + HCl	.....
3.	$nCH_2 = CH_2 \longrightarrow$	.....
4.	CH_4 + ... $\longrightarrow$ CO_2 + ...	.....
5.	..... + $H_2 \longrightarrow CH_3 - CH_3$	.....

Table 2.4

Some important organic compounds

Methanol ($CH_3 - OH$)

Methanol or methyl alcohol is the first member of the alcohol family.

The structural formulae of some alcohols are given below.

(i) $CH_3 - OH$ (ii) $CH_3 - CH_2 - OH$ (iii) $CH_3 - CH_2 - CH_2 - OH$

- Write the name of the functional group.
- Write the IUPAC names of these alcohols.

Methanol is a compound with great industrial significance. It is also called wood spirit.

Methanol is industrially produced by treating carbon monoxide with hydrogen in the presence of catalysts.

The chemical equation of this reaction is given.

$$CO + 2H_2 \xrightarrow[573\ K]{\text{catalyst}} CH_3 - OH$$

Methanol is a poisonous substance.

Uses of methanol

- For manufacturing varnish, paint etc.
- For the manufacture of formic acid, formaldehyde etc. 40% solution of formaldehyde is formalin.

Ethanol ($CH_3 - CH_2 - OH$)

Ethanol or ethyl alcohol is another industrially important alcohol.

Industrial preparation of ethanol

Ethanol is manufactured by the fermentation of molasses. During the production of sugar from sugarcane, a viscous concentrated sugar solution is left behind after the separation of sugar crystals. This solution is called molasses.

The fermentation is carried out by adding yeast to the dilute molasses. The enzyme invertase present in yeast converts sugar solution to glucose and fructose. Then another enzyme zymase, converts glucose and fructose into ethanol.

Analyse the chemical equation of this reaction given below.

$$\underset{\text{(Sugar solution)}}{C_{12}H_{22}O_{11} + H_2O} \xrightarrow{\text{Invertase}} \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Fructose}}{C_6H_{12}O_6}$$

$$\underset{\text{Glucose / Fructose}}{C_6H_{12}O_6} \xrightarrow{\text{Zymase}} \underset{\text{Ethanol}}{2C_2H_5OH} + 2CO_2$$

- 8-10% ethanol thus obtained is known as ‘wash’.

- When wash is subjected to fractional distillation, 95.6% of ethanol is obtained. This is known as rectified spirit.
- 100% of ethanol is known as absolute alcohol.
- Power alcohol is a mixture of 20% absolute alcohol and 80% of petrol. It is used as fuel in vehicles.

Ethanol is an organic compound used in the manufacture of various other organic compounds. In such situations, toxic substances like methanol/pyridine/rubber distillate etc. are added to ethanol in order to prevent its misuse as a beverage. Ethanol thus obtained is called denatured spirit.

When denaturing is done with methanol, the resulting ethanol is called methylated spirit.

Uses of ethanol

- Production of power alcohol.
- As a solvent for medicines.
- Manufacture of paints.
- As preservatives.
- Production of organic compounds.

Sanitizers

Sanitizers are chemicals used to eliminate micro organisms like bacteria from the surface of objects making them safe. The word 'sanitizer' is derived from the Latin word 'sanitus' which means 'health'. They are available in the form of liquid, gel or foam. A solution prepared by mixing 833.3 mL of ethanol (96%), 41.7 mL of hydrogen peroxide (3%) and 14.5 mL of glycerol (98%) and made upto 1 litre using water can be used as a sanitizer. A few drops of perfume can also be added to give it a distinct fragrance.

Ethanoic acid ($CH_3 - COOH$)

Ethanoic acid (acetic acid) is a carboxylic acid having great industrial importance.

The structural formulae and the IUPAC names of few other important carboxylic acids are given in Table 2.5. Complete it.

Structural formulae	IUPAC names
$H - COOH$	Methanoic acid
$CH_3 - COOH$	Ethanoic acid
$CH_3 - CH_2 - COOH$	.....
$CH_3 - CH_2 - C H_2 - COOH$	.....

Table 2.5

Industrial preparation of ethanoic acid

Ethanoic acid can be prepared industrially by treating methanol with carbon monoxide in the presence of a catalyst.

$$CH_3 - OH + CO \xrightarrow{\text{catalyst}} CH_3 - COOH$$

Fermentation of ethanol with acetobacter bacteria in the presence of air yields less concentrated (5-8%) ethanoic acid. This is called vinegar.

Uses of ethanoic acid

- Manufacture of vinegar.
- Production of acetic anhydride, acetate ester, synthetic fibres etc.
- Solvent of polymers and resins.
- Manufacture of disinfectants.
- Manufacture of medicines.

Esters

Esters are formed when alcohols react with carboxylic acids. This reaction is called esterification.

The general formula of esters is $R-\overset{\overset{O}{\|}}{C}-O-R^1$. Here R, R^1 etc, are alkyl groups.

The chemical equation for the formation of the ester, ethyl ethanoate is given.

Methyl salicylate

Methyl salicylate is a methyl ester of the aromatic carboxylic acid, salicylic acid. It relieves the pain of joints and muscles. It is also known as the oil of wintergreen. It is extracted from certain species of evergreen plants which grow in winter and hence the name. This compound used as a flavouring agent, can also be prepared synthetically.

$$CH_3 - COOH + HO - CH_2 - CH_3 \xrightarrow{con.H_2SO_4}$$

$$CH_3 - COO - CH_2 - CH_3 + H_2O$$

Ethyl ethanoate

- What are the reactants?
- Write the names of their functional groups.

The ester, ethyl ethanoate is formed when ethanoic acid reacts with ethanol in the presence of concentrated sulphuric acid.

As esters have the fragrance of flowers and fruits, they are used to make artificial perfumes and juices.

Examine Table 2.6 which shows the names of the carboxylic acids and the alcohols required to prepare certain esters and the fragrance provided by them.

Name of carboxylic acid	Name of alcohol	Name of ester	Fragrance
Ethanoic acid	Isoamyl alcohol	Isoamyl acetate	Banana
Ethanoic acid	Benzyl alcohol	Benzyl ethanoate	Jasmine
Ethanoic acid	Octyl alcohol	Octyl ethanoate	Orange
Butanoic acid	Ethyl alcohol	Ethyl butanoate	Pineapple

Table 2.6

Find the esters from the compounds given below. Complete Table 2.7 by identifying the carboxylic acids and alcohols required to prepare them.

- $CH_3 - COO - CH_2 - CH_2 - CH_3$
- $CH_3 - CH_2 - COOH$
- $CH_3 - CH_2 - CH_2 - OH$

- $CH_3 - CH_2 - COO - CH_3$
- $CH_3 - CH_2 - COO - CH_2 - CH_3$
- $CH_3 - CH_2 - OH$
- $CH_3 - OH$
- $CH_3 - COOH$
- $CH_3 - CH_2 - COO - CH_2 - CH_2 - CH_3$

Ester	Carboxylic acid	Alcohol
$CH_3 - COO - CH_2 - CH_2 - CH_3$	$CH_3 - COOH$	$CH_3 - CH_2 - CH_2 - OH$
.....	.....	.....
.....	.....	.....
.....	.....	.....

Table 2.7

Medicines

Medical science and medicines play a pivotal role in enhancing health and life span. Chemistry has contributed immensely to the advancement of various fields of medical science and pharmaceutical research.

The category and functions of certain medicines used in modern methods of medical therapy are given in Table 2.8.

Category	Function	Examples
Analgesics	Relieve pain	Aspirin
Antipyretics	Reduce body temperature	Paracetamol
Antiseptics	Control microorganism	Dettol
Antibiotics	Destroy infectious microorganisms and prevent their growth.	Penicillin

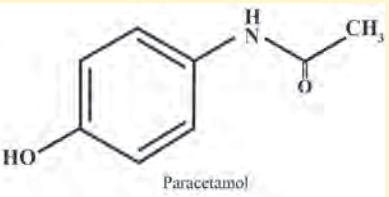
Table 2.8

Paracetamol and aspirin are commonly used medicines in the allopathic treatment system. Paracetamol is used both as an antipyretic and as an analgesic.

As aspirin has anti-blood coagulant property, it is used to prevent heart attack. Aspirin is used as an analgesic too.

Paracetamol

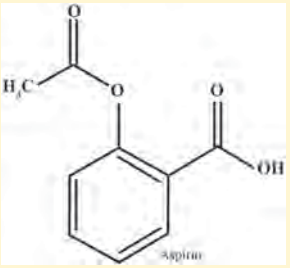
Paracetamol (N-acetyl-p-amino phenol) is a much familiar medicine to all of us. Although it is a medicine with comparatively less side effects, higher levels of its consumption affect the liver adversely. Paracetamol is included in the list of essential medicines of World Health Organisation.



Paracetamol

Aspirin

The chemical name of aspirin is acetyl salicylic acid.



Let us assess

1. a) In which of the following situation is methane converted to chloromethane?
   (i) Chlorine + sunlight
   (ii) Hydrochloric acid + sunlight
   (iii) Oxygen + temperature
   (iv) Heating in the absence of oxygen
   b) Write the name of such types of reactions.

2. a) How many hydrogen molecules are required to convert CH ≡ CH (ethyne) into C_2H_6 (ethane)?
   b) Write the chemical equation of the reaction.
   c) To which category does this chemical reaction belong?

3. a) Complete the chemical equation.
   i) $CH \equiv CH + HCl \rightarrow$ A
   ii) $n\,A \rightarrow$ B
   b) Write the IUPAC names of the molecules A and B.
   c) To which category does each of these chemical reactions belong?

4. a) Which of the given polymers is used to coat the inner surface of cookware? (Polythene, polyvinyl chloride, teflon)
   b) What is the monomer of this polymer?

5. a) Which among the following is a condensation polymer?
   (Polyvinyl chloride, nylon 66, teflon)
   b) What are the monomers of nylon 66?

6. $C_{12}H_{22}O_{11} + H_2O \xrightarrow{A} C_6H_{12}O_6 +$ B

   $C_6H_{12}O_6 \xrightarrow{C} 2C_2H_5OH +$ D

   a) Identify A, B, C and D in the given chemical reactions.
   b) What is wash?
   c) How is rectified spirit obtained from wash?
   d) What is the purpose of denaturing rectified spirit?

7. a) How is ethanoic acid prepared industrially?

   b) 5 - 8% ethanoic acid is called .....

8. $CH_3 - COOH + CH_3 - OH \xrightarrow{\text{conc. } H_2SO_4} CH_3 - COO - CH_3 + H_2O$

   Analyse the equation and answer the following questions.

   a) What is the name of this chemical reaction?

   b) What is the name of the ester formed?

   c) Write any two uses of esters.

Extended activities

1. Write an essay on the harmful effects on the human body and the social issues caused by the use of ethanol as a beverage.
2. Prepare and present a seminar on the topic ‘Polymers in daily life.’
3. Make a presentation on the topic ‘Organic compounds and their importance in daily life.’