
UNIT 7 ALKENES

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7.1 INTRODUCTION

In Unit 1, we mentioned briefly about the alkenes. In this unit, we shall discuss their chemistry in detail. Ethene, the simplest alkene, was known to chemists in the eighteenth century and was obtained in pure form in 1795. Alkenes, also called olefins, are hydrocarbons which contain one or more carbon-carbon double bond(s). Since alkenes evidently contain less than the maximum number of hydrogen atoms, they are referred to as **unsaturated hydrocarbons**.

Alkenes are often found as plant products and in petroleum. Many alkenes are biologically active compounds. For example, ethene induces ripening in fruit.

In this unit, we will discuss structure of alkenes, their spectral and physical properties, different methods for their preparation and finally, we will study their important chemical reactions.

Objectives

After studying this unit, you should be able to :

- classify the types of alkenes,
- explain the structure of monoenes and dienes,
- list their spectral and physical properties,
- list the different methods for their preparation, and
- write down the important chemical reactions of alkenes.

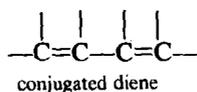
7.2 CLASSIFICATION OF ALKENES

Alkenes can be classified on the basis of the number of double bonds present in the molecule. Hydrocarbons containing one carbon-carbon double bond are called monoenes. The monoenes have the general formula C_nH_{2n} .

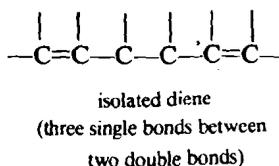
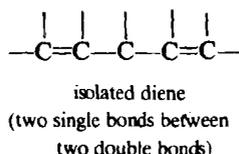
Hydrocarbons containing two double bonds are called diolefins or alkadienes or dienes. They have the general formula C_nH_{2n-2} and are isomeric with alkynes. Trienes have three double

bonds and tetraenes have four double bonds. The term polyene is used for hydrocarbons containing more than four double bonds.

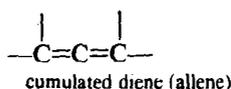
Dienes are divided into three main classes depending on the relative positions of the two double bonds in the molecule: isolated or non-conjugated dienes, conjugated dienes and cumulated dienes. In conjugated dienes, the two double bonds are separated by a single bond. A typical conjugated diene skeleton is given below:



In isolated dienes, the two double bonds are separated by at least two single bonds for which two typical skeletons are given below:



In cumulated dienes, there are two double bonds around the same carbon atom; a typical skeleton is given below:



Compounds that contain cumulated double bonds are known but are very uncommon. The conjugated dienes are the most important among the dienes. They show certain reactions that are not shown by monoenes or other dienes. Thus, in this unit, we shall concentrate our attention on monoenes and conjugated dienes.

Structure of Monoenes and Dienes

The carbon-carbon double bond is both an important structural unit and an important functional group in organic chemistry. The shape of the organic molecule is influenced by the presence of the double bond which is also the site of most of the chemical reactions that alkenes undergo. So it is necessary to understand the structure of these molecules.

Carbon-carbon double bond is the distinguishing feature of the monoenes and dienes. You have already studied about the bonding of monoenes in Unit I of this course and learnt that the carbon atoms involved in double bond formation are sp^2 hybridised. The bond angle around the sp^2 hybridised carbon atoms is 120° (Fig. 7.1). Bonding in dienes with isolated double bonds is similar to monoenes. Thus here we shall discuss π bonds in conjugate and cumulated systems.

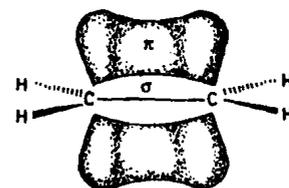
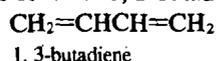


Fig. 7.1 : Orbital picture of ethene.

Let us consider 1, 3-butadiene as an example of a conjugated diene,



Each of the four carbon atoms of butadiene contains an unhybridised p -orbital. The sideways overlap of unhybridised p -orbitals gives rise to two localised π bonds, i.e., the bonds between C_1 and C_2 and C_3 and C_4 (Fig. 7.2). The four carbon atoms and the six hydrogen atoms of butadiene lie in the same plane so that there is a certain amount of overlapping between the electron clouds of the p -orbitals of C_2 and C_3 . This gives rise to completely delocalised π -orbitals spread over all the four carbon atoms. It is this delocalisation of π electrons which imparts stability to 1, 3-butadiene.

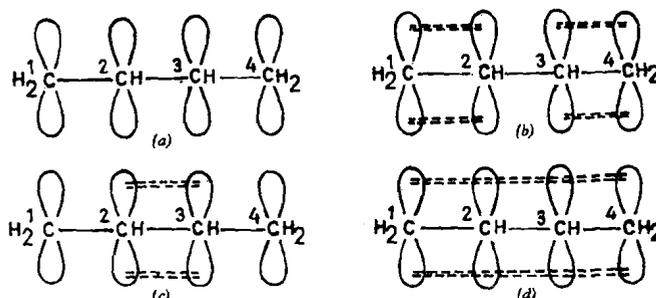


Fig. 7.2 : Orbital structure of 1, 3-butadiene

In the allene molecule, the central carbon atom is sp hybridised while the terminal carbon atoms are sp^2 hybridised. The central carbon atom forms a σ bond with each of the terminal sp^2 hybridised carbon atom. The remaining two p -orbitals of this carbon form two π bonds by sideways overlapping with the p -orbitals of the terminal carbon atoms (Fig. 7.3).

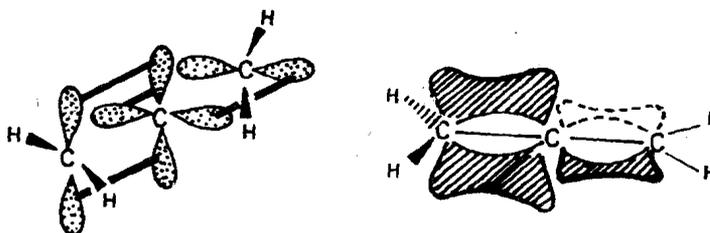


Fig. 7.3 : Molecular orbital picture of allene.

SAQ 1

Fill in the blank in the spaces given below :

- Dienes are isomeric with
- Polyenes contain more than double bonds.
- Double bonds that alternate with single bond are dienes.
- In allene the central atom is hybridised and the terminal atoms are hybridised.

7.3 PHYSICAL PROPERTIES

In general, the physical properties of alkenes are similar to those of the corresponding alkanes. Like alkanes, the boiling points of a homologous series of alkenes increase 20-30 K per CH_2 group except for the very small homologues. Like alkanes, branching in an alkene also lowers the boiling point. Lower alkenes, from ethene to butene, are colourless gases, higher ones, from C_5 - C_{15} , are liquids and the rest are solids at room temperature.

Alkenes are slightly more soluble in water than the corresponding alkanes because the π -electrons are attracted to the partially positive hydrogen of the water molecules.

7.4 SPECTRAL PROPERTIES

In the uv spectrum, although the ethylenic chromophore shows an absorption band below 200 nm, yet it is not of much practical value as measurement of uv spectrum in this region is influenced by the absorption of air and solvent molecules.

The ir spectra are quite useful for structure determination of alkenes. The unsymmetrical alkenes are polar and absorb in the region between 1600 and 1700 cm^{-1} , whereas the symmetrical ones, being nonpolar, do not absorb in this region. Further, depending upon the substituent, one or more bands of medium intensity appear in the region between 3000 and 3100 cm^{-1} for $>\text{C}=\text{C}-\text{H}$ stretching. The *cis*- and *trans*-isomers of the type $\text{RCH}=\text{CHR}$ may be distinguished by $\text{C}-\text{H}$ deformation frequencies. The *cis*-isomer absorbs at $675-730\text{ cm}^{-1}$ and the *trans*-isomer at $960-975\text{ cm}^{-1}$.

In the ir spectra of allenes, a band near 1950 cm^{-1} appears for the $\text{C}=\text{C}$ stretching vibration. The strong band at 850 cm^{-1} arises from $>\text{C}=\text{CH}_2$ wagging and is characteristic of allene. The characteristic $-\text{C}=\text{C}-$ stretching frequencies in conjugated systems is lower and appears around 1600 cm^{-1} .

In the nmr spectra, the chemical shifts of olefinic protons are shifted towards lower field than those of alkane protons. The exact position of absorption depends on the location of the

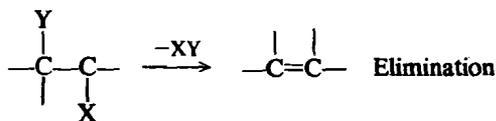
double bond in the hydrocarbon chain. In general, proton on the terminal alkenyl carbon absorb near δ 4.7 ppm, while the protons on the nonterminal carbon absorb slightly farther downfield at δ 5.3 ppm. The protons α to a double bond ($\text{CH}_2\text{CH}=\text{CHCH}_2$) appear at δ 2.06 ppm.

In conjugated dienes, the olefinic protons are more deshielded and consequently resonance due to these protons occurs downfield. In conjugated dienes, the signal due to $\text{CH}_2=\text{CH}$ protons appears at δ 5.3-5.7 ppm and that due to $\text{H}-\text{C}=\text{C}$ proton at δ 6.0-6.5 ppm. In the nmr spectra of the allenes, the alkene hydrogen give rise to signals at δ 5.7-4.7 ppm.

In the mass spectra of alkenes, the molecular ion peak is usually distinct. The fragmentation of interest for alkenes is the allylic cleavage.

7.5 PREPARATION OF ALKENES.

Synthetically, alkenes are prepared by introducing a double bond in saturated hydrocarbons through elimination of atoms or groups from two adjacent carbon atoms. The result is the formation of a double bond between these two carbon atoms.



Alkenes can be prepared from alkyl halides, alcohol and ketones and through cleavage reactions. Some important methods for the preparation of alkenes are summarised in Table 7.1.

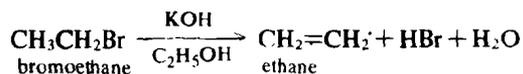
Table 7.1 : Preparation of alkenes

Dehydrohalogenation of Alkyl Halides	
$\begin{array}{c} \text{H} \\ \\ -\text{C}-\text{C}- \\ \quad \\ \quad \text{X} \end{array}$	$\xrightarrow[\text{alcohol}]{\text{KOH}} \begin{array}{c} \quad \\ -\text{C}=\text{C}- \end{array} + \text{HX} + \text{H}_2\text{O}$
Dehydration of Alcohols	
$\begin{array}{c} \text{H} \\ \\ -\text{C}-\text{C}- \\ \quad \\ \quad \text{OH} \end{array}$	$\xrightarrow{\text{acid}} \begin{array}{c} \quad \\ -\text{C}=\text{C}- \end{array} + \text{H}_2\text{O}$
Wittig Reaction	
$\begin{array}{c} \\ -\text{C}=\text{O} \end{array}$	$+ \text{Wittig reagent} \rightarrow \begin{array}{c} \quad \\ -\text{C}=\text{C}- \end{array}$
Retro Diels-Alder Reaction	
	$\xrightarrow[\text{Nichrome}]{\Delta} \begin{array}{c} \text{CH}_2 \\ \text{CH} \\ \text{CH} \\ \text{CH}_2 \end{array} + \begin{array}{c} \text{CH}_2 \\ \\ \text{CH}_2 \end{array}$

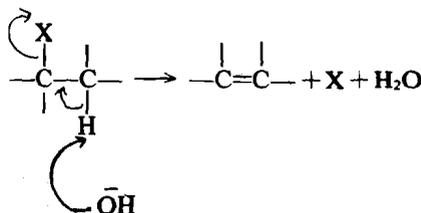
Let us discuss each method in detail.

7.5.1 Dehydrohalogenation of Alkyl Halides

Alkyl halides are converted into alkenes by dehydrohalogenation. Dehydrohalogenation involves elimination of the halogen atom together with a hydrogen atom from an adjacent carbon atom. The elimination is brought about by treating the alkyl halide with a strong base. Thus, bromoethane yields ethene when treated with potassium hydroxide in alcoholic solution.

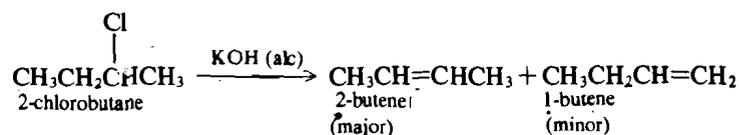
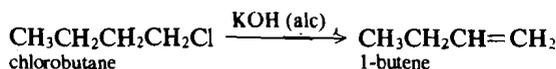


The function of hydroxide ion is to abstract hydrogen from the carbon atom next to the halogen bearing carbon. The carbon halogen bond then cleaves resulting in double bond formation.



Ease of hydrohalogenation of alkyl halides is : *tert* > *sec* > *p*

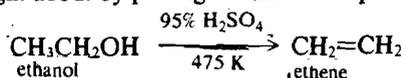
The alkyl halides, in which halogen is attached to a terminal carbon, yield a single alkene but alkyl halides in which the halogen atom is attached to a nonterminal carbon atom and both adjacent position have hydrogen atoms yield a mixture of alkenes.



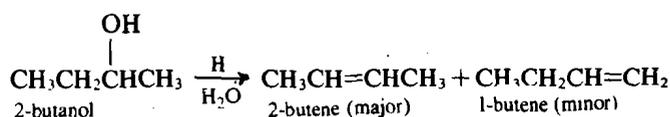
In the first reaction, chlorobutane can lose hydrogen only from C₂; therefore, it gives only one product, i.e., 1-butene. However, in the second reaction, 2-chlorobutane can lose hydrogen from any of the two-β-carbon atoms and, hence, it gives a mixture of 2-butene (80%) and 1-butene (20%). Now you may ask why 2-butene is the major product? Dehydrohalogenation follows Saytzeff rule which says that the more highly substituted alkene is the dominant product. You will study Saytzeff rule in detail in Unit 11.

7.5.2 Dehydration of Alcohols

An alcohol is converted into an alkene by dehydration, i.e., elimination of a molecule of water. Dehydration requires the presence of an acid and the application of heat. The alcohol is heated with sulphuric or phosphoric acid to a temperature as high as 475 K. Dehydration is also brought about by passing the alcohol vapour over alumina (Al₂O₃) at 625-675 K, e.g.,



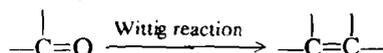
In the case of secondary and tertiary alcohols other than 2-propanol, there exists the possibility of the formation of more than one alkenes. For example, in 2-butanol, hydrogen elimination can occur either from C₁ or C₂. The direction and the rate of reaction again follow the Saytzeff rule and hence 2-butene, the more substituted alkene, is the major product and 1-butene the minor one.



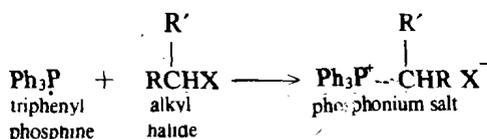
The ease of dehydration of various alcohols has been found to follow the order : *tert* > *sec* > *p*

7.5.3 Wittig Reaction

In 1954, George Wittig reported a method of synthesising alkenes from carbonyl compounds. This reaction is applicable to aldehyde and ketones and leads to replacement of carbonyl oxygen by the group=CRR' (where R and R' are hydrogen or alkyl group).

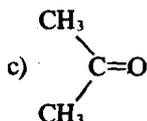
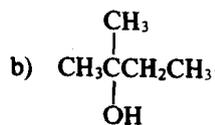


There are two main steps in Wittig reaction. In the first step, the nucleophilic reagent triphenylphosphine reacts with primary or secondary alkyl halide to give phosphonium salt.



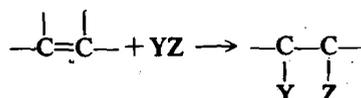
SAQ 2

Write equations for the preparation of alkene from the following starting material. If there is more than one product indicate the major one.



7.6 REACTIONS OF ALKENES

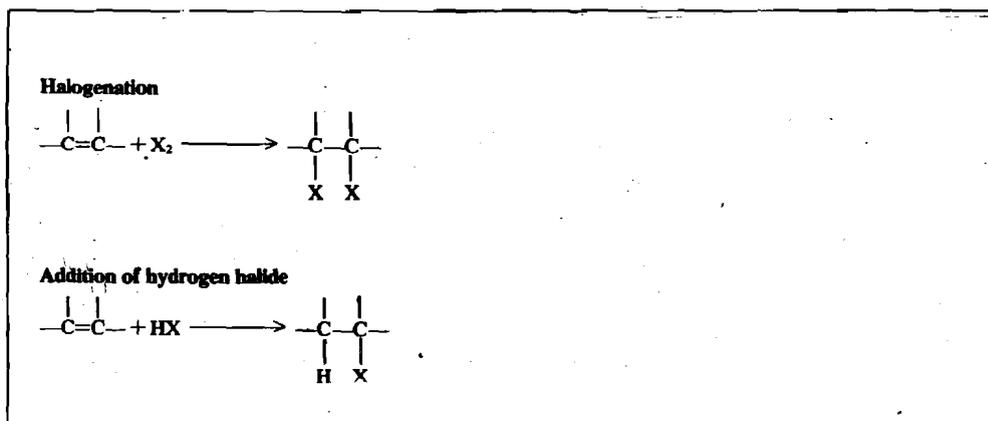
The double bond consists of a strong σ bond and a weak π bond; so most of the reactions of alkenes would involve the breaking of this weaker bond.

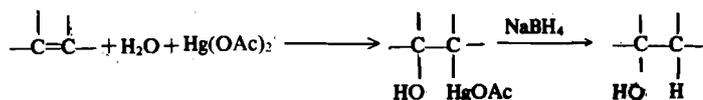
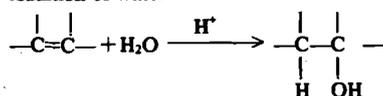
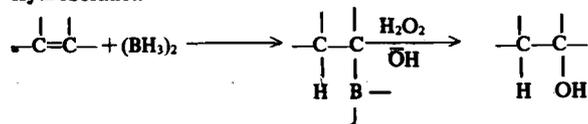
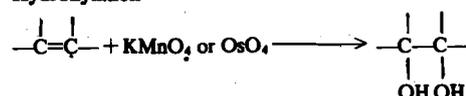
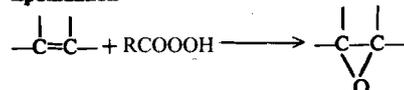
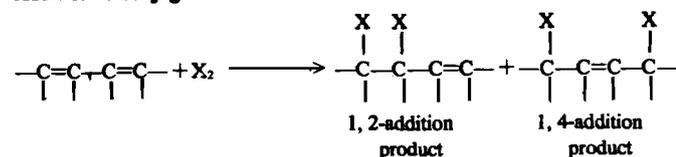
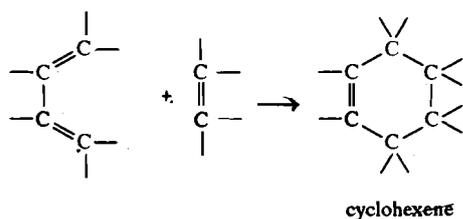


In addition reactions of alkene, the π -bond is broken and the electron pair comprising it, is used in the formation of two new σ bonds. Thus, two sp^2 hybridised carbon atoms are rehybridised to sp^3 carbons. Compounds containing π bonds are usually of higher energy than those having σ bonds. Consequently, addition reactions are usually exothermic processes.

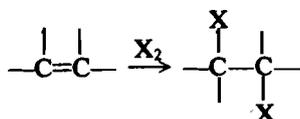
In the region of the double bond, there is a cloud of electrons above and below the plane of bonded atoms. The π electrons are loosely held by the nuclei and are thus easily available to electron-seeking reagent. Such reagents are called electrophilic reagents or electrophiles and the typical reaction of an alkene is the electrophilic addition. Some important reactions of alkenes are given in Table 7.2 and discussed below :

Table 7.2 : Reaction of alkenes



Addition of water**Hydroboration****Ozonolysis****Hydroxylation****Epoxidation****Addition to conjugated diens****Diels-Alder Reaction****7.6.1 Addition of Halogens**

Halogens are quite reactive towards alkenes. Treatment of alkenes with halogens gives 1, 2-dihalogenated alkenes.

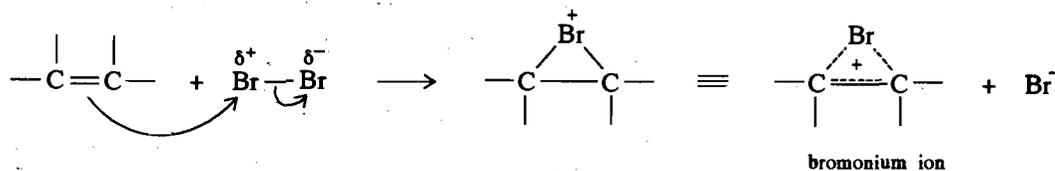


Bromine and chlorine are particularly effective electrophilic addition reagents. Fluorine tends to be too reactive and difficult to control for most laboratory procedures and iodine does not react with alkenes.

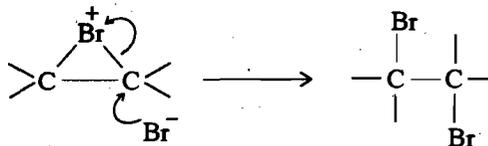
Mechanism

Although bromine is non-polar, it is nevertheless highly polarisable and, in the vicinity of the nucleophilic double bond, the bromine molecule becomes polarised and hence a partial positive charge (δ^+) develops on one bromine atom and a partial negative charge (δ^-) on the other. The π electrons of alkene attack the positive end of the polarised bromine molecule,

displacing bromide ion and forming a cyclic bromonium ion.



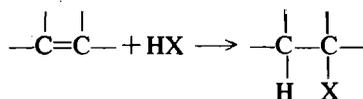
The cyclic structure shields one side of the molecule and, for this reason, Br^- attacks from the opposite side of the erstwhile double bond to give *trans* product. This process is known as *trans* addition. This steric course of the reaction is important in case of alkenes which can give rise to different isomeric products.



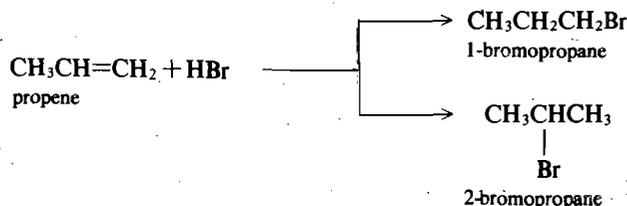
Addition of bromine is extremely useful for detection of carbon-carbon double bond. Rapid decolourisation of bromine solution serves as a test for the presence of the carbon-carbon double bond in a compound.

7.6.2 Hydrohalogenation

An alkene is converted by hydrogen halide (halogen acid) into the corresponding alkyl halide,



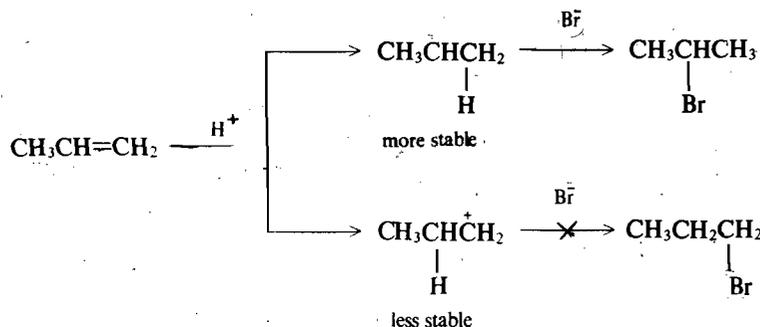
As long as the alkene is symmetrical, we get only one product. In case of unsymmetrical alkene, the position of attachment of nucleophile is governed by the nature of substituents. Addition of HBr to propene should give two products, i.e., 1-bromopropane and 2-bromopropane.

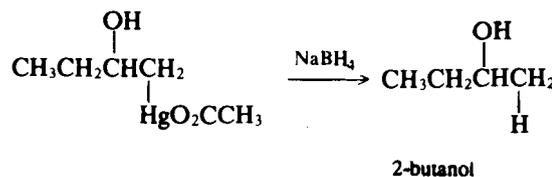
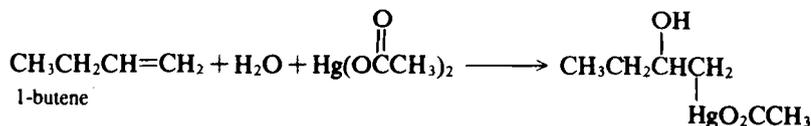


However, only one product, 2-bromopropane, is produced. Such reactions are called **regiospecific** reactions. To explain the exclusive formation of the product, the Russian chemist Markownikoff formulated a rule known after him as Markownikoff's rule, which states that addition of a hydrogen halide to an unsymmetrical alkene takes place in such a way that the negative part of the reagent goes to that carbon atom of the alkene which carries the lesser number of hydrogen atoms.

Regiospecific : Only one of the two directions of addition is observed.

Markownikoff's rule can be explained on the basis of the relative stabilities of carbocations which are of the order of tertiary, > secondary > primary. Accordingly, the more substituted carbocation is formed as an intermediate in preference to the less substituted one. For example, in the addition of H^+ to propene, there exists the possibility of the formation of either a primary or a secondary carbocation. Since, the secondary carbocation is more stable, addition of H^+ gives exclusively 2-bromopropane via the more stable intermediate.

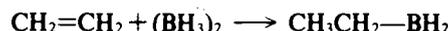




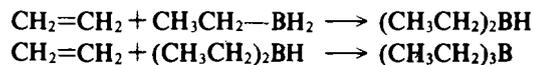
Borane (BH₃) itself is unknown but its dimer, diborane (B₂H₆) behaves as if it were the hypothetical monomer (BH₃)₂.

7.6.4 Hydroboration

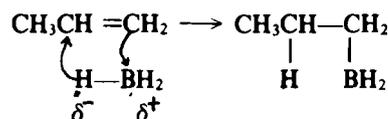
When an alkene reacts with borane, addition to the carbon-carbon double bond takes place to yield an organoborane a compound with a carbon-boron bond. The reaction is known as **hydroboration**. This reaction is very facile and requires only few seconds for completion at 273-K and gives organoboranes in very high yield.



Since BH₃ has three hydrogen, addition occurs three times to produce trialkylborane product e.g.

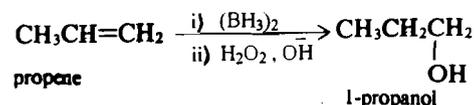


Hydroboration reaction is described as anti-Markownikoff's addition. This is true only in literal sense, because hydrogen is the electronegative portion of the molecule instead of the electropositive portion.

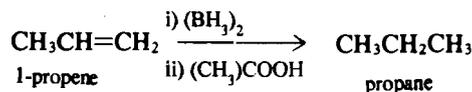


As shown above the hydrogen (as a hydride ion, H⁻) goes to more substituted carbon. The result appears to be anti-Markownikoff's addition.

Organoborane are generally not isolated but are instead used directly as reactive intermediates for further synthetic reaction. For example, oxidation of organoborane by alkaline H₂O₂ gives corresponding alcohol.



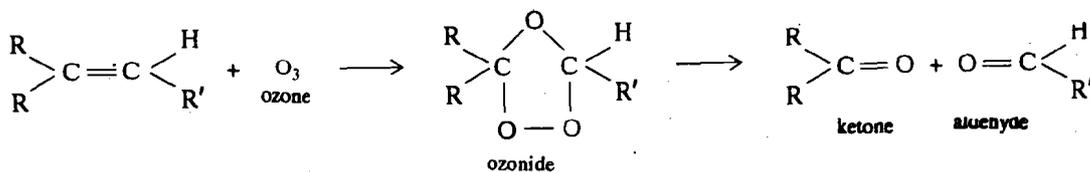
Treatment of organoboranes with a carboxylic acid leads to alkane,



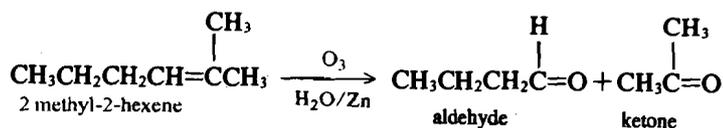
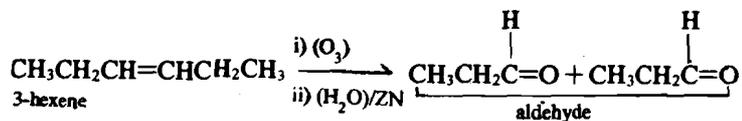
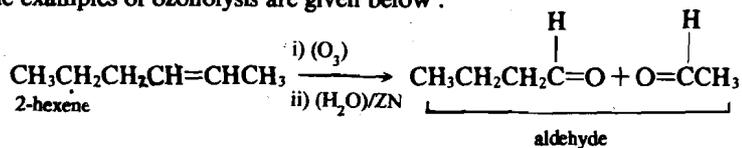
7.6.5 Ozonolysis

In all the reactions of alkenes studied so far, the carbon skeleton of the starting material was left intact. We have seen the conversion of the carbon-carbon double bond into new functional groups (halide, alcohol, etc.) by adding different reagents, but the carbon skeleton was not broken or rearranged. Ozonolysis is a cleavage reaction, i.e. a reaction in which the double bond is completely broken and alkene molecule is converted into two smaller molecules.

Ozonolysis consists of two separate reactions, the first is oxidation of alkene by ozone to give an ozonide; and the second is reduction of the ozonide to yield cleavage product.

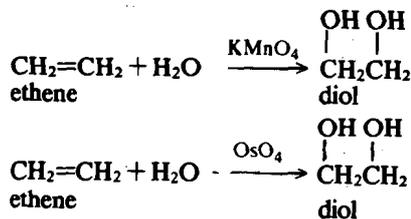


Some examples of ozonolysis are given below :



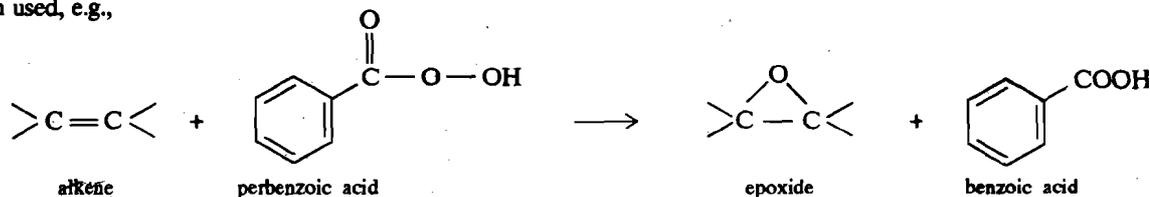
7.6.6 Hydroxylation

Alkenes are readily hydroxylated (addition of hydroxyl groups) to form a dihydroxy compound (diol) known as glycols. The most popular reagent used to convert an alkene to diol is cold alkaline aqueous solution of potassium permanganate or osmium tetroxide.



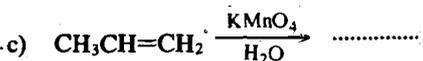
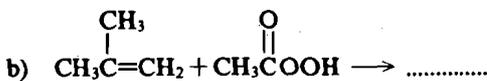
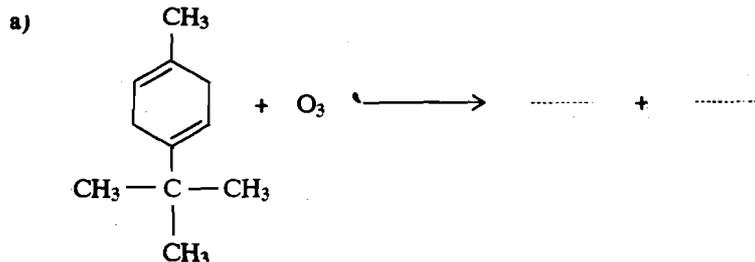
7.6.7 Epoxidation

The double bond in alkene is converted into epoxide by means of peracids. Perbenzoic acid ($\text{C}_6\text{H}_5\text{COO}_2\text{H}$), monopero-phthalic acid ($\text{HO}_2\text{CC}_6\text{H}_4\text{COO}_2\text{H}$) and *p*-nitroperbenzoic acid have been used, e.g.,



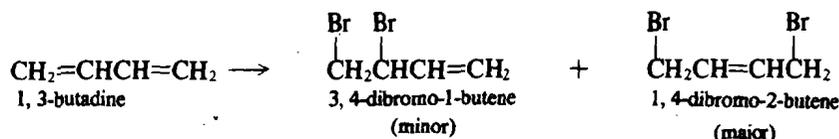
SAQ 4

Predict the products of the following reactions :

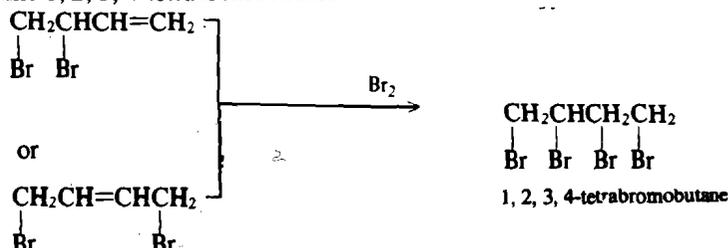


7.6.8 Addition to Conjugated Diene

Alkadienes with conjugated system of double bonds undergo abnormal addition reactions, e.g., when 1, 3-butadiene is treated with bromine, two dibromo derivatives are obtained. One of these is 3, 4-dibromo-1-butene (due to 1:2 addition) and the other is 1, 4-dibromo-2-butene (due to 1:4 addition), a major product.

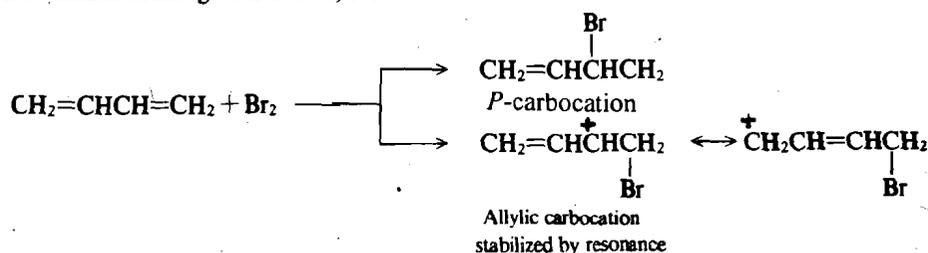


With an excess of bromine, the 1, 4 addition as well as the 1, 2-addition products would yield the same 1, 2, 3, 4-tetrabromobutane.

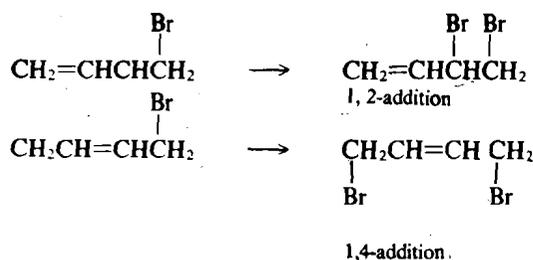


Mechanism

The mechanism of halogenation of 1, 3-butadiene is illustrated below :



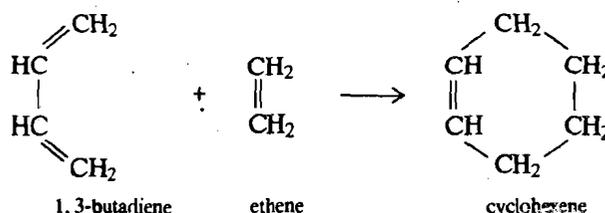
Bromine may attach itself to either C₁ or C₂. The addition of the bromine atom at C₂ would give rise to an unstable primary localized carbocation. But the bromine addition at C₁ results in the formation of resonance stabilized allylic cation. This also explains the enhanced reactivity of dienes over isolated ethylenic double bonds. When the allylic carbocation is attacked by bromine ion (Br⁻) to complete the electrophilic addition reaction, the attack can occur at either C₁ or C₃, since both share the positive charge. The result is a mixture of 1, 2- and 1, 4-addition products, the latter formed in excess since it has the more highly substituted double bond and is hence more stable.



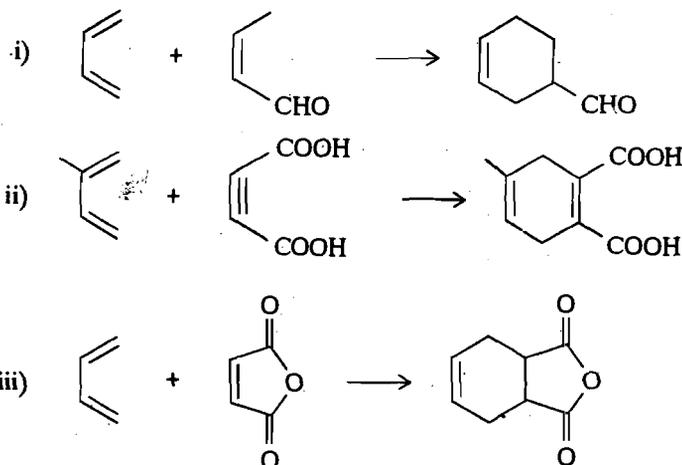
7.6.9 Diels-Alder Reaction

Diels and Alder jointly received the 1950 Noble prize for their work in this area.

In Diels-Alder reaction, a conjugated diene is treated with an unsaturated compound called the dienophile (diene-lover) to yield a cyclic system. This reaction is named after the German chemists, Diel and Alder. It is a very useful reaction for synthesising cyclic systems. The simplest Diels-Alder reaction is the reaction of 1, 3-butadiene with ethene to yield cyclohexene. The resulting product (here cyclohexene) is called the adduct:



This is a very slow reaction and it occurs only under conditions of heat and pressure. Diels-Alder additions take place most rapidly and give the highest yield if the alkene component has electron withdrawing groups or the diene has electron donating groups. The reaction has wide scope because triple bonded systems also may be used as dienophiles. Some important examples of Diels-Alder reaction are given below :



SAQ 5

a) Write the structure of all possible carbocation intermediates in the addition of HI to 2, 4-hexadiene.

.....

b) Which carbocation, of the above problem, would you expect to be more stable?

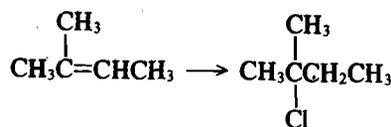
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7.7 SUMMARY

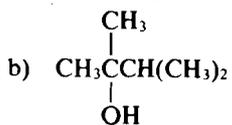
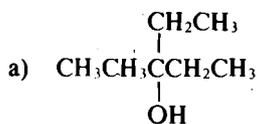
- Hydrocarbons containing one carbon-carbon double bond are known as monoene or olefins. Hydrocarbons containing two double bonds are known as alkenedienes or dienes. Dienes are divided into three classes, i.e., conjugated dienes, isolated dienes and cumulated dienes.
- In general, the physical properties of alkenes are similar to the corresponding alkanes.
- Alkenes are generally prepared by the elimination of atoms or groups from the adjacent carbon atoms. Two such reactions are dehydrohalogenation of alkyl halides and dehydration of alcohols. The ease of dehydrohalogenation of alkyl halide or dehydration of alcohol is :
 $tert > sec > p$
- Alkenes can also be prepared from aldehydes or ketones by Wittig reactions.
- Dienes are prepared by retro Diels-Alder reactions.
- The main reactions of alkenes are electrophilic addition reactions. These reactions include addition of halogen, addition of alkyl halide, addition of water, etc.
- Alkenes can be oxidised by ozone, permanganate and osmium tetroxide. Alkenes on ozonolysis give aldehydes or ketones and on oxidation give 1, 2-diol.
- Addition of halogen to conjugated dienes give normal 1, 2-addition product as a minor product and abnormal 1, 4-addition product as a major product.
- Alkenes undergo Diels-Alder reaction.

7.8 TERMINAL QUESTIONS

1) Give a structural formula for the carbocation intermediate that leads to the principle product in the following reaction :



2) Identify the alkene obtained on hydration/dehydrohalogenation of each of the following compounds:

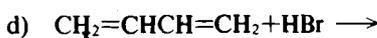
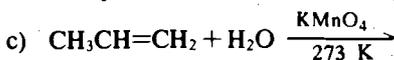
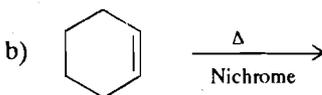
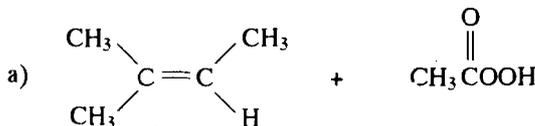


3) Give the product formed when HBr reacts with 2-methyl-2-butene in presence of peroxide and in absence of peroxide.

4) Arrange the following alkenes in order of decreasing stability.



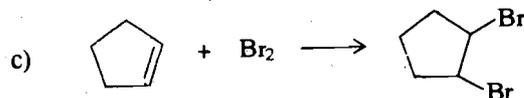
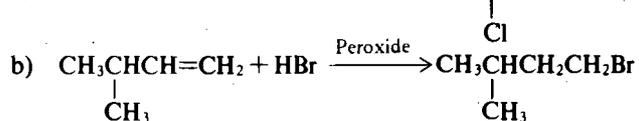
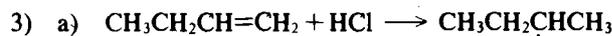
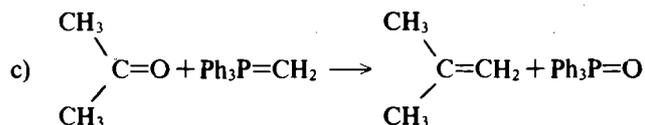
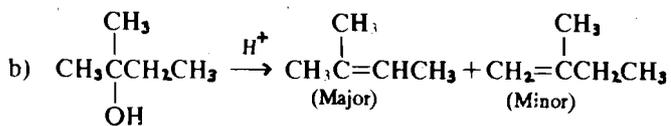
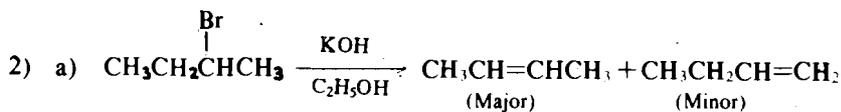
5) Complete the following reactions :



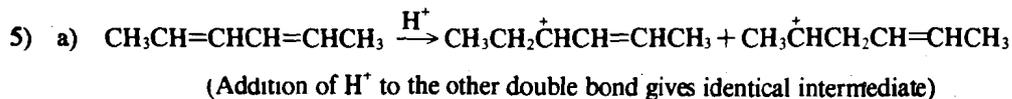
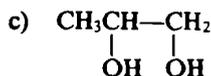
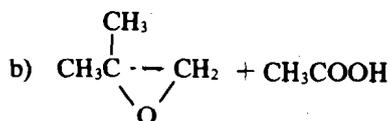
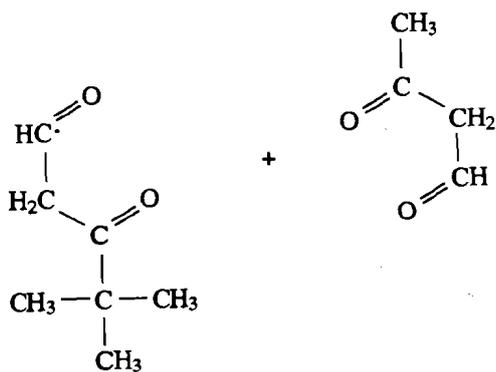
7.9 ANSWERS

Self Assessment Questions

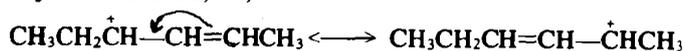
- 1) a) alkyne
b) four
c) conjugated
d) sp , sp^2



4) a)

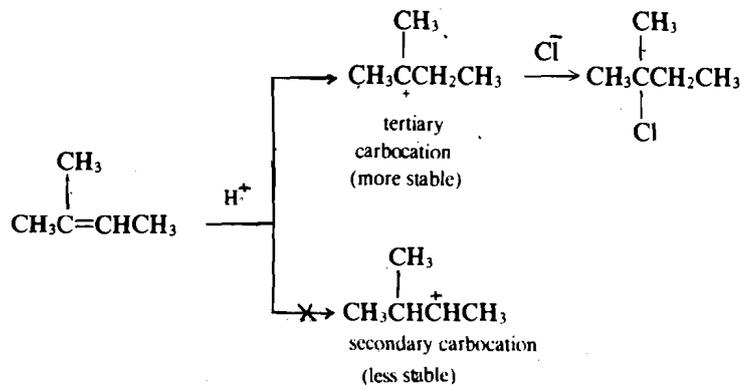


b) The first carbocation shown would be more stable because it is resonance stabilized allylic carbocation, i.e.,

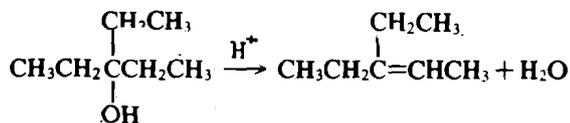


Terminal Questions

1)

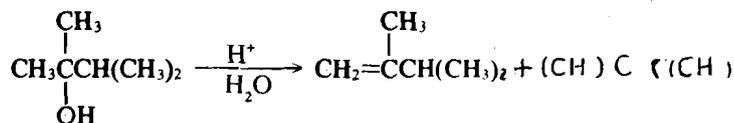


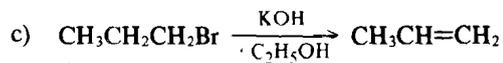
2) a)



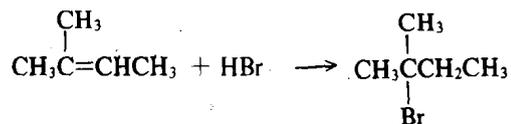
The hydroxyl group is located on carbon that bears three equivalent ethyl substituents in the starting alcohol. Elimination can occur in either of the three equivalent directions to give the same alkene.

b)

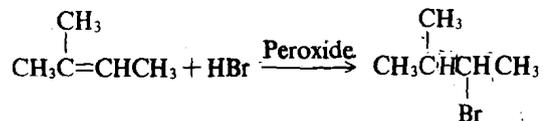




3) The addition of HBr in absence of peroxide gives Markownikoff's product,



The addition of HBr in the presence of peroxide gives anti-Markownikoff's product, i.e.:



4) $\text{R}_2\text{C}=\text{CR}_2 > \text{R}_2\text{C}=\text{CHR} > \text{R}_2\text{C}=\text{CH}_2, \text{RCH}=\text{CHR} > \text{RCH}=\text{CH}_2 > \text{CH}_2=\text{CH}_2$

