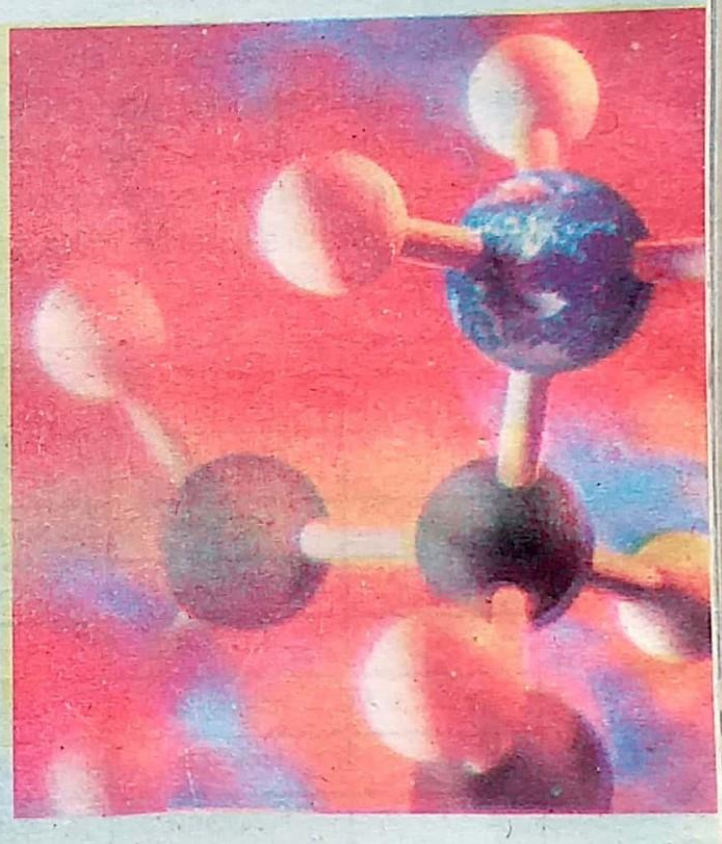
Chapter

12

Hydrocarbons



In this chapter you will be able to:

- Explain why a systematic method of naming chemical compounds is necessary.
- Characterize a hydrocarbon.
- Draw electron cross and dot structures of simple alkanes.
- Write a chemical equation to show the preparation of alkanes from hydrogenation of alkenes and alkynes and reduction of alkyl halides.
- Draw structural formulae of alkanes, alkenes and alkynes up to 5 carbon atoms.
- Write a chemical equation to show the preparation of alkenes from dehydration of alcohols and dehydrohalogenation of alkyl halides.
- Write a chemical equation to show the preparation of alkynes from Dehalogenation of 1,2-dihalides and tetrahalides.
- Write chemical equations showing halogenations of alkanes, alkenes and alkynes.
- Write chemical equations showing reaction of KMnO4, with, alkenes and alkynes.

Introduction to Hydrocarbons

Hydrocarbons are considered as parent organic compounds. Hydrocarbons are the organic compounds which contain only carbon and hydrogen. They are classified as saturated hydrocarbons and unsaturated hydrocarbons.
Saturated Hydrocarbons are called alkanes and unsaturated as alkenes and alkynes.

12.1 Alkanes

Alkanes are saturated hydrocarbons. Alkane series has the general formula C_nH_{2n+2}, Where "n" is the number of carbon atoms. The carbon atom in the molecules of alkanes is bonded by single covalent bonds. Each carbon atom of an alkane is linked to four other atoms to use its four valence electrons. Hence, alkanes are saturated hydrocarbons.

Alkanes contain single covalent bonds between C-C and C-H atoms. Therefore, this class of hydrocarbons are chemically inert. They are sometimes referred to *paraffins* which is a Latin word meaning "little affinity".
The names of first ten alkanes along with their physical states, melting and boiling points are given in Table –12.1.

Table 12.1

C-atoms	Name	Formula C_nH_{2n+2}	Physical State	Melting Point (°C)	Boiling Point (°C)
1	Methane	CH_4	Gas	–183	–162
2	Ethane	C_2H_6	Gas	–172	–89
3	Propane	C_3H_8	Gas	–188	–42
4	Butane	C_4H_{10}	Gas	–138	–0.5
5	Pentane	C_5H_{12}	Liquid	–130	36
6	Hexane	C_6H_{14}	Liquid	–95	69
7	Heptane	C_7H_{16}	Liquid	–91	98
8	Octane	C_8H_{18}	Liquid	–57	126
9	Nonane	C_9H_{20}	Liquid	–51	151
10	Decane	$C_{10}H_{22}$	Liquid	–30	174

12.1.1 Preparation of Alkanes.

Alkanes are prepared by the following methods.

12.1.1.1 Hydrogenation of alkenes and alkynes:

Unsaturated hydrocarbons, like alkenes and alkynes react with hydrogen in the presence of nickel as catalyst at 200-300°C to form alkanes.
For example ethene and ethyne on reaction with hydrogen at 200-300°C in the presence of nickel form ethane.

i) $CH_2= CH_2 + H_2 \xrightarrow[200–300\ ^\circ C]{Ni} CH_3–CH_3$

ii) $CH\equiv CH + 2H_2 \xrightarrow[200–300\ ^\circ C]{Ni} CH_3–CH_3$

12.1.1.2 Reduction of alkyl halides:

Alkyl halides on reduction with nascent hydrogen (hydrogen at the time of its generation is called nascent hydrogen) form corresponding alkanes.

$$R–X + 2[H] \xrightarrow{Zn + HCl} RH + HX$$

For example methyl iodide gives methane on reduction.

$$CH_3–I + 2[H] \xrightarrow{Zn + HCl} CH_4 + HI$$

12.1.2 Properties and Important Reactions of Alkanes.

12.1.2.1 Physical properties

i) First four alkanes methane, ethane, propane and butane are gases. Next thirteen members are colourless liquids while the higher alkanes are solids.

ii) Alkanes are insoluble in water but soluble in organic solvents such as ether and acetone etc.

iii) The melting and boiling points generally increase with increase in molecular masses.

12.1.2.2 Chemical properties

Alkanes, due to their saturated nature are chemically inert at room temperature. However, at high temperatures or on absorption of light the following reactions take place. The important reactions of alkanes are as follows.

1. Halogenation

The substitution of hydrogen by halogen in alkanes is called Halogenation.
For example methane reacts with chlorine in diffused sun light to produce chloromethane.

$$CH_4 + Cl_2 \xrightarrow{\text{sunlight}} \underset{\text{Chloromethane}}{CH_3Cl} + HCl$$

The reaction does not stop at this stage. The remaining three hydrogen atoms are successively replaced by chlorine atoms to give di, tri and tetra chloromethane respectively.

$$CH_3Cl + Cl_2 \xrightarrow{\text{sunlight}} \underset{\text{Dichloromethane}}{CH_2Cl_2} + HCl$$

$$CH_2Cl_2 + Cl_2 \xrightarrow{\text{sunlight}} \underset{\substack{\text{Trichloromethane} \\ \text{(chloroform)}}}{CHCl_3} + HCl$$

$$CHCl_3 + Cl_2 \xrightarrow{\text{sunlight}} \underset{\substack{\text{Tetrachloromethane} \\ \text{(carbon Tetrachloride)}}}{CCl_4} + HCl$$

2. Combustion

Alkanes in the presence of oxygen at high temperature burn to form CO_2 and H_2O with evolution of heat

$$CH_{4\,(g)} + 2\,O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(g)} + \text{heat}$$

12.2 Alkenes

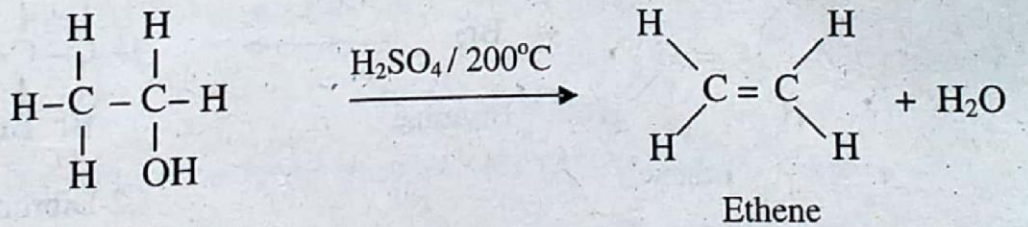
Alkenes are unsaturated hydrocarbons containing at least one double bond between two carbon atoms. The general molecular formula of alkenes is C_nH_{2n}. It is obvious from the formula that alkenes have two hydrogen atoms less than the corresponding alkanes. Alkenes also make a homologous series and each member of the series is less by a CH_2 group than its next higher member.

12.2.1 Preparation

Most of the methods of preparation of alkenes involve elimination of two atoms or groups from the two adjacent carbon atoms.

12.2.1.1 Dehydration of alcohols

When an alcohol is heated at 200°C in the presence of sulphuric acid, a molecule of water is eliminated and an alkene is formed. For example, ethyl alcohol on dehydration yields ethene.

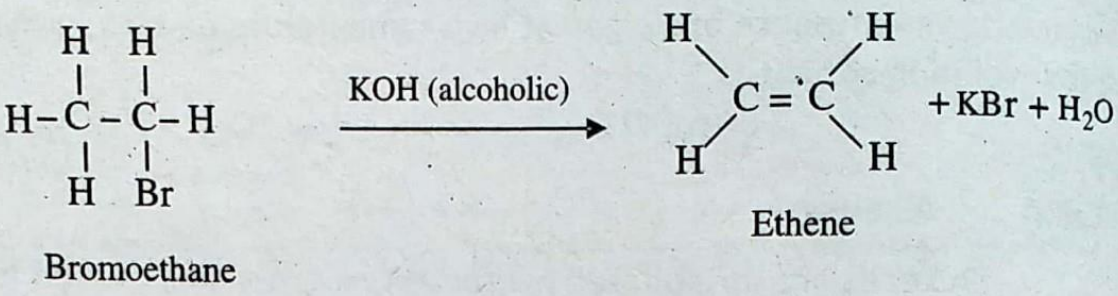


Ethyl alcohol — Ethene

12.2.1.2 Dehydrohalgenation of alkyl halides

When an alkyl halide is heated with an alcoholic solution of potassium hydroxide, a molecule of hydrogen halide is removed and an alkene is formed. In this elimination halogen is removed from one carbon and hydrogen from the

other adjacent carbon atom. For example, ethyl bromide on dehydrohalogenation, gives ethene and hydrogen bromide.



Bromoethane

Ethene

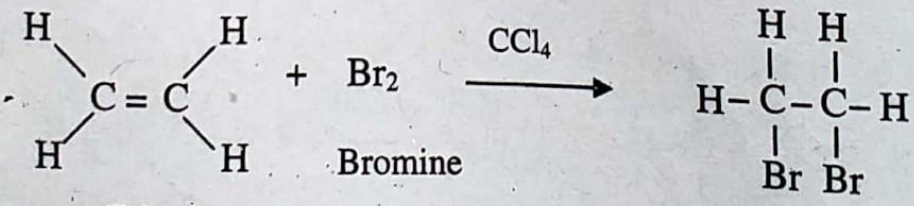
12.2.2 Important Reactions

Because of the unsaturated nature of alkenes, they easily undergo addition reactions and in this way, they are converted into saturated compounds.

1. Addition of halogens

Chlorine and bromine readily add to a double bond of alkenes, in the presence of an inert solvent like carbon tetrachloride to form dihalo compounds. It does not need any high temperature or sun light.

For example, addition of bromine to ethene decolourizes the red colour of bromine and produces 1,2-dibromoethane.



Ethene

Bromine

1,2-Dibromoethane

Activity 1

You have bromine solution and two gases ethane and ethene. Distinguish between these hydrocarbons.

2. Addition of hydrogen halides

A molecule of hydrogen halide adds to alkene giving the corresponding alkylhalide.

$$CH_2=CH_2 + HBr \longrightarrow \underset{\text{Bromoethane}}{CH_3-CH_2-Br}$$

3. Oxidation by $KMnO_4$

Alkenes react with cold dilute potassium permanganate solution to form glycols. Glycols are alcohols which contain two hydroxyl groups (–OH) on two adjacent carbons.

$$3CH_2=CH_2 + 2KMnO_4 + 4H_2O \longrightarrow \underset{\text{Ethylene glycol}}{3\,\overset{OH}{\overset{|}{CH_2}}-\overset{OH}{\overset{|}{CH_2}}} + 2MnO_2 + 2KOH$$

Potassium permanganate is changed to manganese dioxide and potassium hydroxide so its purple colour disappears. This is a very useful test for the detection of double bond and is called *Baeyer's test*.

4. Hydrogenation

Alkenes readily react with hydrogen in the presences of nickel as a catalyst at 240ºC forming the corresponding alkanes. Hydrogenation is an exothermic process.

$$CH_2=CH_2 + H_2 \xrightarrow[240^\circ C]{Ni} H-\overset{H}{\overset{|}{C}}-\overset{H}{\overset{|}{C}}-H + Heat$$

Hydrogenation of alkenes is industrially used for the conversion of vegetable oils into ghee.

Activity 2 Distinguish between propane and propene using Baeyer's test.

11.3 Alkynes

Unsaturated hydrocarbons which contain at least a triple bond are called alkynes. They have two hydrogen atoms less than the corresponding alkenes. Their general formula is C_nH_{2n-2}. Example of alkyne are Ethyne, Propyne and butyne etc.

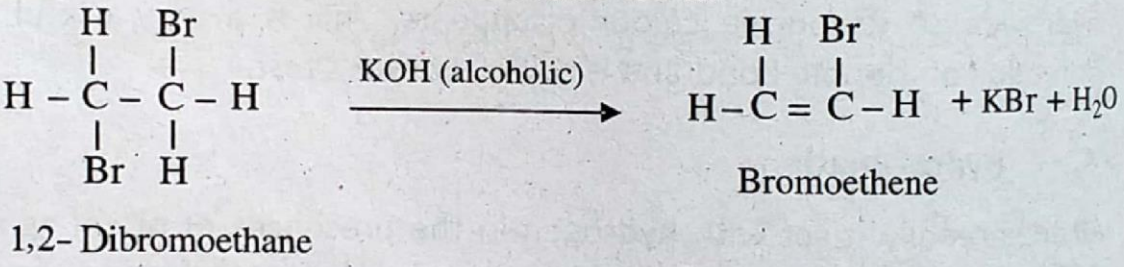
11.3.1 Preparation

Alkynes are prepared by the following methods.

11.3.1.1 Dehydrohalogenation of 1,2-dihalides

Compounds that contain two halogen atoms at the first two adjacent carbon atoms are called 1,2-dihalides. Alkynes are obtained by reacting 1,2-dihalides with alcoholic potassium hydroxide, two molecules of hydrogen halide are eliminated.

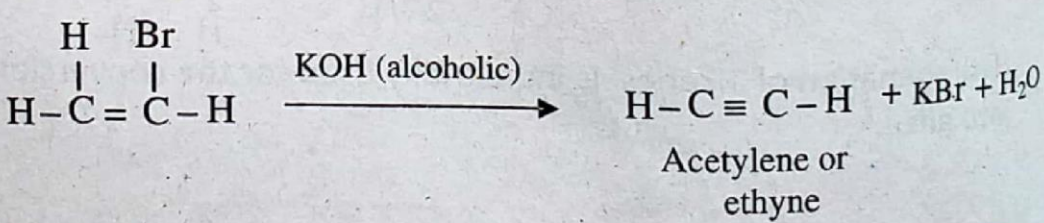
Acetylene can be prepared by this method by the reaction of 1,2-dibromo ethane with alcoholic potassium hydroxide. This reaction is completed in two steps. In the first step, one molecule of hydrogen bromide is eliminated and single bond between C-C atoms is converted to a double bond.



1,2- Dibromoethane

Bromoethene

In the second step, another molecule of hydrogen bromide is eliminated and the double bond is converted into a triple bond.



Acetylene or ethyne

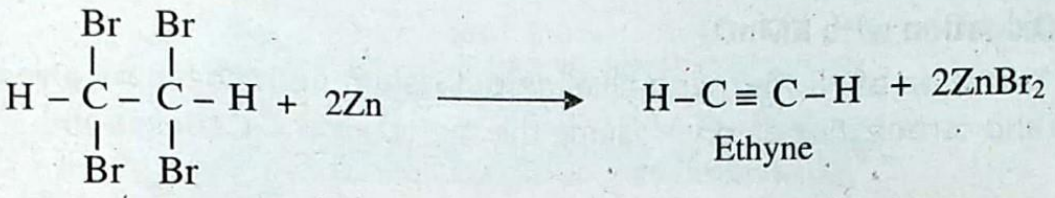
Activity 3

Synthesize acetylene from ethane.

11.3.1.2 Dehalogenation of tetrahalides

Compounds that contain four halogen atoms at the two adjacent carbon atoms are called tetrahalides.

Tetrahaloalkanes are heated with active metal like zinc dust to produce alkynes.



1,1,2,2-Tetrabromo ethane

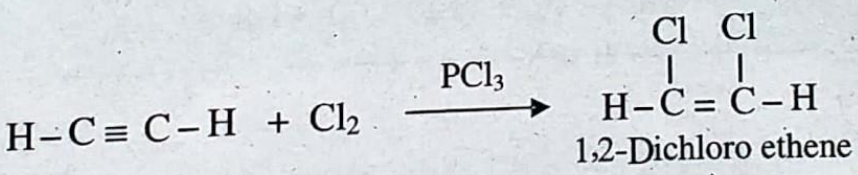
Ethyne

11.3.2 Important Reactions

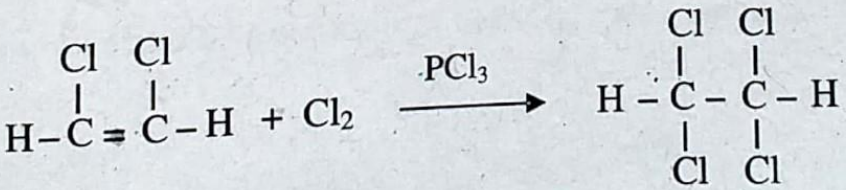
Because of the unsaturated nature of alkynes, they easily undergo addition reactions and in this way, they are converted into saturated hydrocarbons.

1. Halogenation

Addition of halogen at the double and triple bonds is called halogenation. Two molecules of halogen add to the triple bond in two steps forming a di and a tetrahalide. Chlorine and bromine react readily while iodine reacts slowly. PCl_3 is used as a catalyst.



1,2-Dichloro ethene



1,1,2,2-Tetrachloro ethane

2. Oxidation with $KMnO_4$

The oxidation of alkynes with alkaline potassium permanganate gives carboxylic acid and carbon dioxide on breaking the molecule at C-C triple bond.

$$R-C\equiv C-H \ + 4[O] \xrightarrow{KMnO_4} R-COOH + CO_2$$

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Hydrocarbons are currently the main source of the world's electric energy and heat sources (such as home heating) because of the energy produced when burnt. Often this energy is used directly as heat such as in home heaters, which use either oil or natural gas. The hydrocarbon is burnt and the heat is used to heat water, which is then circulated. A similar principle is used to create electric energy in power plants.

Common properties of hydrocarbons are the facts that they produce steam, carbon dioxide and heat during combustion and that oxygen is required for combustion. The simplest hydrocarbon, methane, burns as follows:

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

KEY POINTS

- Alkanes are saturated hydrocarbons having general formula C_nH_{2n+2}
- First four alkanes are gases, next thirteen liquids while higher alkanes are solids.
- In alkanes substitution reactions take place.
- Alkenes are unsaturated hydrocarbons with two hydrogen atoms less than the corresponding alkanes.
- Alkenes are very reactive compounds. They readily undergo addition reactions and become saturated.
- Alkenes are easily oxidized by the cold and dilute solution of $KMnO_4$. It decolourizes its purple colour. This test is called the Baeyer'test, which distinguishes alkenes from alkanes
- Hydrocarbons containing a triple bond are called alkynes.
- Alkynes have a triple bond between two carbon atoms. The electron density between the two carbon atoms is very high which draws the two atoms close to each other. So the reactivity of alkynes is less than alkenes but greater than alkanes.
- Addition of halogens at the double or triple bonds is called halogenation.
- Alkynes undergo addition reactions, due to their unsaturated nature.
- Alkynes are oxidized by a solution of $KMnO_4$ to give carboxylic acids.

EXERCISE

Q.1. Choose the correct option from the given choices.

i. Dehydration of ethyl alcohol with conc. H_2SO_4 results in the formation of:

A) Ethane
B) Methane
C) Acetylene
D) Ethene

ii. Which one of the following reagents distinguishe ethene from acetylene:

A) Alkaline solution of $KMnO_4$
B) Bromine solution
C) Carbon tetrachloride solution
D) Alcoholic KOH

iii. The final product X in the following reaction is: $HC{\equiv}CH + 2HBr \rightarrow X$

A) $\begin{matrix} CH = CH \\ | \quad\quad | \\ Br \quad Br \end{matrix}$

B) $\begin{matrix} \quad\quad Br \\ \quad\quad | \\ CH_3 - CH \\ \quad\quad | \\ \quad\quad Br \end{matrix}$

C) $\begin{matrix} Br \quad Br \\ | \quad\quad | \\ CH - CH \\ | \quad\quad | \\ Br \quad Br \end{matrix}$

D) $CHBr_3$

iv. Which one of the following decolourises Br_2 water:

A) Propane
B) Ethene
C) Ethane
D) Methane

v. Ethene reacts with HBr, the compound formed is:

A) CH_3-CH_2-Br
B) $Br-CH_2-CH_2-Br$
C) $CH_3-CH_2-CH_3$
D) Acetylene

vi. Which of the following statements is not true for alkynes:

A) They contain a triple bond
B) They burn to form CO_2
C) They perform Baeyer's test
D) They undergo addition reaction

vii. General formula for alkenes is:

a) $C_nH_{2n}O_n$ B) C_nH_{2n-1}
C) C_nH_{2n-2} D) C_nH_{2n}

viii. All the members of alkane series have:

A) All single bonds
B) At least one double bond
C) At least one triple bond
D) All types of bonds

ix. Baeyer's reagent is:

A) Conc. $KMnO_4$ B) Alkaline $KMnO_4$
C) Acidic $KMnO_4$ D) Hot $KMnO_4$

x. Which one gives carboxylic acid with alkaline $KMnO_4$:

A) Ethane B) Ethene
C) Acetylene D) Methane

xi. Which one gives a mixture of hydrocarbons on halogenation:

A) Ethyne B) Ethene
C) Ethane D) Ethyl alcohol

xii. Baeyer's test shows the presence of:

A) A single bond B) A double bond
C) A triple bond D) No bond

xiii. Which one is the least reactive :

A) Ethyne B) Propene
C) Ethene D) Ethane

xiv. Ethane reacts with chlorine in the presence of:

A) Carbon tetra chloride
B) Ether
C) Sunlight
D) water

Q. 2. Write short answers for the given questions.

i. Why alkane is inert in nature.
ii. What is Baeyer's test?
iii. What do you mean by saturated hydrocarbons?
iv. What are addition reactions?
v. What is alkene? Give examples.
vi. Why alkenes are more reactive than the corresponding alkane.
vii. How Ethane can be produced from ethene?
viii. Why addition reactions take place in ethene and ethyne but not in ethane.
ix. Write down two methods of preparation of alkyne?

Q.3. Write long answers of the following questions.

i. Differentiate between alkanes and alkenes. Give methods of preparation for alkanes.
ii. Give important reactions of alkenes.
iii. Give oxidation reactions of ethene and ethyne.
iv. Give important reactions of ethyne.