



12

HYDROCARBONS



After completing this lesson, you will be able to:

This is 10 days lesson
(period including homework)

- Explain why 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 from reduction of alkyl halides.
- Draw structural formulas 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 dehydrohalogenation of 1, 2- dihalides and dehalogenation of tetrahalides.
- Write chemical equations showing halogenation of alkanes, alkenes and alkynes.
- Write chemical equations showing reaction of $KMnO_4$ with, alkenes and alkynes.
- Determine the boiling point of alcohol.
- Explain hydrocarbons as fuel.
- Explain hydrocarbons as feed stock in industry.



Reading

INTRODUCTION

The simplest organic compounds are hydrocarbons. **The organic compounds which contain only two elements, carbon and hydrogen are called hydrocarbons.** There are several kinds of hydrocarbons. They are classified according to the type of bonding between the carbon atoms. You have learnt differences between alkanes, alkenes and alkynes in the previous chapter.

About 90% of the energy used to sustain our way of life comes from **fossil fuels**. Coal, natural gas and petroleum are called **fossil fuels**. Why are these



fuels called as fossil fuels? Natural gas is a mixture of low molecular weight hydrocarbons. Mainly it contains methane. Petroleum is a liquid mixture of mainly hydrocarbons. When these fuels are burnt, they produce carbon dioxide, water and heat. It has been estimated that the concentration of carbon dioxide in the atmosphere has increased up to 20% by the end of twentieth century. Carbon dioxide and other gases produce **greenhouse effect** (section 14.3.1).

Do you know?

Carbon dioxide and other gases in the air let the sun rays in, to warm the surface of earth. When the earth tries to radiate this heat back into the space, molecules of these gases trap this energy

About 25 billion tons of carbon dioxide is released into the atmosphere each year, 22 billion tons of it comes from the burning of fossil fuels. About 15 billion tons per year is removed by the plants. Thus 10 billion tons of carbon dioxide remains in the air. This is causing global warming. (For detail see section 14.3.1)

Although hydrocarbons burn, many of them are not generally used as fuel. They are mostly used as feed stock in industry. These hydrocarbons are starting raw materials for the synthesis of large number of organic compounds. These compounds have commercial importance.

Society, Technology and Science

Alkenes are starting materials for the synthesis of many valuable materials, especially polymers. Some alkenes and alkynes serve as starting materials for synthesis. For instance ethene and ethyne are used to synthesize a number of polymers. Polymers are made from smaller molecules such as ethene. Look around you, you will find polymers everywhere. Your clothes, carpets, curtains, towels, sheets, floor tiles, furniture, toys etc. are polymers made from ethene and ethyne. Even in your car, the dash board, seats, tyres, floor mat, ceiling, are also made of polymers. Hydrocarbons are also used as raw materials for the synthesis of synthetic rubber, plastic, films, adhesives, drugs and dyes. In the field of medicine, body replacement parts are made from polymers. In future we will have artificial bones that can stimulate bone growth. We can also expect to have artificial lungs as well as artificial hearts. Industries are day and night busy in synthesizing marvelous new products. Is there anything that can replace petroleum as raw material for making plastics and other polymers?

Millions of organic compounds exist. To understand, recognize and classify these compounds, systematic naming of organic compounds is necessary. Organic chemists began in the last century to devise a system of naming organic compounds that depends on their structure. An international body, **the International Union of Pure and Applied chemistry (IUPAC, pronounced “eye-you-pac”)** constantly reviews the rules for naming organic compounds. IUPAC system of naming organic compounds is based on the following principle.

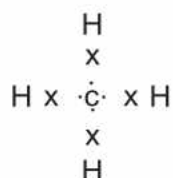
Each different organic compound should have a different name.

12.1 ALKANES

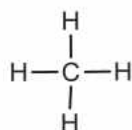
Alkanes are saturated hydrocarbons. They have general formula C_nH_{2n+2} . Each carbon atom forms four bonds and each hydrogen atom forms only one bond. So the simplest alkane



molecule that is possible is CH_4 . It is called methane. Methane is the main component of natural gas. Electron dot and cross structure for methane is as follows.

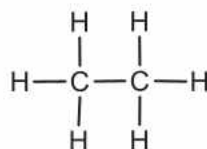


So the structural formula for methane is



Recall that structural formula shows which atoms are bonded to each other. The next member of alkane series is ethane, C_2H_6 .

Ethane molecules has following structure



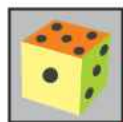
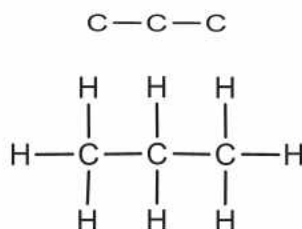
Example 12.1: Writing structural formula for an alkane.

Write structural formula for propane.

Problem Solving Strategy

- Prop-means three carbon atoms.
- Ending -ane indicates an alkane.
- Write a string of three carbon atoms.
- Attach hydrogen atoms to the carbon atoms to give each carbon atom four bonds.

Solution



Self-Assessment Exercise 12.1

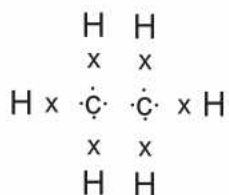
Write structural formulas for (a) Butane (b) Pentane

**Example 12.2: Writing electron dot and cross structure for alkanes.**

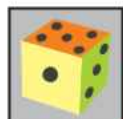
Draw the electron dot and cross structure for ethane.

Problem Solving Strategy

- (i) Write carbon atoms in a row.
- (ii) Show four valence electrons by dots around each carbon atom.
- (iii) Arrange hydrogen atoms around carbon atoms so that each carbon is surrounded by four atoms.
- (iv) Show valence electrons of hydrogen by cross.
- (v) Connect atoms by electron pairs

Solution**Do you know?**

Many halogenated hydrocarbons have important commercial uses. Methyl chloride is a gas at room temperature. Dichloromethane, trichloromethane and tetra chloromethane are liquids. These three liquids can be used as solvents for grease, oils and other organic substances. Chloroform is used as an anesthetic. Tetrachloromethane has carcinogenic effects at high concentration.

**Self-Assessment Exercise 12.2**

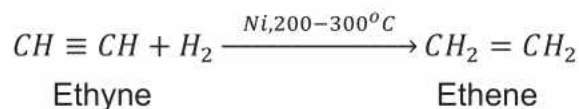
Draw electron dot and cross structures for the following.

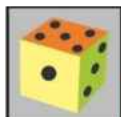
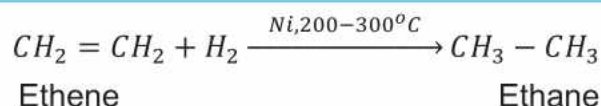
(a) Propane (b) Butane

**Reading****12.1.1. General Methods of Preparations of Alkanes****1. By Hydrogenation of alkenes and alkynes**

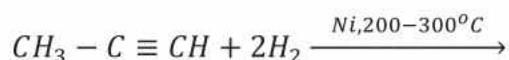
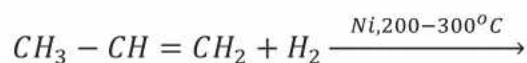
Addition of hydrogen molecule across carbon-carbon multiple-bond is called hydrogenation. Hydrogenation takes place in presence of finely divided nickel at 200 – 300°C and high pressure. Hydrogenation can also be done in presence of Pt or Pd at room temperature.

Alkynes add two molecules of hydrogen. Why?

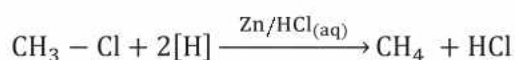


**Self-Assessment Exercise 12.3**

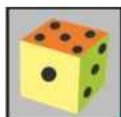
Complete the following reactions

**Reading****2. By the reduction of alkyl halides**

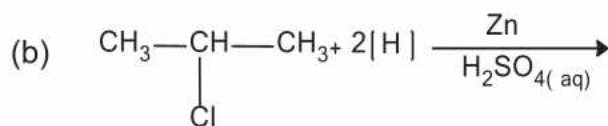
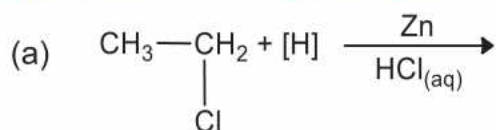
When an alkyl halide is treated with Zn in presence of an aqueous acid, an alkane is produced. Usually aqueous solution of HCl or CH₃COOH is used.



Zn reacts with aqueous acid to liberate atomic hydrogen called nascent hydrogen. Nascent hydrogen reduces alkyl halide. Addition of nascent hydrogen is called reduction.

**Self-Assessment Exercise 12.4**

Complete the following reactions.

**Reading****12.1.2. Properties of Alkanes**

Alkane molecules are essentially non-polar. They are less dense than water and are insoluble in it. Chemically alkanes are unreactive towards most ionic compounds. This lack of



reactivity makes them useful solvents. For instance hexane is used to extract vegetable oils from Corn, Soya beans, Cotton seed etc.

Alkanes containing upto four carbon atoms are colourless, odourless gases. Alkanes containing five to seventeen atoms are colourless, odourless liquids. Higher alkanes are solids which are also colourless and odourless.

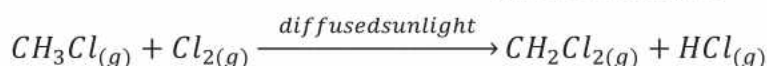
1. Halogenation

Although unreactive towards ionic substances, alkanes readily react with halogens in sunlight. The reaction of an alkane and a halogen is a **substitution reaction**. In this reaction a halogen atom substitutes for one or more of the hydrogen atoms of an alkane.

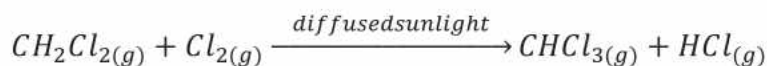
For examples the reaction of methane and chlorine in diffused sunlight occurs as follows.



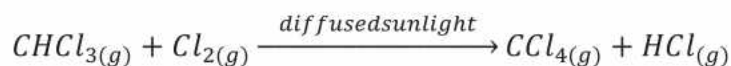
Chloromethane



Dichloromethane

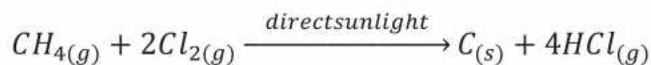


**Trichloromethane
(Chloroform)**



**Tetrachloromethane
(carbon tetrachloride)**

In direct sunlight the reaction of methane with chlorine is explosive and forms carbon and HCl.



The chlorination of methane usually produces a mixture of products. The trend in reactivity of halogen with an alkane is as follows



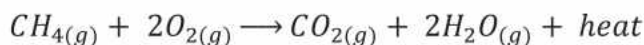
Fluorine reacts explosively; chlorine reacts slowly in dark at room temperature but rapidly in strong sunlight. Bromine is less reactive than chlorine and requires high temperature or strong sun light. Iodine is essentially unreactive.

2. Combustion

A reaction of a substance with oxygen or air that causes the rapid release of heat and the appearance of a flame is called combustion. Complete combustion of an alkane produces carbondioxide, water and heat. Most of alkanes burn with blue flame.



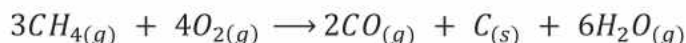
For example, following reaction occurs when natural gas is burned.



The lighter alkanes are widely used as fuel. This is because:

- (i) Their combustion can be controlled.
- (ii) They produce large amount of heat per gram.
- (iii) They are cheap and readily available.

Incomplete combustion occurs in presence of limited supply of oxygen. Incomplete combustion of methane gives CO, C and H_2O .



Uses of methane

Methane is used

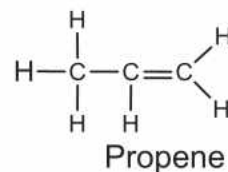
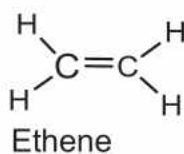
- (i) as domestic fuel (Sui gas).
- (ii) as a fuel for automobiles (CNG).
- (iii) to manufacture urea fertilizer.

12.2. ALKENES

Alkenes have one or more double bond between carbon atoms. They have the general formula C_nH_{2n} . When two carbon atoms share two pairs of electrons, they form a double bond between the carbon atoms. How many electrons are left on each carbon atoms? Doubly bonded carbon atoms form single bond with two other atoms.

Do you know?

Ethylene or ethene is the most important commercial organic chemical. It is used in the manufacturing of polythene, one of the most familiar plastics. It is also converted to ethylene glycol which is used as antifreeze in auto mobile radiators.



Example 12.3: Writing structural formulas for alkenes.

Draw structural formulas for

- (a) 1- Butene
- (b) 2- Butene

Problem Solving Strategy

- (i) But- means four carbon atoms.
- (ii) Ending – ene indicates and alkene.
- (iii) Write a string of four carbon atom and assign number to each carbon atom from one side.



Teacher's Point

Teacher may give example of blackening of cooking pots for in complete combustion of CH₄.

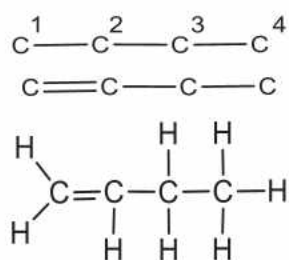


- (iv) Number written before the name indicates the position of double bond. Make a double bond between indicated carbon-atom and the atom next to it.
- (v) Attach enough hydrogen atoms to the carbon atoms to give each carbon atom four bonds.

Solution

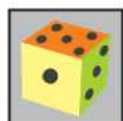
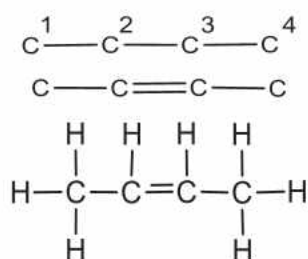
- (a) 1 – Butane

Indicates double bond between C¹ and C²



- (b) 2 - Butene

Indicates double between C² and C³



Self-Assessment Exercise 12.5

Draw structural formulas for the following compounds.

- (a) 1 - Pentene

- (b) 2 – Pentene



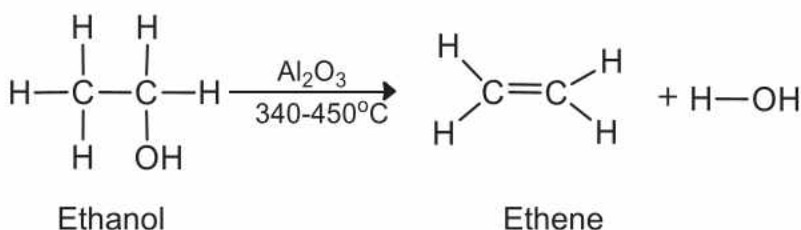
Reading

12.2.1. General Methods of Preparation of Alkenes

Alkenes are prepared by the following methods.

1. By Dehydration of Alcohols

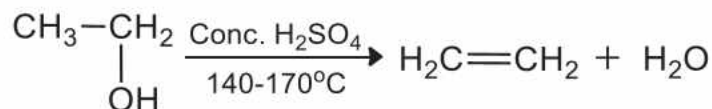
Dehydration means loss of water. Alcohols dehydrate when their vapour are passed over heated alumina.





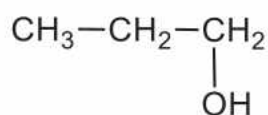
Phosphoric acid (H_3PO_4) and phosphorus pentoxide (P_4O_{10}) can also be used as catalyst for dehydration of alcohols.

Concentrated sulphuric acid is also used for dehydration.



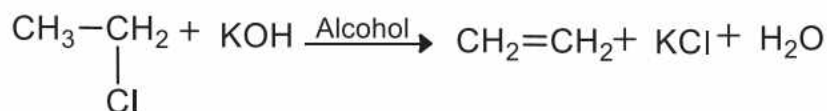
Note that in dehydration reaction -OH group is removed from one carbon and H atom from the adjacent carbon atom. Two such carbon atoms form double bond. Such a reaction is called elimination reaction.

Which alkene is formed by the dehydration of following alcohol?

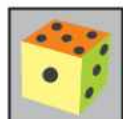


2. Dehydrohalogenation of alkyl halides

Dehydrohalogenation means loss of hydrogen halide. Alkyl halides on heating with alcoholic potassium hydroxide undergo dehydrohalogenation.

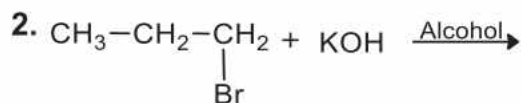
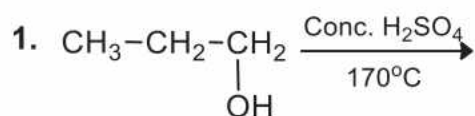


Note that removal of H and halogen takes place from two adjacent carbon atoms. Is dehydrohalogenation an elimination reaction?



Self-Assessment Exercise 12.6

Complete the following reactions.



Reading

Science titbits

Alkenes occur widely in nature. Ripening fruits and vegetables give off ethene which helps in further ripening. So artificially ethene is used to hasten the normal ripening process. For example 1 kg of tomatoes can be ripened by exposure to 0.1mg of ethene for 24 hours. The red color of tomatoes is due to an alkene called Lycopene.

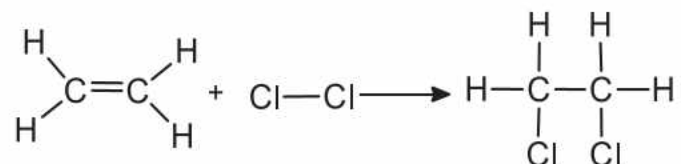
12.2.2 Properties of Alkenes

Alkenes are unsaturated hydrocarbons. First three members i.e. ethene, propene and butene are gases while $\text{C}_5\text{-C}_{15}$ members are liquids and the higher members are solids. They are insoluble in water but soluble in organic solvents such as alcohol etc. The two carbons atoms

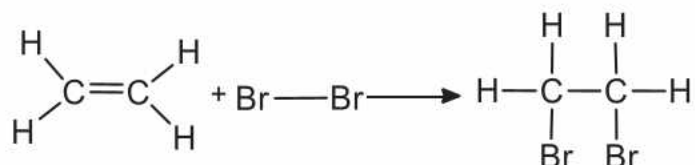
forming double bond are joined to only three atoms. Since a carbon atom can join to four atoms. So other molecules can attack at this site of double bond.

Reaction with halogens

Chlorine and bromine add to the double bond. One chlorine atom becomes attached with one carbon and the one with other carbon atom.



Such a type of reaction is called addition reaction. Alkenes react with bromine water in the same way.

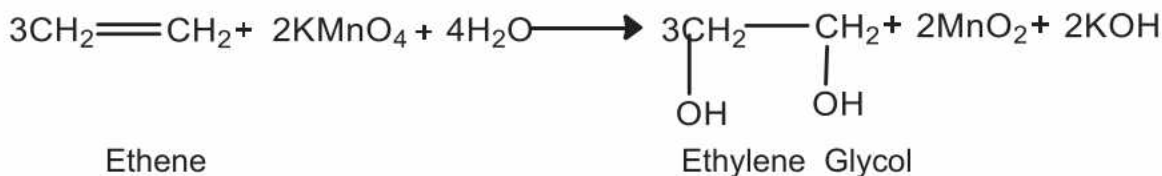


Ethene (colourless) (Reddish-brown) 1,2-Dibromethane (colourless)

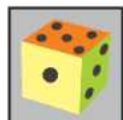
Bromine is a reddish-brown liquid and the product is colourless. When bromine water is added to an alkene, the red-brown color disappears. The decolourization of bromine solution is frequently used as a simple test for the presence of unsaturation. Alkynes also give this reaction. (See section 12.3.2)

Reaction with $KMnO_4$

When an alkene is treated with dilute alkaline aqueous solution of KMnO_4 (1%) addition of two hydroxyl groups occurs across the double bond. The pink colour of KMnO_4 solution is discharged during the reaction. This reaction is used as a test for the presence of an alkene and is known as Baeyer's test.



Ethylene glycol is used as an anti-freeze.



Self-Assessment Exercise 12.7

Complete the following reactions

1. $CH_3-CH=CH_2 + Br_2 \rightarrow$
2. $CH_3-CH=CH_2 + KMnO_4 + H_2O \rightarrow$
3. $CH_3-CH=CH_2 + Cl_2 \rightarrow$

**Reading****Do you know?**

Acetylene is used in oxy-acetylene torches for cutting and welding metals. Such torches can produce temperature as high as 3000°C .

12.3. ALKYNES

Hydrocarbons which have at least one triple bond between carbon atoms are called alkynes. Those with one triple bond have the general formula C_nH_{2n-2} .

Structure:

Ethyne, also called acetylene is the simplest member of alkyne family. In ethyne the two carbon atoms share three pairs of electrons. This means the carbon atoms are joined by a triple bond. How many

hydrogen atoms can share electrons with each triply bonded carbon atoms? Structure of ethyne is

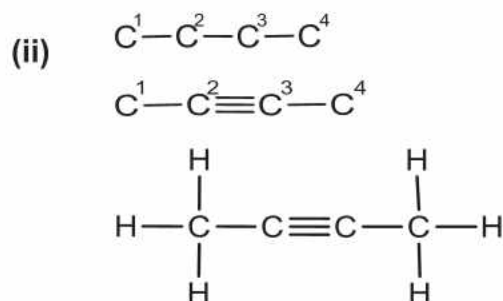
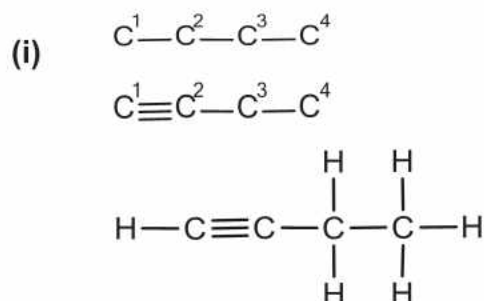
**Example 12.4: Writing structural formulas of alkynes****Draw structural formulas for**

(a) 1-Butyne

(b) 2-Butyne

Problem Solving Strategy

- (i) But– means four carbon atoms.
- (ii) Ending –yne indicates an alkyne.
- (iii) Write a string of four carbon atoms and give number to each carbon atom from one side.
- (iv) Number written before the names indicates the position of triple bond. Make a triple bond between this Carbon atom and next to it.
- (v) Attach required number of hydrogen atoms to the carbon atoms to give each carbon atom four bonds.

Solution



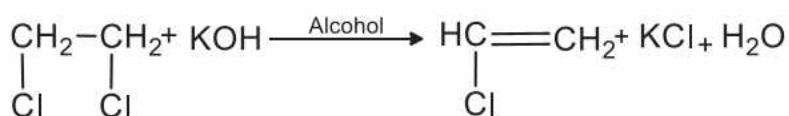
12.3.1. General Methods of Preparation of Alkynes

1. By Dehydrohalogenation of vicinal dihalides

A vicinal dihalide has two halogen atoms on adjacent carbon atoms. Which is vicinal dichloride?



Vicinal dihalide on treatment with alcoholic potassium hydroxide eliminates two molecules of hydrogen halides from adjacent carbon atoms. Removal of two molecules forms a triple bond between two carbon atoms. Reaction occurs in two steps.

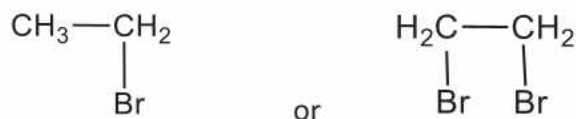


1,2Dichloroethane (Vicinal dihalide) Vinylchloride



Ethyne

Which of the following alkyl halide will form alkyne on treatment with alcoholic KOH?

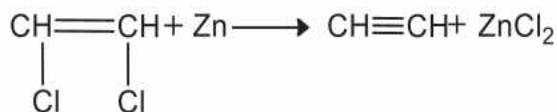


2. By Dehalogenation of Tetrahalides.

Tetra halides on treatment with Zn dust undergo dehalogenation forming an alkyne.



1, 1, 2, 2-Tetrachloroethane 1, 2-Dichloroethene



Ethyne



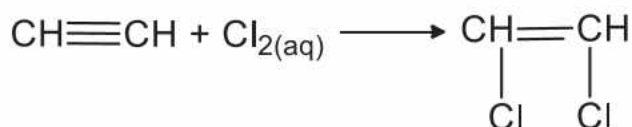
12.3.2. Properties of Alkynes

Like alkenes, alkynes are also unsaturated hydrocarbons. The first three members are gases, next eight members are liquids and higher members are solids. They are non-polar and dissolve readily in organic solvents. Ethyne has garlic like odour. Alkynes are reactive compounds due to presence of a triple bond. Alkynes undergo addition reaction across the triple bond.

One molecule is added across the double bond in an addition reaction. Alkynes also undergo addition reactions like alkene. How many molecules will add across the triple bond?

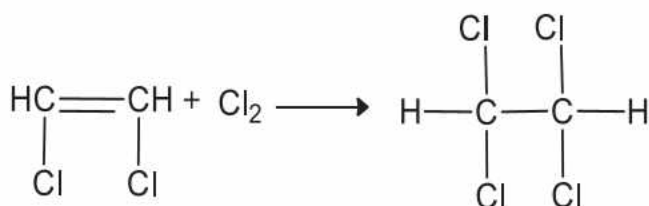
1. Addition of Halogens

Alkynes add two molecules of halogens.



Ethyne

1,2 – Dichlorethene

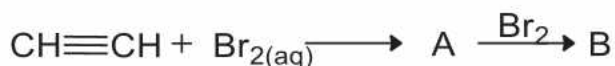


Tetrachloroethane



Self-Assessment Exercise 12.8

Write chemical reaction of ethyne and bromine. Why this reaction is used to identify the unsaturation in a molecule?

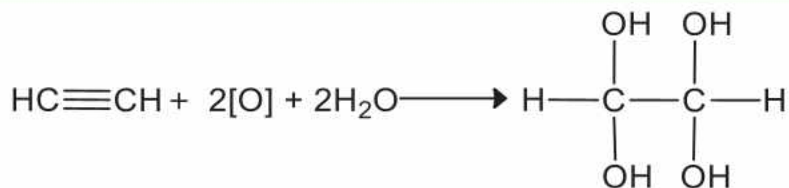


Reading

2. Reaction with KMnO_4

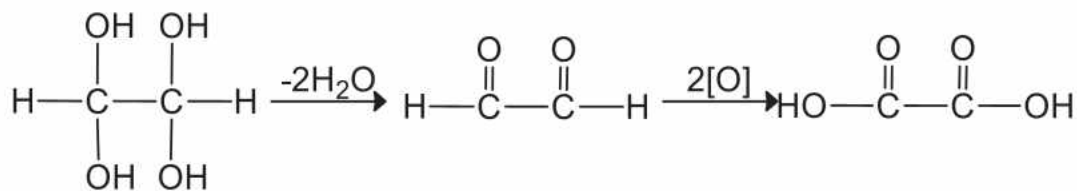
Alkynes do not react with dilute alkaline aqueous solution of KMnO_4 . However, they are oxidized by strong alkaline solution of KMnO_4 to give oxalic acid. First four hydroxyl groups are added across the triple bond.





Tetrahydroxy ethane

Tetrahydroxy ethane is unstable compound; it loses two water molecules to form glyoxal which finally oxidizes to oxalic acid.



Glyoxal

Oxalic acid

Society, Technology and Science

Natural gas, petroleum and coal are important sources of hydrocarbons. These hydrocarbons are major source of energy. When they burn in air a highly exothermic reaction occurs. This reaction is called combustion reaction.

For example



Hydrocarbons are used as fuel to meet our energy needs in homes, industries, motor vehicles and power generation.

Uses of Ethyne (Acetylene)

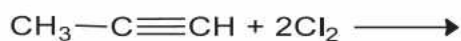
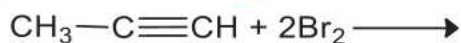
Ethyne is used:

- (i) In oxy-acetylene torch for welding and cutting metals.
- (ii) For ripening of fruits.
- (iii) For the manufacture of polyvinyl acetate (PVA), polyvinyl chloride (PVC), polyvinyl ethers and rubber.



Self-Assessment Exercise 12.9

Complete the following reaction





SKILLS



Activity 12.1

Determining boiling point of alcohol

Perform this activity in the laboratory.

You will need:

- Bunsen burner, stand, wire gauze, stirrer, thread, fusion tube, capillary tube, beaker, thermometer and match box.
- An alcohol such as ethyl alcohol.

Carry out the following:

1. Place small amount of alcohol in the fusion tube and tie it to the thermometer with thread. The ends of fusion tube and thermometer should be equal.
2. Place a long capillary tube in the fusion tube.
3. Place the beaker containing water on the stand.
4. Suspend thermometer along with fusion tube in water. **(See figure 12.1)**
5. Heat the beaker and stir water with the stirrer.
6. Continue heating and stirring until bubbles start rising from the lower end of the capillary tube.
7. See the temperature on the thermometer when bubbles start to come from lower end of capillary tube. This is the boiling point of the liquid.

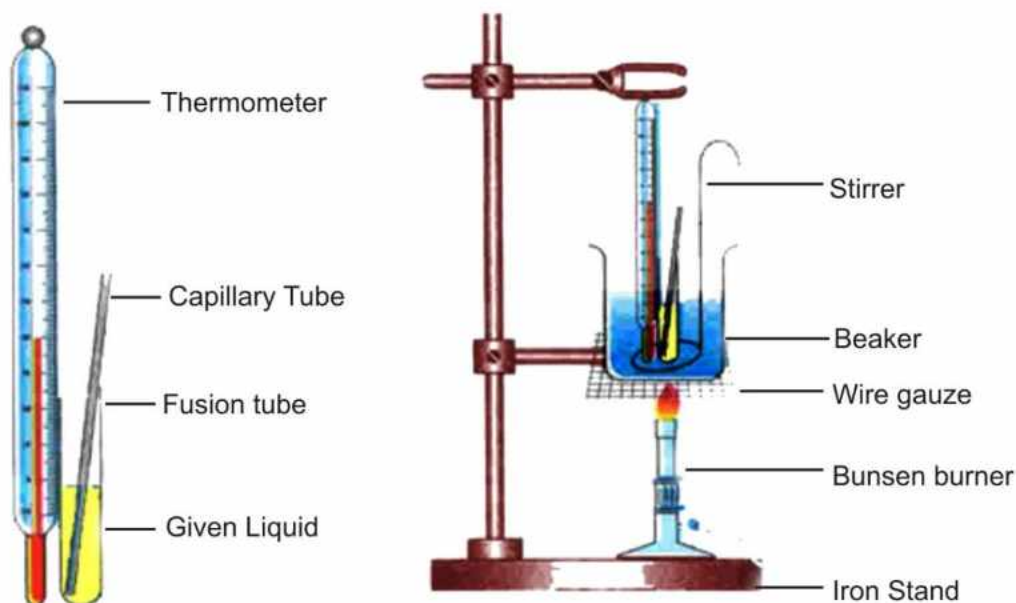
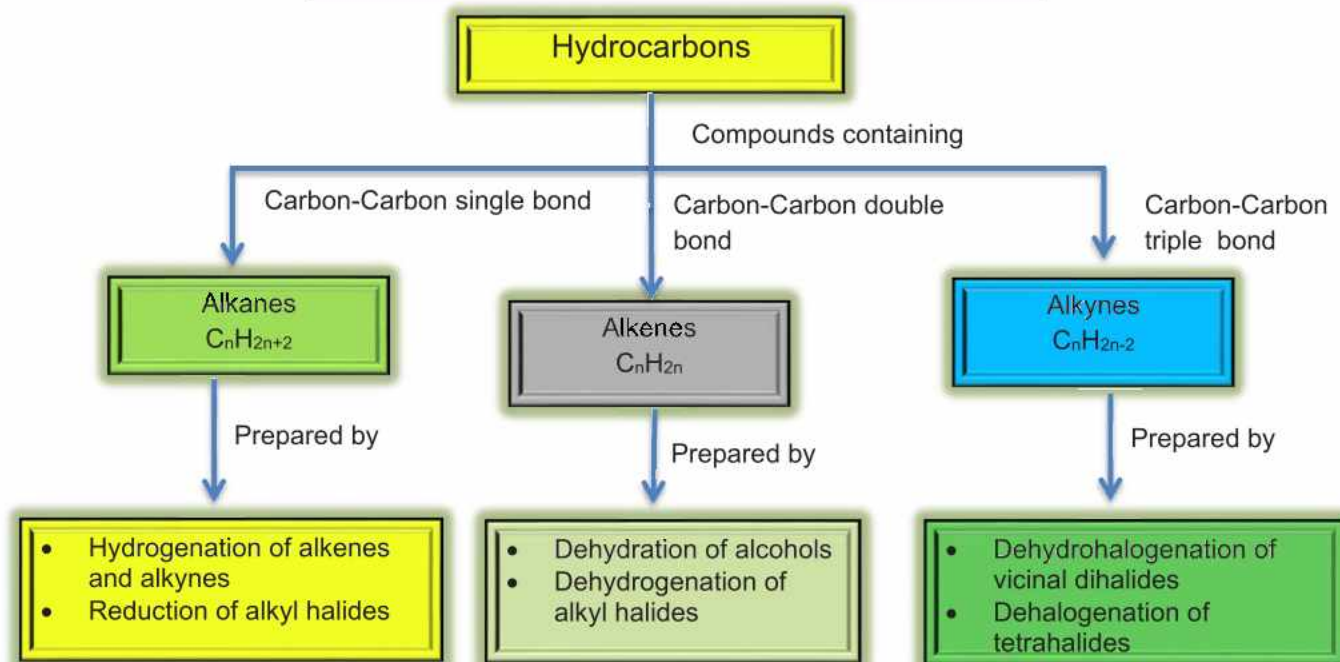


Figure 12.1: Determination of the boiling point of alcohol.



Concepts in brief



Key Points

- ❖ Hydrocarbons are compounds that contain carbon and hydrogen only.
- ❖ The simplest hydrocarbon that is possible is CH_4 .
- ❖ Addition of hydrogen across carbon-carbon double or triple bond is called hydrogenation.
- ❖ Hydrocarbons that have at least one carbon-carbon double bond are called alkenes.
- ❖ Hydrocarbons that have at least one carbon-carbon triple bond are called alkynes.
- ❖ Dehydration is the loss of water.
- ❖ Removal of hydrogen halide is called as dehydrohalogenation.
- ❖ Alkenes and alkynes are unsaturated hydrocarbons.
- ❖ 1% alkaline aqueous solution of $KMnO_4$ is used to detect the presence of an alkene. The reaction is known as **Baeyer's test**.
- ❖ In alkynes the two carbon atoms share three pairs of electrons.
- ❖ A vicinal dihalide has two halogen atoms on adjacent carbon atoms.

References for additional informations.

- ❖ Longman chemistry for IGCSE.
- ❖ Chemistry, Addison, Wesley. Fifth Edition.



Review Questions

1. Encircle the correct answer

- (i) Which molecule contains a carbon-carbon double bond?
(a) Ethane (b) Ethene (c) Ethyne (d) Ethyl alcohol
- (ii) Which product is obtained when chloromethane (or methyl chloride) is reduced?
(a) Ethane (b) Ethene (c) Methane (d) Ethyne
- (iii) Which reacts explosively with methane?
(a) F_2 (b) Cl_2 (c) Br_2 (d) I_2
- (iv) By dehydration we mean, the removal of
(a) Hydrogen (b) Water (c) Halogen (d) Hydrogen halide
- (v) Ethene and ethyne can be differentiated by
(a) Hydrogenation (b) Bromine water
(c) Strong alkaline aqueous solution of $KMnO_4$ (d) Hydrohalogenation
- (vi) Which is used for dehydrohalogenation?
(a) Br_2 water (b) Conc. H_2SO_4 (c) Al_2O_3 (d) Alcoholic KOH
- (vii) Which substance reacts with $KMnO_4$ to produce oxalic acid?
(a) Ethane (b) Ethene (c) Ethyne (d) Ethyl alcohol
- (viii) The reduction of alkyl halides takes place in the presence of
(a) Al_2O_3 at $350^\circ C$ (b) Conc. H_2SO_4 at $170^\circ C$
(c) $Zn + Dust$ (d) $Zn + HCl$
- (ix) Which process produces an alkane?
(a) Combustion (b) Hydration (c) Dehydration (d) Hydrogenation
- (x) Does not react with aqueous solution of bromine
(a) C_2H_6 (b) C_2H_4 (c) C_2H_2 (d) C_3H_6

2. Give short answers.

- (i) Give three examples of unsaturated hydrocarbons.
- (ii) Draw electron dot and cross structure for ethene.
- (iii) Draw structural formulas of an alkane, an alkene and an alkyne containing five carbon atoms.
- (iv) How can you differentiate ethane from ethene?
- (v) What do you mean by dehydration reaction? Give one example

**3. How can you convert**

- (i) ethene into ethane
 (ii) methane into carbontetrachloride
 (iii) ethene into glycol
 (iv) ethyl chloride into ethane
 (v) ethyl bromide into ethene

4. Write a chemical equation to show the preparation of an alkane from an alkene and an alkyne.**5. Write a chemical equation to show the preparation of ethene from dehydration of an alcohol and dehydrohalogenation of alkyl halides.****6. Write a chemical equation to show the preparation of ethyne from dehalogenation of 1,2 -dihalide and a tetrahalide.****7. Write chemical equations showing reaction of $KMnO_4$ with ethene and ethyne.****8. List some industrial uses of ethene and ethyne.****9. Explain why a systematic method of naming chemical compounds is necessary.****10. Draw electron dot and cross structure for**

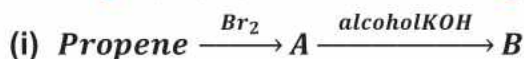
- (a) Propane (b) Propyne (c) Propene

**Think-Tank****11. Write chemical equations for the preparation of propene from**

- (a) $CH_3-CH_2-CH_2-OH$ (b) $CH_3-C \equiv CH$

12. Write down structural formulas for the products which are formed when 1-butene is reacted with

- (a) H_2 / Ni (b) dilute alkaline aqueous $KMnO_4$ solution
 (c) bromine water (d) chlorine

13. Identify A, B, C, D in the following reactions.**14. Construct a scheme to convert ethene into ethyne?****15. You are given two flammable liquid hydrocarbons. One of them is an alkene and the other is an alkane. Design an experiment to find out which is which.****16. How many possible products are there when chlorine reacts with ethane? Sketch them all.****17. Differentiate between ethene and ethyne.**