Chapter 11

HYDROCARBONS

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Student Learning Outcomes

After studying this chapter, students will be able to:

- Classify hydrocarbons as aliphatic and aromatic. **(Understanding)**
- Describe the nomenclature of alkanes and cycloalkanes. **(Understanding)**
- Explain the shapes of alkanes and cycloalkanes exemplified by ethane and cyclopropane. **(Understanding)**
- Explain the unreactive nature of alkanes towards polar reagents. **(Understanding)**
- Define homolytic and heterolytic fission, free radical initiation, propagation and termination. **(Understanding)**
- Describe the mechanism of free radical substitution in alkanes exemplified by methane and ethane. **(Understanding)**
- Identify organic redox reactions. **(Understanding)**
- Explain the nomenclature of alkenes. **(Understanding)**
- Explain the shape of the ethene molecule in terms of s and p C – C bonds. **(Understanding)**
- Describe the structure and reactivity of alkenes as exemplified by ethene. **(Understanding)**
- Explain with suitable examples the terms isomerism, stereoisomerism, and structural isomerism. **(Understanding)**
- Explain the dehydration of alcohols and dehydrohalogenation of RX for the preparation of ethene. **(Understanding)**
- Describe the chemistry of alkenes by the following reactions of ethene: hydrogenation, hydrohalogenation, hydration, halogenation, halo hydration, epoxidation, ozonolysis, and polymerization. **(Understanding)**
- Explain the concept of conjugation in alkenes having alternate double bonds. **(Understanding)**
- Describe the mechanism of electrophilic addition in alkenes, using bromine/ ethene and hydrogen bromide propene as examples. **(Understanding)**
- Use the IUPAC naming system for alkenes. **(Understanding)**
- Explain the inductive effects of alkyl groups on the stability of primary, secondary and tertiary cations formed during electrophilic addition (this should be used to explain Markovnikov addition). **(Understanding)**

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- **Hydrocarbons** is a class of organic compounds that consists of only carbon and hydrogen. Hydrocarbons are abundantly found in petroleum and natural gas.
- **Uses of Hydrocarbons:** They are frequently used as domestic and industrial fuels. Generally, hydrocarbons have many synthetic applications.
- **Unsaturated hydrocarbons**, especially alkenes, are used as the starting materials for a number of industrial products. Most of the products in the form of medicines, plastics, perfumes, polymers have their origins in hydrocarbons.
- **Classification:** Hydrocarbons are broadly divided into two classes:
  (i) Aliphatic hydrocarbons (ii) Aromatic hydrocarbons

ALIPHATIC AND AROMATIC HYDROCARBONS

➲ Aliphatic Hydrocarbons

The compounds that are not aromatic are called aliphatic hydrocarbons. Aliphatic compounds may be open chain and cyclic, also they may be saturated or unsaturated. If there are only carbon and hydrogen atoms in an aliphatic compound, it is called aliphatic hydrocarbon. Alkanes are acyclic aliphatic hydrocarbons, whereas cycloalkanes are cyclic aliphatic hydrocarbons. Alkenes and alkynes are acyclic and unsaturated aliphatic hydrocarbons. Figure shows some examples of aliphatic hydrocarbons.

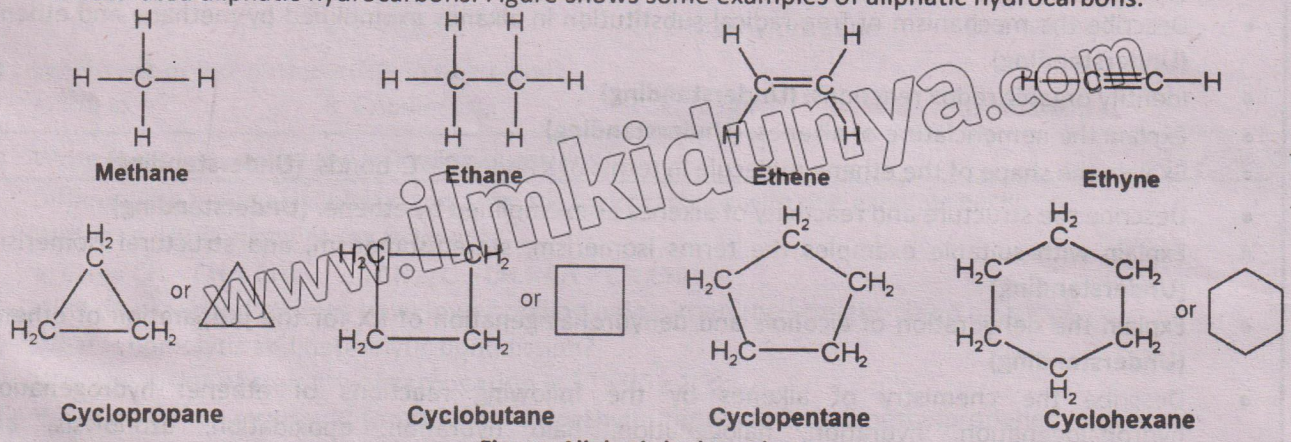


Figure: Aliphatic hydrocarbons

➲ Aromatic Hydrocarbons

Aromatic hydrocarbons is a special class of cyclic hydrocarbons that have high carbon to hydrogen ratio and are based on benzene (C_6H_6) or resembling compounds. Benzene is the basic aromatic compound and other compounds such as toluene and phenol are its derivatives. Figure presents the structures of some aromatic hydrocarbons.

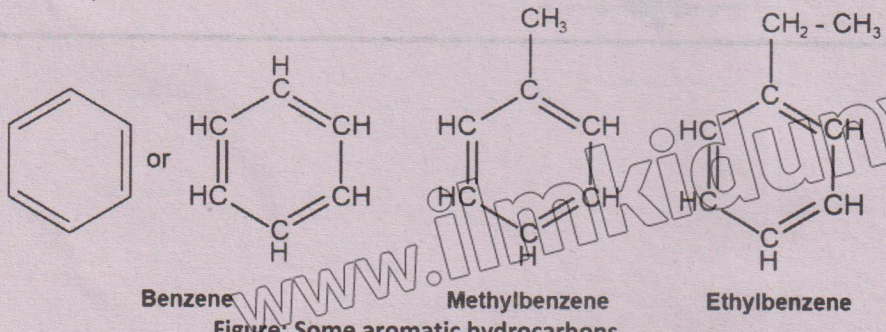


Figure: Some aromatic hydrocarbons

Rack Your Mind!

1. **Methyl benzene is also called:**
   A) Xylene B) Toluene
   C) Cyclohexane D) n-heptane

Interesting Information!

The term aromatic was derived from the Greek word 'aroma' meaning "fragrant" and is used in organic chemistry for a special class of compounds (aromatic compounds) having characteristic odour.

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NOMENCLATURE

➲ Alkanes or Paraffins (Latin Parum-Little, affins = affinity)

Alkanes are saturated hydrocarbons with the general formula C_nH_{2n+2}. Methane (CH_4) is the simplest member of this family. The homologous series of alkanes with condensed structural formulae and molecular formulae are shown in Table.

Table: Condensed structural formulae and molecular formulae of alkanes

IUPAC Name	Molecular formula	Condensed structure
Methane	CH_4	CH_4
Ethane	C_2H_6	CH_3CH_3
Propane	C_3H_8	$CH_3CH_2CH_3$
Butane	C_4H_{10}	$CH_3CH_2CH_2CH_3$
Pentane	C_5H_{12}	$CH_3CH_2CH_2CH_2CH_3$
Hexane	C_6H_{14}	$CH_3CH_2CH_2CH_2CH_2CH_3$
Heptane	C_7H_{10}	$CH_3CH_2CH_3CH_2CH_2CH_2CH_3$
Octane	C_8H_{18}	$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_3$
Nonane	C_9H_{20}	$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_3$
Decane	$C_{10}H_{22}$	$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_3$

Did You Know?

Butane is a fuel used in lighters. Isobutane is used as a propellant in products such as shaving gel.

➢ Alkyl Group:

The group obtained after the removal of one hydrogen atom from an alkane is called an alkyl group. The resulting alkyl groups are named by replacing –ane of the alkanes with –yl. Few examples are shown in Table2 & Table 3.

Table: alkyl groups, their names and abbreviations

Alkane	Alkyl group	Abbreviation
CH_4 Methane	CH_3- Methyl	Me–
CH_3-CH_3 Ethane	CH_3-CH_2- Ethyl	Et–

For alkanes with more than two carbon atoms, more than one alkyl groups can be derived.

Table: Alkyl groups, straight chain and branched and their names

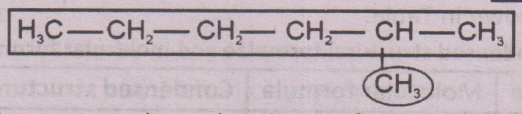
Alkane	Possible Alkyl Groups			
$CH_3CH_2CH_3$ Propane	$CH_3CH_2CH_2-$ n-Propyl group (Propyl)		$CH_3\underset{\displaystyle CH_3}{\overset{\displaystyle |}{C}}HCH_3$ isoPropyl group (1-Methylethyl)	
$H_3CH_2CH_2CH_3$	$CH_3CH_2CH_2CH_2-$ n-Butyl group (Butyl)	$CH_3CH_2\underset{\displaystyle CH_3}{\overset{\displaystyle |}{C}}HCH_3$ sec-Butyl group (1-Methylpropyl)	CH_3CHCH_2- (CH3 below) IsoButyl group (2-Methylpropyl)	$H_3C-\underset{\displaystyle CH_3}{\overset{\displaystyle |}{\overset{\displaystyle |}{C}}}-CH_3$ tert-Butyl group (1,1-Dimethylpropyl)

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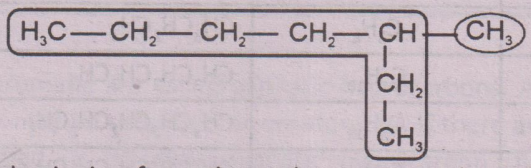
➲ Nomenclature of Alkanes

Branched chain alkanes are named according to the following rules.

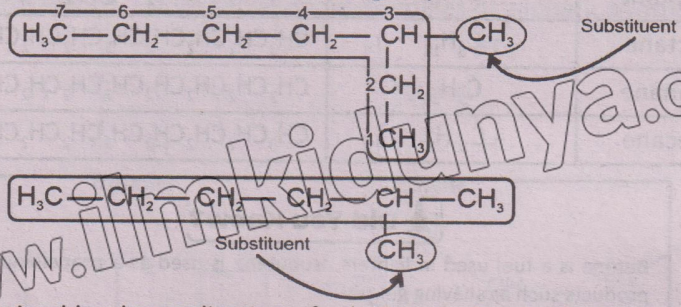
1. Locate the longest continuous chain of carbon atoms; this chain determines the parent name for the alkane. We designate the following compound as a hexane because the longest continuous chain contains six carbon atoms.



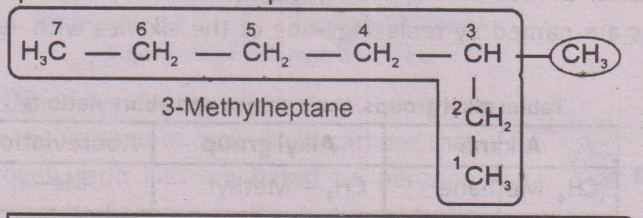
The longest continuous chain may not always be obvious from the way the formula is written. Notice, for example, that the following alkane is designated as a heptane because the longest chain contains seven carbon atoms.

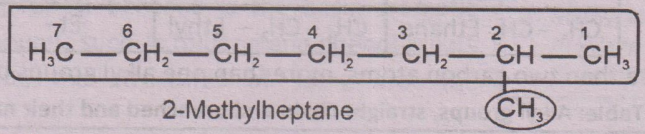


2. Number the longest chain beginning from the end nearest to the substituent. Applying this rule, we number the two alkanes shown above in the following way.

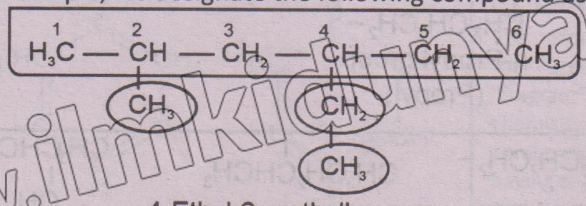


3. Use the numbers obtained by the application of rule 2 to designate the location of the substituent group. The parent name is placed last, and the substituent group, preceded by the number designating its location on the chain, is placed first. For example:





4. When two or more substituents are present, give each substituent a number corresponding to its location on the longest chain. For example, we designate the following compound as 4-Ethyl-2-methylhexane.



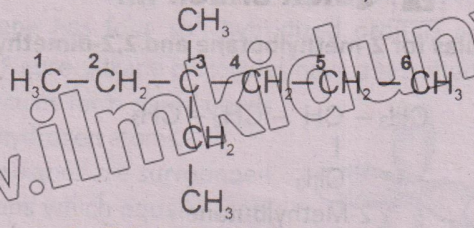
The substituent groups should be listed alphabetically (i.e. ethyl before methyl). While deciding on alphabetical order ignored multiplying prefixes such as "di" and "tri".

Rack Your Mind!

2. Write down names of the following compounds according to IUPAC system.
(a) $(CH_3CH_2)_3CH$ (b) $(C_6H_5)_3CH$

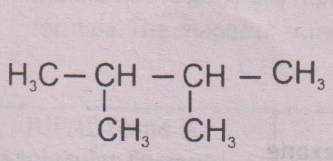
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5. When two substituents are present on the same carbon atom, use that number twice.

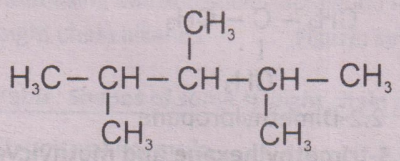


3 - Ethyl - 3 - methylhexane

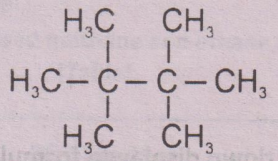
6. When two or more substituents are identical, indicate this by the prefixes di, tri, tetra, and so on. Then make certain that each and every substituent has a number.



2, 3 - Dimethylbutane



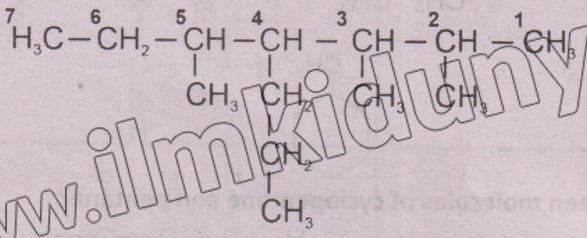
2, 3, 4 - Trimethylpentane



2, 2, 3, 3 - Tetramethylbutane

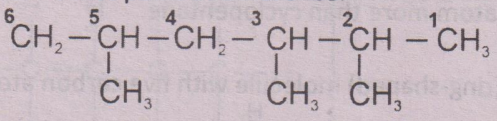
Application of these six rules allows us to name most of the alkanes that we shall encounter. Two other rules, however, may be required occasionally.

7. When two chains of equal length compete for selection as the parent chain, choose the chain with the greater number of substituents.



2, 3, 5 - Trimethyl - 4 - n - propylheptane

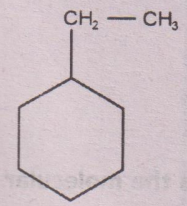
8. When branching first occurs at an equal distance from either end of the longest chain, choose the name that gives the lower number at the first point of difference.



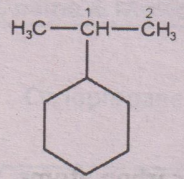
2, 3, 5 - Trimethylhexane (not 2, 4, 5 - Trimethylhexane)

➲ Nomenclature of Cycloalkanes

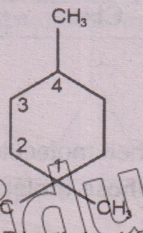
Cycloalkanes are named by attaching the prefix 'cyclo' to the names of the alkanes possessing the same number of carbon atoms. Figure 11.3



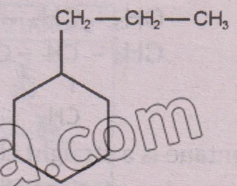
Ethylcyclohexane



Common name: Isopropylcyclohexane
IUPAC name: 1-Methylethylcyclohexane



1, 1,4-Trimethylcyclohexane



Common name: n-Propylcyclohexane
IUPAC name: Propylcyclohexane

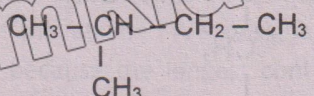
Figure: Naming cycloalkanes

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☑ QUICK CHECK 11.1

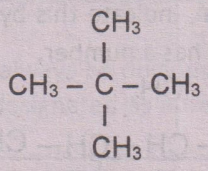
a) Write down the structural formulas for 2-methylbutane and 2,2-dimethylpropane.

Ans. 2-Methylbutane (Isopentane)



2-Methylbutane

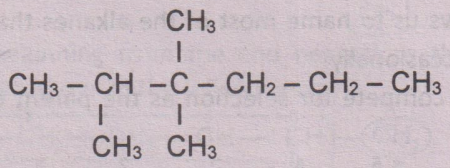
2,2-Dimethylpropane (Neopentane)



2,2-Dimethylpropane

b) Write down displayed formula of 2,3,3-trimethylhexane and methylcyclohexane.

Ans. 2,3,3-trimethylhexane



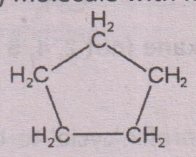
Methylcyclohexane



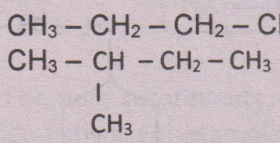
c) Give two differences between molecules of cyclopentane and pentane?

Ans.

1. **Chemical Formulas**
   Cyclopentane: C_5H_{10}, **Pentane:** C_5H_{12}
   Pentane has two hydrogen atom more than cyclopentane.
2. **Structure**
   Cyclopentane: It is a cyclic (ring-shaped) molecule with five carbon atoms forming a closed ring.



3. **Pentane**



A pentane is a straight chain or branched molecule.

d) Eicosane is a straight chain alkane whose molecules contain 20 carbon atoms. What is the molecular formula of eicosane?

Ans. The molecular formula of eicosane (a straight-chain alkane with 20 carbon atoms) is:

$$C_{20}H_{42}$$

Explanation:

General formula for alkanes: C_nH_{2n+2}

For n = 20:

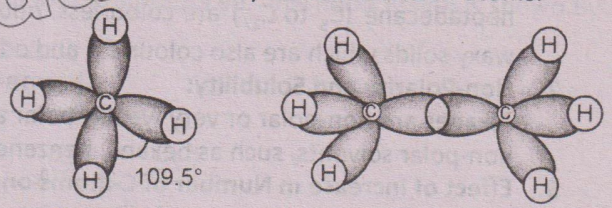
$$H = (2 \times 20) + 2 = 42$$

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Shapes of Alkanes and Cycloalkanes

The carbon atom in an alkane has four sp^3 hybridized orbitals and forms four single bonds that are equidistant from each other Figure. Alkane molecules have a tetrahedral shape around carbon atoms. Carbon atoms in alkane molecules form sigma bonds with surrounding carbon and hydrogen atoms.

As a result, carbon atoms in alkanes are surrounded by 4 pairs of bonding electrons which equally repel each other to form 109.5° bond angles and a C–C bond length of 1.54 Å. The shapes of organic molecules are generally represented using ball and stick formula. The shapes of some straight chain alkanes

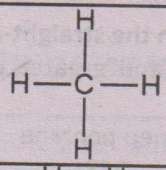
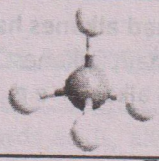
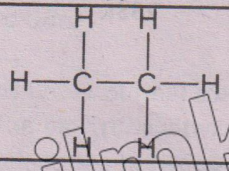
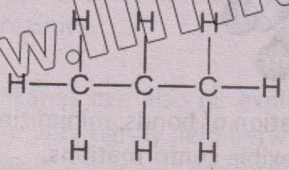
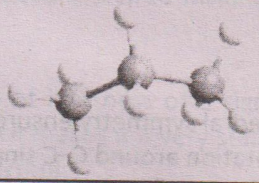
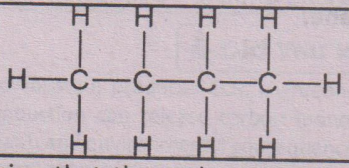
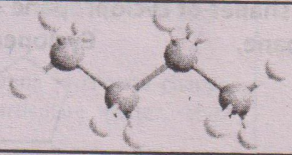


Methane
sp^3 hybrid tetrahedral

Ethane

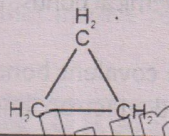
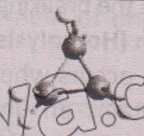
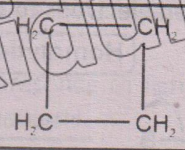
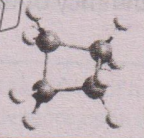
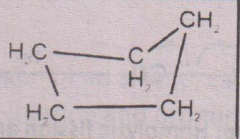
Figure: sp^3 hybridised methane and ethane are shown (Table).

Table: Shapes of some straight chain alkanes

IUPAC name & Molecular Formula	Structural Formula	3D Structure
Methane CH_4		
Ethane C_2H_6		
Propane C_3H_8		
Butane C_4H_{10}		

Cycloalkanes are cyclic, meaning that the carbon atoms of the molecule are arranged in the form of a ring. Cycloalkanes are also saturated, meaning that all of the carbons atoms that make up the ring are singly bonded to other atoms. The structural shapes of cyclopropane, cyclobutane and cyclopentane are shown below (Table)

Table: Shapes of few cycloalkanes

IUPAC name & Molecular formula	Structural formula	3D Structure
Cyclopropane C_3H_6		
Cyclobutane C_4H_8		
Cyclopentane C_4H_{10}		

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➲ Physical Properties of Alkanes

1. **Physical State:**
   Alkanes containing upto four carbon atoms are colourless, odourless, gases while pentane to heptadecane (C_5 to C_{17}) are colourless, odourless liquids. The higher members from C_{18} onwards are waxy solids which are also colourless and odourless.
2. **Non-Polarity and Solubility:**
   Alkanes are non-polar or very weakly polar and are insoluble in polar solvents like water, but soluble in non-polar solvents, such as hexane, benzene, ether, etc.
3. **Effect of Increase in Number of C-atoms on Physical Constants:**
   Their physical constants, e.g. boiling points, melting points, density, etc. increase with the increase in number of carbon atoms, whereas solubility decreases with the increase in molecular mass. The boiling points of alkanes having branched chain structures are lower than their isomeric normal chain alkanes.

normal 〉 iso 〉 neo

e.g., straight change butane has a higher boiling point –0.50°C than 2-Methylpropane (isobutane, –11.7°C).

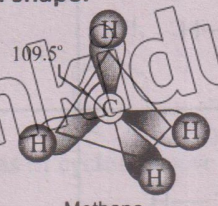
☑ QUICK CHECK 11.2

a) Why do branched alkanes have lower boiling points than the straight-chain alkanes?

Ans. The straight chain alkanes have greater polarizability and greater inter molecular forces than the branched chain alkanes. e.g., Boiling points of

n-pentane 〉 isopentane 〉 neo pentane
309K 301K 283K

b) Explain why alkanes have a tetrahedral shape.

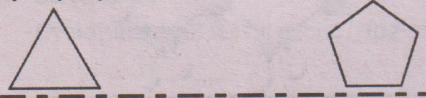


Methane

- Tetrahedral symmetry ensures maximum separation of bonds, minimizing electron repulsion.
- Free rotation around C–C single bonds allows flexible conformations.

c) Draw the shapes of cyclopropane and cyclopentane.

Ans. Cyclopropane, **Cyclopentane**



REACTION MECHANISM AND MODES OF BOND BREAKING

Reaction mechanism is the series of steps that take place in the course of the overall reaction. Like all chemical reactions, organic reactions involve the breaking of chemical bonds. There are two ways in which covalent bonds can break.

(a) Homolytic Fission (Homolysis)

Homolytic fission occurs when the covalent bond breaks evenly to produce free radicals. Free Radical is a species that contains an unpaired electron and is very reactive. Free radicals are extremely reactive because of the tendency of unpaired electrons to become paired.

Homolytic Cleavage

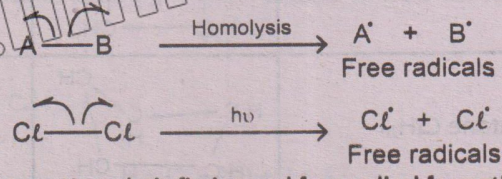


Figure: Homolytic fission and free radical formation

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(b) Heterolytic Fission (Heterolysis)

Heterolytic fission occurs when the covalent bond breaks in such a way that the originally shared pair of electrons is gained by one atom only and oppositely child ions are produced. This bond fission is shown by full curly arrows in mechanisms.

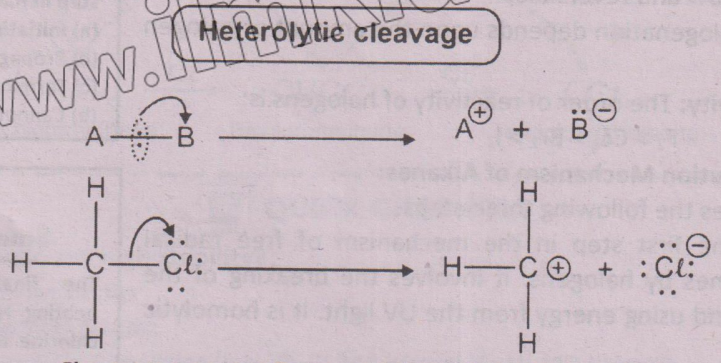


Figure: Heterolytic fission and formation of radical ions

UNREACTIVE NATURE OF ALKANES TOWARDS POLAR REAGENTS

The alkanes or paraffins (Latin: parum = little, affins = affinity) are inert towards acids, alkalis, oxidizing and reducing agents under ordinary condition.

(i) Non-Polar Nature

The lack of reactivity of alkanes under normal conditions may be explained on the basis of the non-polarity of the bonds forming them. The electronegativity values of carbon (2.5) and hydrogen (2.1) do not differ appreciably and the bonding electrons between C – H and C – C are equally shared making them almost non-polar and generally unreactive.

(ii) Inertness of a Sigma Bond

The unreactive nature of alkanes can also be explained on the basis of inertness of a sigma bond. In a sigma bond the electrons are very tightly held between the nuclei which makes it a very stable bond. A lot of energy is required to break it. e.g., C – H bond energy is about 412 kJ/mol.

Did You Know?

Hydrocarbon combustion produces CO_2, a greenhouse gas contributing to climate change. Incomplete combustion can release carbon monoxide (CO) and particulate matter, which have serious health and environmental consequences.

REACTIONS OF ALKANES

Under high temperature or suitable conditions, alkanes undergo two types of reactions.

i. Thermal and Catalytic Reactions, **e.g.,** Combustion and cracking

ii. Free radical substitution reactions are the reactions that involve replacement of one atom, or group of atoms by another through the free radical mechanism.

(Exercise L.Q.3)

Q. Describe the free radical halogenation of methane using Cl_2 as an example.

➲ Free radical Substitution Reactions

Substitution reactions of alkanes take place in the presence of light energy through the formation of highly reactive free radicals.

The extent of halogenation of alkanes depends upon the concentration of X_2 used.

➢ **Example:**

Halogenation:

- The substitution of a halogen atom with a hydrogen of an alkane, called halogenation.
- **With Chlorine and Bromine:** Alkanes react with chlorine and bromine in the presence of sunlight or UV light resulting in the successive replacement of hydrogen atoms with halogens.

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- **With Fluorine:** Reaction of alkanes with fluorine is highly violent and results in a mixture of carbon, fluorinated alkanes and hydrofluoric acid.
- **With Iodine:** Iodine does not substitute directly because the reaction is too slow and reversible.
- The extent of halogenation depends upon the amount of halogen used.
- **Order of Reactivity:** The order of reactivity of halogens is:

$$F_2 > Cl_2 > Br_2 > I_2$$

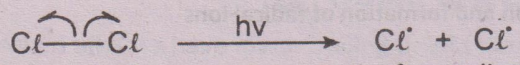
MCQ

The slowest and rate determining step in halogenation of alkane is:
(a) Initiation
(b) Propagation
(c) Termination
(b) Cannot be predicted

Free Radical Substitution Mechanism of Alkanes:

Halogenation involves the following three steps.

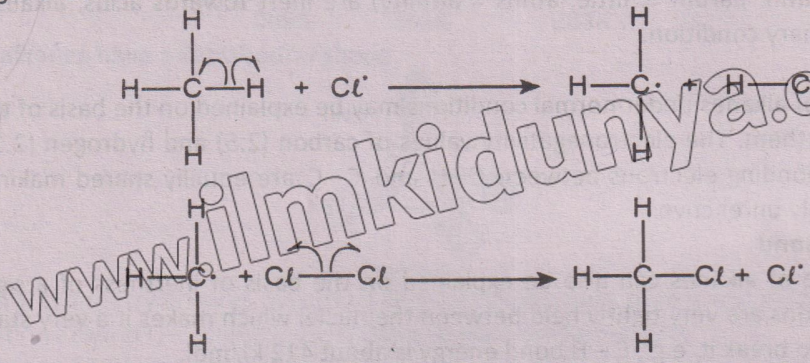
i) **Initiation step** is the first step in the mechanism of free radical substitution of alkanes by halogens. It involves the breaking of the halogen-halogen bond using energy from the UV light. It is homolytic fission.



Smart Thinking

The final product obtained by heating $H_3C - CH_3$ with excess of chlorine in the presence of sunlight is:
(a) Monochloro ethane
(b) Dichloro ethane
(c) Tetrachloro ethane
(d) Hexachloro ethane

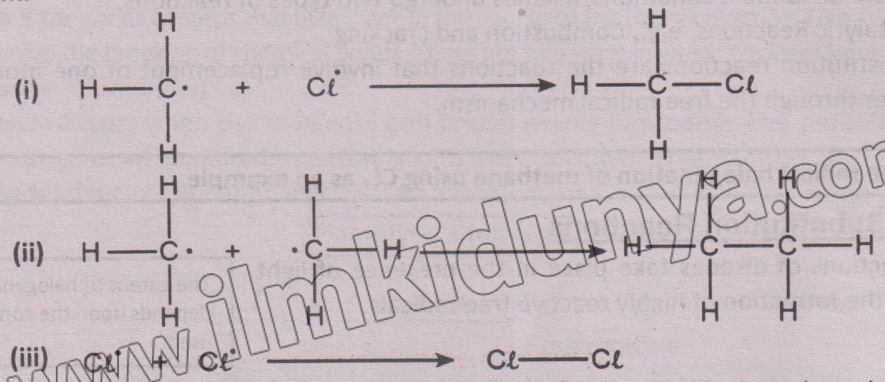
ii) **Propagation step** is the second step in the free radical substitution in which the initially formed radicals attack the alkane molecule generating more free radicals.



iii) **Termination step** is the final step in a free radical substitution in which two free radicals react together to form a product.

The termination step may take place in different ways. The chloride and alkyl radicals may combine to form a chloroalkanes or two chloride radicals may also react to make the chlorine molecule.

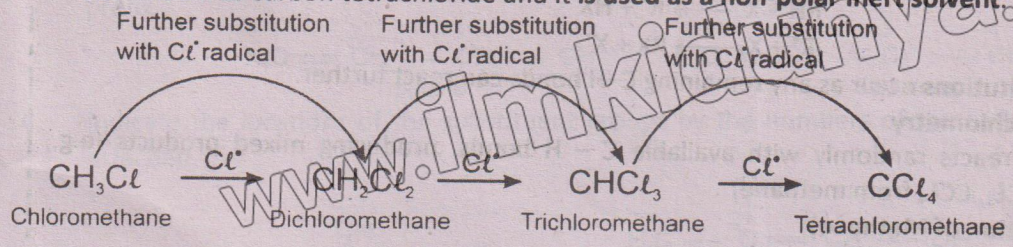
Another termination mode is the formation of alkane with double number of carbon atoms which takes place when two alkyl radicals merge together. This type of termination is rare and the alkanes with double carbon atoms are formed in traces. However, its presence is evident of free radical substitution mechanism.



By repetition of step (ii), propagation step, a mixture of halogen substituted products (chloroalkanes) is obtained. The more the chlorine gas in reaction mixture to start with, the greater the proportions of chlorine atoms in the chloroalkane molecules formed.

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Note: Trichloromethane is also known as chloroform. Tetrachloromethane is also known as carbon tetrachloride and it **is used as a non-polar inert solvent.**



Interesting Information!
Haloalkanes are anaesthetic in nature. The anesthetic power of a haloalkane increases with the number of halogen atoms. Use of these as organic solvents in lab is strictly monitored due to their toxic nature.

QUICK CHECK 11.3

a) Explain why alkanes have high stability?

Ans. Stability of Alkanes is due to:

1. **Strong C–C and C–H Bonds:**
   High bond dissociation energies (e.g., C–C: 348 kJ/mol, C–H: 413 kJ/mol).
2. **Nonpolar Bonds:**
   Electronegativity difference between C and H is negligible ($\Delta EN \approx 0.4$), making them resistant to electrophilic/nucleophilic attacks.
3. **Saturated Hydrocarbons:**
   Only single bonds (σ-bonds) with no reactive π-electrons (unlike alkenes/alkynes).
4. **Tetrahedral Symmetry:**
   sp^3 hybridization minimizes steric strain and electron repulsion.
5. **Inertness to Common Reagents:**
   Unreactive toward acids, bases, and oxidizing agents at room temperature.
6. **Combustion Requires High Energy:**
   Need strong ignition sources (e.g., heat/sparks) to break stable σ-bonds.

Conclusion: Stability arises from strong, nonpolar, single bonds and lack of functional groups.

b) What are major types of reactions that alkanes undergo?

Ans.

1. **Combustion:**
   Burns in oxygen to form $CO_2 + H_2O$ + energy (e.g., methane: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$).
2. **Halogenation (Free Radical Substitution):**
   Reacts with halogens (Cl_2/Br_2) under UV light to form alkyl halides (e.g., $CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$).
3. **Cracking (Thermal Decomposition):**
   Breaks into smaller alkanes/alkenes at high temperatures (e.g., $C_{10}H_{22} \rightarrow C_8H_{18} + C_2H_4$).
4. **Isomerization:**
   Converts straight-chain alkanes to branched isomers (catalyzed by acids/metal catalysts).
5. **Reforming:**
   Converts alkanes to cycloalkanes/aromatics (e.g., hexane → benzene).

Conclusion: Alkanes are **unreactive** except under extreme conditions (heat/light).

c) How the termination step occurs in the halogenation of alkenes?

Ans. See Free Radical Substitution Mechanism of Alkanes: (iii. Termination Step)

d) State the conditions under which a mixture of halogenoalkanes is obtained from the halogenation of alkanes.

Ans. A **mixture of halogenoalkanes** is obtained during the halogenation of alkanes under the following conditions:

1. **Excess Alkane (Low Halogen Concentration)**
   Prevents complete substitution, yielding mono-, di-, tri-, etc., halogenated products.
2. **Non-Selective Free Radical Mechanism**
   - **Initiation:**

$$X_2 \xrightarrow{UV/h\nu} 2X^\bullet$$

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- **Propagation:**

$$RH + X^{\bullet} \longrightarrow R^{\bullet} + HX$$
$$R^{\bullet} + X_2 \longrightarrow RX + X^{\bullet}$$

- **Multiple substitutions occur as any remaining C–H bonds can react further.**

3. **No Controlled Stoichiometry**
   Halogen (Cl_2/Br_2) reacts randomly with available C – H bonds, producing mixed products (e.g., CH_3Cl, CH_2Cl_2, $CHCl_3$, CCl_4 from methane).
4. **Example (Chlorination of Methane):**

$$CH_4 \xrightarrow{Cl_2/UV} CH_3Cl + CH_2Cl_2 + CHCl_3 + CCl_4 + HCl$$

e) Predict the products of the free radical chlorination of ethane.

Ans.

1. **Monochlorination:**
   Chloroethane (Ethyl chloride)

$$CH_3CH_3 + Cl_2 \xrightarrow{UV/h\nu} CH_3CH_2Cl + HCl$$

2. **Dichlorination:**
   1,1-Dichloroethane

$$CH_3CH_2Cl + Cl_2 \longrightarrow CH_3CHCl_2 + HCl$$

   1,2-Dichloroethane

$$CH_3CH_2Cl + Cl_2 \longrightarrow CH_2ClCH_2Cl + HCl$$

3. **Trichlorination:**
   1,1,1-Trichloroethane

$$CH_3CHCl_2 + Cl_2 \longrightarrow CH_3CCl_3 + HCl$$

   1,1,2-Trichloroethane

$$CH_2ClCH_2Cl + Cl_2 \longrightarrow CH_2ClCHCl_2 + HCl$$

4. **Tetrachlorination:**
   1,1,1,2-Tetrachloroethane

$$CH_3CCl_3 + Cl_2 \longrightarrow CH_2ClCCl_3 + HCl$$

   1,1,2,2-Tetrachloroethane

$$CH_2ClCHCl_2 + Cl_2 \longrightarrow CHCl_2CHCl_2 + HCl$$

5. **Pentachlorination & Hexachlorination:**
   Pentachloroethane ($CHCl_2CCl_3$)
6. **Hexachloroethane (CCl_3CCl_3)**

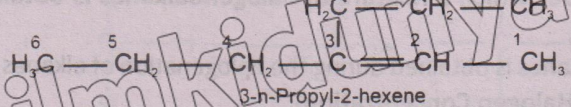
ALKENES

Alkenes are unsaturated hydrocarbons, ***unsaturated hydrocarbons*** are compounds of hydrogen and carbon only whose molecules contain carbon to carbon double bonds (or triple bonds). Alkenes have two hydrogen atoms less than the corresponding saturated hydrocarbons.

➲ Nomenclature of Alkenes

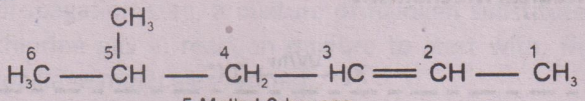
The IUPAC rules for naming alkenes are similar in many respects to those for naming alkanes.

1. Select the longest continuous chain that contains the C = C as the parent chain. Change the ending of the name of the alkane of identical length from –ane to –ene, e.g.,



3-n-Propyl-2-hexene

2. Number the chain so as to include both carbon atoms of the double bond. Numbering begins from the end nearer to the double bond.



5-Methyl-2-hexene

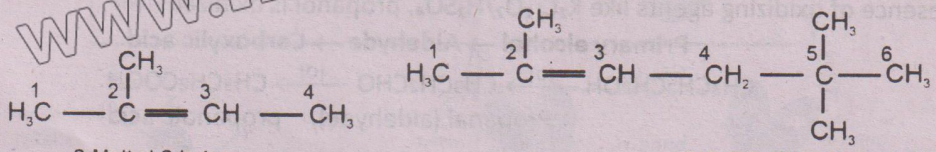
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3. Designate the location of the double bond by using the number of the first atom of the double bond as a prefix.



1-butene 1-pentene

4. Indicate the locations of the substituent groups by the numbers of the carbon atoms to which they are attached.



2-Methyl-2-butene 2, 5, 5-Trimethyl-2-hexene

5. If the parent chain contains more than one double bonds, they are alkadienes for two, alkatrienes for three and so on.

(Exercise L.Q.4)

Q. Describe the following methods for the preparation of alkenes:
i) Dehydrohalogenation of alkyl halides ii) Dehydration of alcohols

➲ Preparation of Alkenes

Alkenes are prepared by the removal of small atoms (H, OH, X) from the adjacent carbon atoms of the saturated compounds, so as to create a double bond between carbon atoms. These reactions are known as elimination reactions.

In such reactions, a small molecule such as H_2O or HCl, is removed from adjacent carbons in an organic molecule. Preparation of ethene through various methods is being discussed below.

i) Dehydration of Alcohols

Ethene is prepared by heating a mixture of ethanol and excess of concentrated sulphuric acid at 180°C. The reaction involves the removal of a water molecule from the alcohol molecule.

$$\underset{\text{Ethanol}}{CH_3CH_2OH} \xrightarrow[\text{heat}]{H_2SO_4} \underset{\text{Ethene}}{CH_2=CH_2} + \underset{\text{water}}{H_2O}$$

In the first step, ethyl hydrogen sulphate is formed which decomposes on heating to produce ethene.

$$CH_3-CH_2OH + H_2SO_4 \xrightarrow{180^\circ C} CH_3-CH_2-OSO_3H + H_2O$$

$$CH_3-CH_2OSO_3H \xrightarrow{\text{heat}} H_2C=CH_2 + H_2SO_4$$

ii) Dehydrohalogenation of Alkyl Halides

On heating, ethyl bromide with alcoholic KOH, ethene is formed. Removal of hydrogen and halogen takes place from adjacent carbon atoms to create a double bond.

$$H_3C-CH_2-Br + KOH_{(\text{alcoholic})} \xrightarrow{\text{heat}} H_2C=CH_2 + KBr + H_2O$$

$$H_3C-CH_2-CH_2-Br + KOH \xrightarrow{\text{Alcohol}} H_3C-CH=CH_2 + KBr + H_2O$$

➲ Physical Properties

i. First three members i.e. ethene, propene and butene are gases at room temperature while C_5 to C_{15} are liquids and the higher members are solids.
ii. They are insoluble in water but soluble in alcohol.
iii. They have characteristic smell and burn with luminous flame.
iv. Unlike alkanes, Alkenes show weakly polar properties because of sp^2 hybridization

☑ QUICK CHECK 11.4

a) Give the reactions of propanol with H_2SO_4, write down all the reaction involved.

Ans.

1. Dehydration to Alkene (Elimination Reaction)

Condition: Conc. H_2SO_4, heat (170 °C)

Reaction: $CH_3CH_2CH_2OH \xrightarrow{H_2SO_4, \Delta} CH_3CH=CH_2 + H_2O$

Propene (alkene)

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2. Formation of Alkyl Hydrogen Sulphate (Addition Reaction)

Condition: Cold conc. H_2SO_4 (0–20 °C)

Reaction: $CH_3CH_2CH_2OH + H_2SO_4 \longrightarrow CH_3CH_2CH_2OSO_3H + H_2O$

Propyl hydrogen sulphate

3. Oxidation:

In presence of oxidizing agents like $K_2Cr_2O_7/H_2SO_4$, propanol is oxidized:

Primary alcohol → Aldehyde → Carboxylic acid

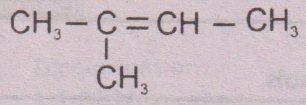
$$CH_3CH_2CH_2OH \xrightarrow{[O]} CH_3CH_2CHO \xrightarrow{[O]} CH_3CH_2COOH$$

Propanal (aldehyde), propanoic acid

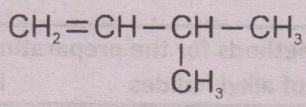
b) Name the following alkenes

i) $CH_3C(CH_3)=CH-CH_3$ **ii)** $CH_2=CHCH(CH_3)_2$

Ans:



2-methyl-2-butene

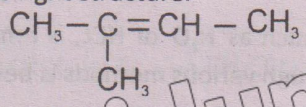


3-methyl-1-butene

c) Draw the structural formulas of the following alkenes.

i) 3-Methyl-2-butene

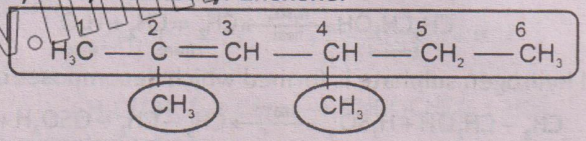
Ans: Correction: 2-Methyl-2-butene is the right structure.



2-methyl-2-butene

ii) 2-Methyl-4-ethyl-2-pentene

Ans. (This is not correct). It may be **2, 4-dimethyl-2hexene.**



2, 4-dimethyl-2-hexene

d) Give the dehydrohalogenation reaction of bromopropane?

Ans. $CH_3-CH_2-CH_2-Br + KOH_{(alcoholic)} \longrightarrow CH_3-CH=CH_2 + KBr + H_2O$

Propene

e) Can propanol undergo dehydration? If yes give reactions involving dehydration.

Ans. $CH_3-CH_2-CH_2-OH \xrightarrow[140-170°C]{75\%H_2SO_4} CH_3-CH=CH_2 + H_2O$

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STRUCTURE AND REACTIVITY OF ALKENES

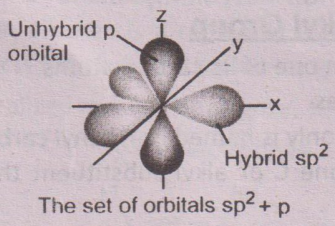
➲ Structure of Alkenes

- Ethene (C_2H_4) is the simplest alkene. Each carbon atom in ethene is **sp^2 hybridized** and forms three equivalent sp^2 hybrid orbitals which lie in the same plane. The unhybrid p orbital lies perpendicular (90°) to the plane of hybrid orbitals shown in Figure.
- These sp^2 orbitals are formed by mixing of the 2s orbital with two 2p orbitals leaving one unhybrid p orbital. In ethene, each carbon uses two sp^2 orbitals to form two C – H bonds each. The remaining sp^2 orbital on each carbon is used to form a carbon-carbon σ bond by linear overlap as in Figure.
- The unhybrid p-orbitals of each carbon atom which are parallel to each other overlap laterally to form another carbon-carbon bond. This bond formed by the lateral overlap of p-orbitals is called a π bond.

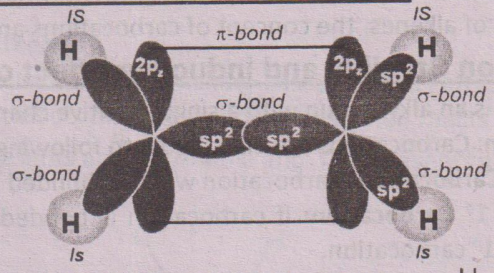
Interesting Information!

Plants produce ethene as a natural ripening hormone. For efficiency harvesting and transportation to market, fruits and vegetables are often picked unripe and exposed to ethene so they could ripen in short time.





The set of orbitals $sp^2 + p$



- The two carbon atoms forming a double bond and the four atoms attached directly to them lie in the same plane. The remaining p-orbital on each carbon is used to form the π bond.
- The sp^2 hybridization results in a trigonal planar arrangement around each carbon atom. The bond angles are approximately 120°, leading to a planar molecule as shown in Figure.

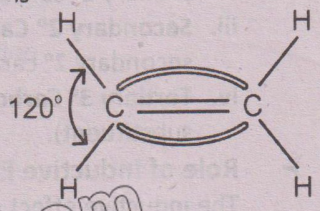


Figure: Structure of ethene

Reactivity of π bond

Comparison of Reactivity of Alkanes and Alkenes: Alkenes are more reactive than alkanes due to the presence of the double bond. The probability of finding electron is away from the line joining the two nuclei. Due to this reason π-electrons are less firmly held between the nuclei. A π bond is, therefore, a weak bond as compared to a σ-bond. During a reaction it breaks comparatively easily rendering alkenes as reactive group of compounds. Moreover, the loosely held π-electrons are more exposed to attack by the electrophilic reagents. Alkenes, therefore, undergo electrophilic addition reactions very easily.

Rack Your Mind!

3. Differentiate between electrophiles and nucleophiles.

Did You Know?

Electrophile is a species that can act as electron pair acceptor, it is represented by E^+. Alkenes act as nucleophile because they contains pi electrons. **Nucleophile** is a species that can act as a donor of a pair of electrons, it is represented by $Nu^{\bullet\bullet}$.

Rack Your Mind!

4. Which of the following is not a nucleophile?

(A) H_2O (B) H_2S
(C) BF_3 (D) NH_3

QUICK CHECK 11.5

a) How does an alkane differ from an alkene in stability?

Ans. Alkanes are more stable than alkenes because:

- Alkanes have only single bonds (σ^- bonds), which are stronger and less reactive.
- Alkenes contain a double bond ($\sigma^+ \pi$ bond), the π bond is weaker and more reactive, making alkenes less stable.

b) Which of the following species is likely to act as a nucleophile? Why?

i) H_2 **ii) H^+** **iii) OH^-**

Ans. iii) OH^-

Explanation:

Nucleophile:

A nucleophile is a species that donates a pair of electrons to form a bond.

OH^- has a lone pair and a negative charge and is a strong nucleophile

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c) **Which of the following species is likely to act as an electrophile?**

i) H_2 ii) H^+ iii) OH^-

Ans. ii) H^+

Explanation:

Electrophiles are electron-deficient species that "accept electrons" (Lewis acids).

H^+ has an empty 1s orbital and strongly attracts electrons.

The reactions of alkenes mostly proceed through the formation of carbocations. Therefore, before studying the addition reactions of alkenes, the concept of carbocations and their stability is very important.

➲ Carbocation Stability and Inductive Effect of Alkyl Group

Carbocation is an alkyl group with a single positive charge on one of its carbon atoms.

Classification: Carbocations are classified into following types.

i. **Methyl Carbocation:** Carbocation which is bonded to H only is named as methyl carbocation.

ii. **Primary 1° Carbocation:** If carbocation is bonded to one C or alkyl substituent then it is named as primary 1° carbocation.

iii. **Secondary 2° Carbocation: If it is bonded to 2 carbons** (alkyl substituent) directly, then it is named as secondary 2° carbocation.

iv. **Tertiary 3° Carbocation:** It is named as tertiary 3° carbocation if it is directly bonded to 3 carbons (alkyl substituent).

➢ Role of Inductive Effect:

The inductive effect of alkyl groups plays an important role in the stability of carbocation. The polarization of a σ bond due to electron withdrawing or electron donating effect of adjacent groups or atoms is referred to as inductive effect.

Electron Donating Inductive Effect: Alkyl groups have a slightly electron donating Inductive effect. Electron donating species, are said to have **positive inductive effect (+I),** whereas electron withdrawing species, such as a halogen atom, have a negative inductive effect (–I).

The alkyl groups attached to the positively charged carbon atoms are electron donating groups. Due to the positive charge on the carbon atom, carbocation is electrophile. The inductive effect is shown by the arrowheads on the bonds to show the alkyl groups pushing electrons towards the positively charged carbon.

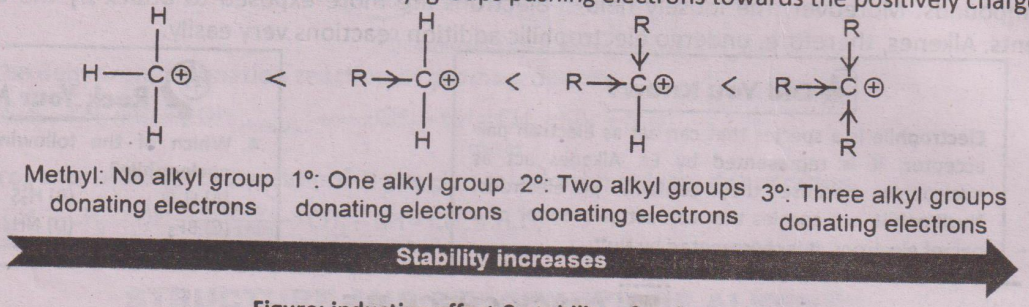


Figure: inductive effect & stability of carbocation

As a result of this, the carbocation become less positively charged which makes it energetically more stable. The stability of carbocation ions increases with a number of alkyl groups due to their +I effect. This means that tertiary carbocation is the most stable as they have three electron-donating alkyl groups which energetically stabilize the carbocation Figure.

➲ Electron withdrawing Inductive Effect

Electron withdrawing groups, such as a halogen atom, have a negative inductive effect (–I). Halogen withdraws bonded electrons from carbon to carbon bond and thus displays negative inductive effect. This causes a permanent dipole to arise in the molecule wherein the halogen atom holds a negative charge and carbon become partial positive Figure.

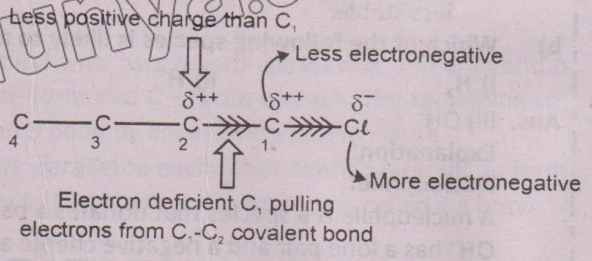


Figure: Inductive effect: Polarization of sigma bond

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REACTIONS OF ALKENES

Alkenes are unsaturated hydrcarbons and they undergo electrophilic addition reactions mostly. Other minor types of reactions include oxidation, combustion and polymerization reactions.

➲ Electrophilic Addition Reactions

The reactions in which an electrophile is added to the double bond of an alkene is called electrophilic addition reaction.

➢ Mechanism of Electrophilic Addition in Alkenes

The C = C in alkenes is a region of high electron density making susceptible to attack by electrophiles. Alkenes reacts with an electrophile to give a carbocation intermediate that then reacts with a nucleophile. In the generalized mechanism Figure, X^+ represents an electrophile and Y^- represents a nucleophile.

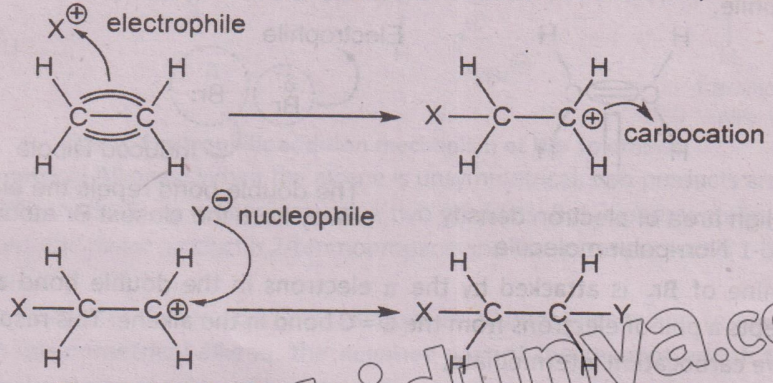


Figure: Generalized mechanism of electrophilic addition

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☑ QUICK CHECK 11.6

a) How do alkenes react with an electrophile?

Ans. Alkenes react with electrophiles through electrophilic addition. The general steps are:

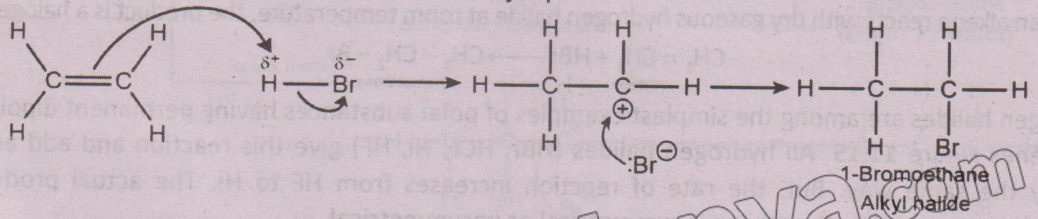
1. **Attack by π-electrons:** The alkene's π-electrons attack the electrophile (E^+), forming a carbocation intermediate.
2. **Nucleophilic attack:** A nucleophile (Nu^-) attacks the carbocation, forming the final product.

Example with HBr:

- **Step 1:** π-electrons attack H^+, forming a carbocation.
- **Step 2:** Br^- attacks the carbocation, yielding a bromoalkane.

Key Points:

- Follows Markovnikov's rule (H adds to the less substituted carbon).
- Carbocation stability determines the major product.



b) Why the order of stability of carbocation is 3° > 2° > 1° ?

Ans. The stability of carbocations follows **3° > 2° > 1°** due to:

1. **Hyperconjugation** – More alkyl groups donate electron density via σ bonds, stabilizing the positive charge.
2. **Inductive Effect** – Alkyl groups are electron-donating (+I effect), dispersing the positive charge.
3. **Resonance (if applicable)** – Delocalization further stabilizes the carbocation.

3° carbocations have the most alkyl groups, providing maximum stabilization, while **1°** has the least.

In this chapter, only the mechanism of halogen addition and hydrogen halide addition will be learnt.

1. Halogenation

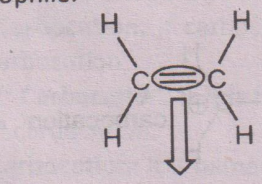
Halogenation means addition of halogens like chlorine or bromine. When bromine water (a solution of bromine in water having red-brown colour) is added to ethene in an inert solvent like carbon tetrachloride, its reddish brown colour is discharged at once. This reaction is used to identify the unsaturation of an organic compound.

$$CH_2 = CH_2 + Br_2 \xrightarrow{C\ell_4} Br - CH_2 - CH_2 - Br$$

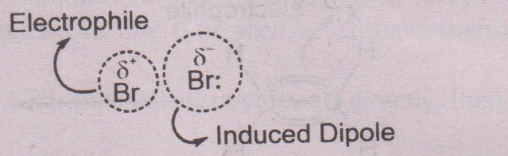
Mechanism:

The above reaction proceeds through a three-steps mechanism as given below:

i) Bromine (Br_2) is a non-polar molecule, however, when a bromine molecule gets closer to the double bond of an alkene, the high electron density in the double bond repels the electron pair in Br – Br away from the Br atom. As a result of this, the Br atom closest to the double bond is slightly positive and acts as an electrophile.



High area of electron density
Non-polar molecule

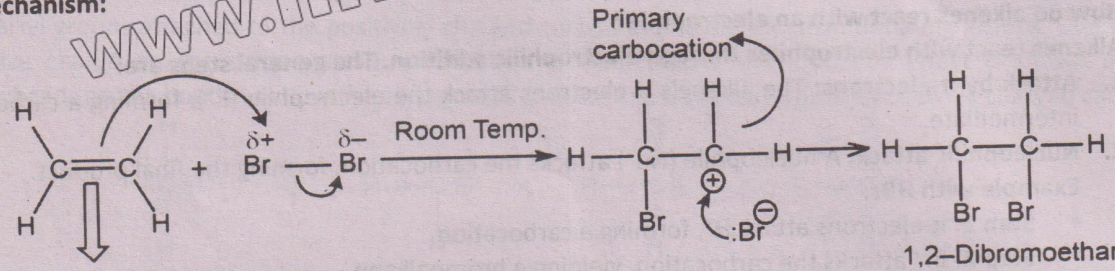


The double bond repels the electrons away from the closest Br atom

ii) The δ^+ bromine of Br_2 is attacked by the π electrons in the double bond and the partial positive bromine accepts a pair of electrons from the C = C bond in the alkene. This results in the formation of a highly reactive carbocation intermediate.

iii) This carbocation intermediate reacts with the Br^- (nucleophile) to make the product. Mechanism is shown below Figure.

Mechanism:



Donates electrons pair to Br^+

1,2–Dibromoethane

Figure: Electrophilic addition mechanism of ethene and Br_2

2. Hydrohalogenation

When an alkene reacts with dry gaseous hydrogen halide at room temperature, the product is a halogenoalkane.

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

Hydrogen halides are among the simplest examples of polar substances having permanent dipoles that add to alkenes Figure 11.15. All hydrogen halides (HBr, HCℓ, HI, HF) give this reaction and add across C = C exactly the same way. But, the rate of reaction increases from HF to HI. The actual product formed depends upon whether the alkene is symmetrical or unsymmetrical.

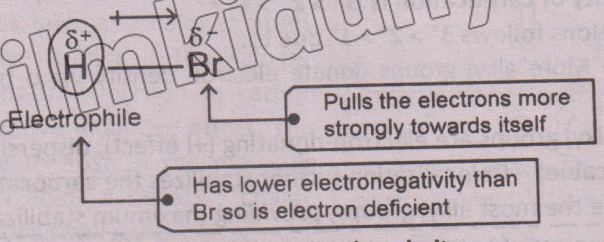


Figure: HBr molecule polarity

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Q. Describe the mechanism of electrophilic addition of hydrogen halides to alkenes. Discuss Markovnikov's Rule in the context of hydrogen halide addition.

i) **Addition to Symmetrical Alkenes:** When the alkene (e.g. ethene) is symmetrical only one product is theoretically possible. Let us look at the mechanism of addition of HBr to ethene.

Mechanism:

i. Nucleophilic pi-bond attacks the hydrogen in hydrogen halide. Hydrogen bromide gives a bromide ion (Br^-). Ethene is converted to carbocation by adding hydrogen to one of the double bonded carbons.

ii. The bromide ion (nucleophile) attacks the carbocation to give the addition product Figure.

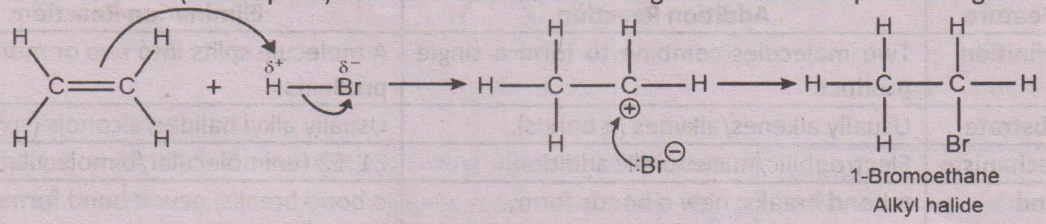


Figure: Electrophilic addition mechanism of HBr to ethene

ii) **Addition to Unsymmetrical Alkenes:** When the alkene is unsymmetrical, two products are theoretically possible. For example, the addition of HBr to propene can give two products. But experimentally, it has been found that under these conditions, the major product is 2-bromopropane and the minor product is 1-bromopropane.

Markovnikov's Rule:

Markovnikov's Rule is applicable for addition reactions in alkenes. According to this rule, "When a polar reagent adds to an unsymmetrical alkene, the negative part of the reagent attach to the double bonded carbon which bears the lesser number of hydrogen."

Mechanism:

Propene reacts with HBr in two ways. The mechanism of this reaction involves the following steps.

i. The pi electrons of C = C attacks on partial positive end of H – Br. Hydrogen bromide breaks heterolytically creating bromide ion (electrophile) and hydrogen is added to double bonded carbon with more number of hydrogen, creating a 2° carbocation.

ii. The bromide ion attacks the secondary carbocation to give the major product. The minor product is formed by the attack on primary carbocation Figure.

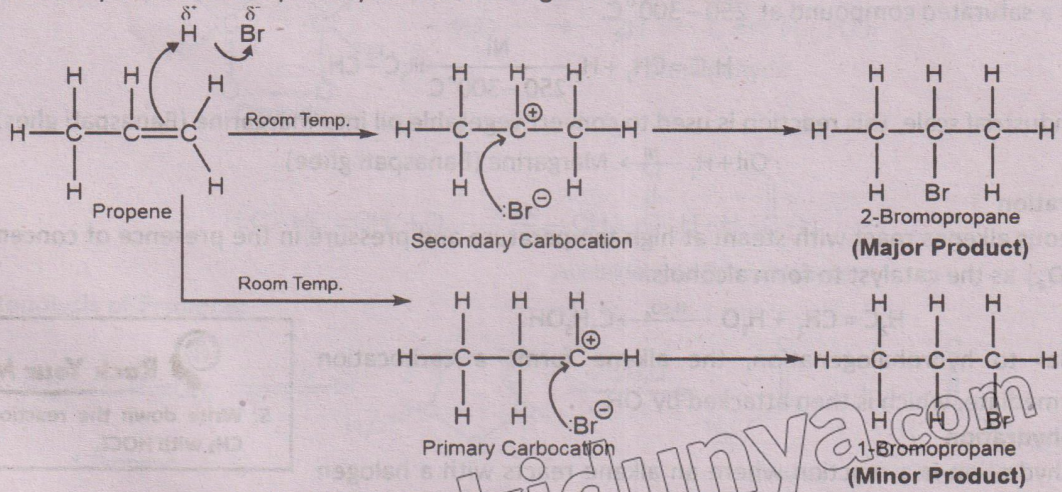


Figure: Electrophilic addition mechanism of HBr to propene

QUICK CHECK 11.7

a) Compare and explain the relative rates of addition to alkenes (reactivities) of HCl, HBr and HI

Ans. Order of Halogen Acid:

The **reactivity order** for addition of hydrogen halides to alkenes is:

$$HI \rangle HBr \rangle HCl$$

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Explanation:

1. **Bond Strength** – The H-X bond strength decreases down the group (HCℓ > HBr > HI), making HI the easiest to break (fastest reaction).
2. **Electrophilicity – Iodine (I)** is less electronegative than Br or Cℓ, so HI is a better proton (H^+) donor, increasing its reactivity.
3. **Carbocation Stability** – The larger halide (I^-) stabilizes the intermediate carbocation better via polarizability, speeding up the reaction.

b) Explain the difference between an addition reaction and an elimination reaction?

Ans.

Feature	Addition Reaction	Elimination Reaction
Definition	Two molecules combine to form a single product.	A molecule splits into two or more products.
Substrate	Usually alkenes/alkynes (π bonds).	Usually alkyl halides/alcohols (sp^3 C–X).
Mechanism	Electrophilic/nucleophilic addition.	E1, E2 (unimolecular/bimolecular).
Bond Changes	π bond breaks; new σ bonds form.	σ bond breaks; new π bond forms.
Reagents	HX, X_2, H_2O (electrophiles/nucleophiles).	Base (OH^-, RO^-) + heat (for E2/E1).
Example	C = C + HBr → C – C – Br	R – CH_2 – CH_2 – Br → C = C + HBr
Product	Saturated (alkane) or functionalized molecule.	Unsaturated (alkene/alkyne) or smaller molecule.

c) How alkene react with an electrophile?

Ans. See Mechanism of Halogenation of Alkenes (a)

d) Explain how Markovnikov's rule is applied in addition of HBr to 2-pentene.

Ans.

$$H_3C-CH_2-CH=CH-CH_3 + H-Br \longrightarrow \underset{\text{2-Bromopentane}}{CH_3-CH_2-CH_2-\overset{\overset{Br}{|}}{CH}-CH_3}$$

3. Hydrogenation

Hydrogenation means addition of molecular hydrogen to an alkene in the presence of a catalyst (Ni/Pt) to form a saturated compound at 250 – 300°C.

$$H_2C=CH_2 + H_2 \xrightarrow[250-300^\circ C]{Ni} H_3C-CH_3$$

On industrial scale, this reaction is used to convert vegetable oil into margarine (Banaspati ghes).

$$Oil + H_2 \xrightarrow{Ni} \text{Margarine (Banaspati ghee)}$$

4. Hydration

Gaseous alkenes react with steam at high temperature and pressure in the presence of concentrated acid (H_2SO_4) as the catalyst to form alcohols.

$$H_2C=CH_2 + H_2O \xrightarrow{H_2SO_4} C_2H_5OH$$

Similar to hydrohalogenation, the alkene forms a carbocation intermediate, which is then attacked by OH^-.

5. Halohydration

Halohydration is a reaction where an alkene reacts with a halogen (such as bromine or chlorine) in the presence of water to form a halohydrin. For ethene (C_2H_4), the reaction specifically produces a bromohydrin or chlorohydrin, depending on the halogen used.

$$H_2C=CH_2 + Br_2 + H_2O \longrightarrow \underset{\text{2-Bromoethanol}}{\overset{OH}{H_2C}-\overset{Br}{CH_2}}$$

Rack Your Mind!

5. Write down the reaction of $H_2C = CH_2$ with HOCℓ.

Rack Your Mind!

6. Write down the reaction of $CH_3 - CH = CH_2$ with HOCℓ.

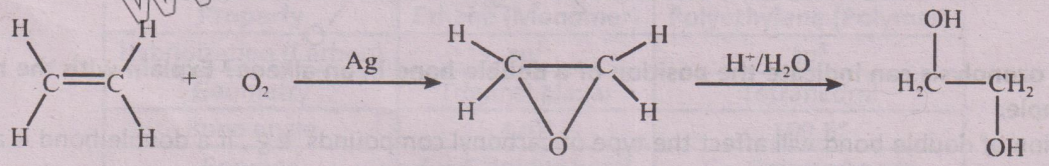
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6. Epoxidation

The epoxidation of alkenes gives an oxygen-containing three-membered cyclic ether called epoxide. In the case of ethene (C_2H_4), this reaction can be accomplished using various oxidizing agents.

Catalyst: Ethene can also be converted to ethylene oxide using molecular oxygen and metal catalysts. A transition metal catalyst facilitates the reaction, forming an epoxide directly from the alkene.

Use: The epoxides can be converted in to diols by acid hydrolysis.



7. Ozonolysis

Ozonolysis is a method of oxidatively cleaving alkenes using ozone (O_3), a reactive allotrope of oxygen. Alkenes react with ozone (O_3) to form ozonides, which can be further reduced to carbonyl compounds (aldehydes or ketones), and ultimately to alcohols.

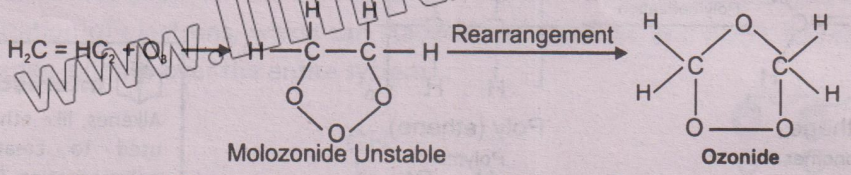
> Ozonolysis is used to detect the position and number of multiple bonds and structure of compounds.

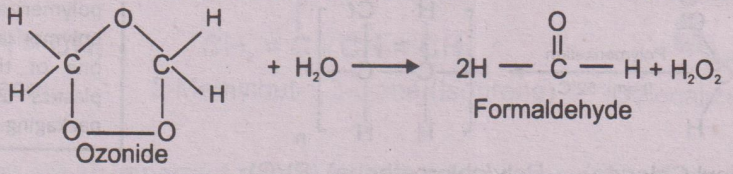
Use: Ozonolysis is often used to identify the structure of unknown alkenes by breaking them down into smaller, more easily identifiable pieces.

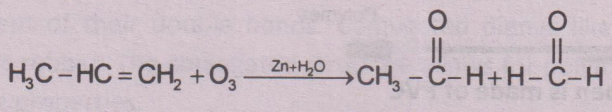
Examples:

(i) Ozonolysis of Ethene: $C_2H_4 + O_3 \longrightarrow C_2H_4O_3 \longrightarrow 2CH_2O$

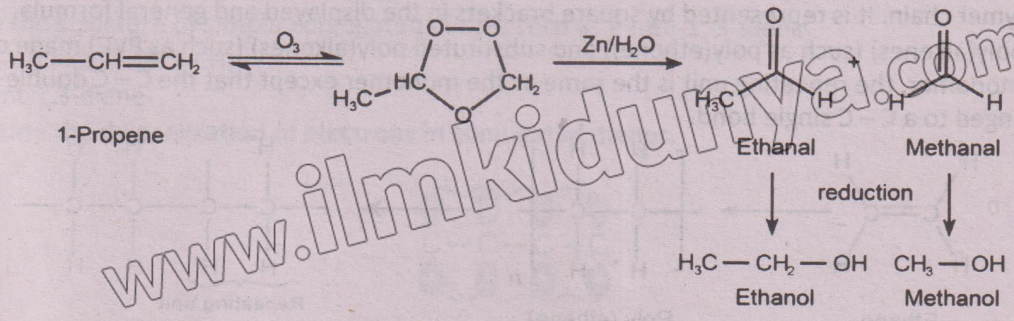
(OR)







(ii) Ozonolysis of Propene:



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QUICK CHECK 11.8

a) Write the equation for the ozonolysis of ethene.

Ans. See Above Point 7 Ozonolysis.

b) Give the epoxidation reaction of 2-Butene.

Ans.

$$CH_3 - CH = CH - CH_3 + \frac{1}{2} O_2 \xrightarrow[300^\circ C]{Ag_2O} CH_3 - \underset{\diagdown\ \diagup}{CH - CH} - CH_3 \quad (O)$$

c) How ozonolysis can indicate the position of a double bond in an alkene? Explain with the help of an example.

Ans. Position of double bond will affect the type of carbonyl compounds. e.g., if a double bond is at the end of alkene chain aldehyde will be formed. e.g., Ozonolysis of 1-butene.

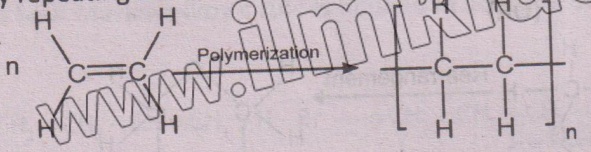
$$CH_3 - CH_2 - CH = CH_2 + O_3 \xrightarrow{Zn/H_2O} CH_3 - CH_2 - \overset{O}{\overset{\|}{C}} - H + H - \overset{O}{\overset{\|}{C}} - H$$

8. Polymerization

Polymerization is the formation of extremely long molecules (polymers) from small reactive molecules that join together (monomers). Addition polymerization is one of the most important addition reactions of alkenes which form the basis of the plastics industry.

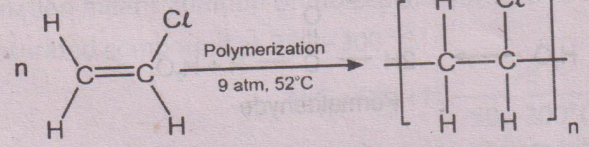
Addition polymerization is the reaction in which many monomers containing at least one C = C double bond form long chains of polymers as the only product.

Just like in other addition reactions of alkenes, the π-bond in each C–C bond breaks and then the monomers link together to form new C–C single bonds. A polymer is a long-chain molecule that is made up of many repeating units.



Ethene
Monomer

Poly (ethene)
Polymer



Chloroethene (Vinyl Chloride)
Monomer

Poly(chloroethene) (PVC)
Polymer



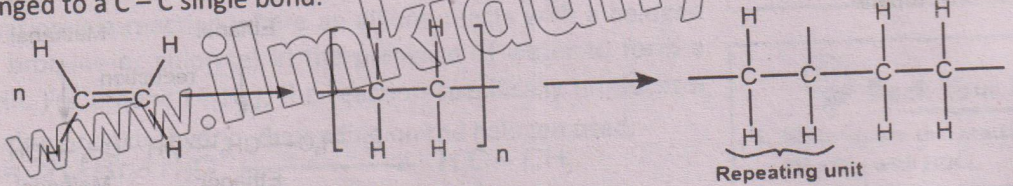
This ball pen is made of PVC

Interesting Information!

Alkenes, like ethene and propene, are used to create plastics through polymerization. Ethene, for instance, is polymerized to make polyethylene, one of the world's most common plastics used in bags, bottles, and packaging.

➢ Deducing Repeating Units

- A repeating unit is the smallest group of atoms that when connected one after the other make up the polymer chain. It is represented by square brackets in the displayed and general formula.
- In poly(alkenes) (such as poly(ethene)) and substituted poly(alkenes) (such as PVC) made of one type of monomer, the repeating unit is the same as the monomer except that the C – C double bond is changed to a C – C single bond.



Ethene
Monomer

Poly (ethene)
Polymer

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QUICK CHECK 11.9

a) Ethene is a monomer used in the polymerization process to create polyethylene.

(i) Discuss how the chemical structure of ethene makes it suitable for polymerization.

Ans. See Above Topic Polymerization of Alkenes (Point 8).

(ii) Discuss the change in hybridization and bond angle during this reaction.

Ans.

Property	Ethene (Monomer)	Polyethylene (Polymer)
Hybridization (Carbon)	sp^2	sp^3
Geometry	Trigonal planar	Tetrahedral
Bond angle	120°	109.5°
Bonding	C = C double bond	C – C single bonds

b) Explain why an addition reaction increases the saturation of a molecule.

Ans. An addition reaction increases the saturation of a molecule because it involves the conversion of multiple bonds (double or triple bonds) into single bonds, allowing more atoms (typically hydrogen or halogens) to attach to the carbon atoms.

Example: Ethene + Hydrogen → Ethane

$$CH_2 = CH_2 + H_2 \rightarrow CH_3 - CH_3$$

CONJUGATED DIENES

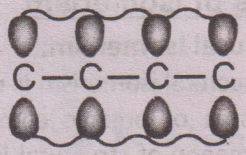
As the name indicates, a diene is a molecule containing two double bonds between carbon atoms. In a Conjugated diene, the double bonds in the carbon chain are separated by a single bond. The adjacent double bonds in conjugated dienes allow for the overlap of p-orbitals on three or more adjacent atoms. This overlap leads to a delocalization of electrons, which can stabilize the molecule and affect its reactivity. In conjugated dienes pi-bond overlap extends over the entire system.

$CH_2 = CH - CH = CH_2$

But-1,3-diene

$CH_2 = C(CH_3) - CH = CH_2$

2-Methylbut-1,3-diene (Isoprene)



Delocalization of pi electrons

➢ **Significance:**

Conjugated alkenes are an important class of compounds in organic chemistry, featuring unique properties due to the arrangement of their double bonds. Conjugated dienes like 1,3-butadiene are used in the production of synthetic rubber. The conjugated structure allows for polymerization, leading to long chains that exhibit rubber-like properties.

QUICK CHECK 11.10

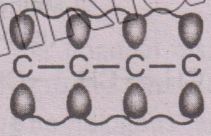
a) Draw the structure of simple conjugated dienes such as Penta-1, 3-diene.

Ans. $H_3C - CH = CH - CH = CH_2$

Pent-1,3-diene

b) Illustrate the delocalization of electrons in conjugated dienes.

Ans.



Delocalization of pi electrons

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ISOMERISM

The concept of isomerism is an important feature of organic compounds.

Definition: Two or more compounds having the same molecular formula but different structural formulas and properties are said to be isomers and the phenomenon is called isomerism.

- The structural formula of a compound shows the arrangement of atoms and bonds present in it.
- The simplest hydrocarbon to have structural isomers is butane (C_4H_{10}). If we study the structural formula of butane or other higher hydrocarbons of the alkane family, we will observe that it is possible to arrange the atoms present in the molecule in more than one way to satisfy all valencies. This means that it is possible to have two or more different arrangements for the same molecular formula.
- **Example:** Chlorobutane molecule has two structural formulas:

$CH_3CH_2CH_2CH_2C\ell$ and $CH_3CHC\ell CH_2CH_3$

1 – Chlorobutane 2 – Chlorobutane

This fact has been supported by an experimental evidence that there are two compounds with different physical properties but with the same molecular formula of $C_4H_9C\ell$. Isomerism is not only possible but common if the compound contains more than three carbon atoms. As the number of carbon atoms in a hydrocarbon increases, the number of possible isomers increase very rapidly. The five carbon compound, pentane, has three isomers.

Tip **Formula to find no. of chain isomers of Alkanes up to carbon no.7 is $2^{nc-4}+1$**

e.g., if nc = 6 (Hexane)

then,

$2^{6-4}+1 = 2^2+1 = 5$

- **For carbon no. 8 (Octane)**

$2^{nc-4}+2 = 2^{8-4}+2 = 2^4+2 = 16+2 = 18$

- **For carbon no. 9 (Nonane)**

$2^{nc-4}+3$

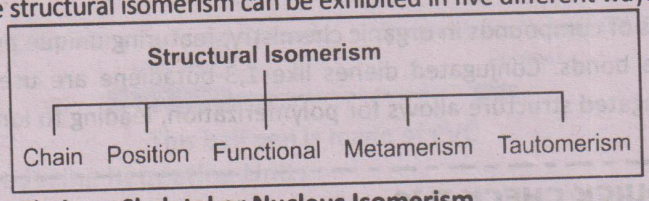
$= 2^{9-4}+3 = 2^5+3$

$= (2\times2\times2\times2\times2)+3 = 32+3 = 35$

➲ Types of Isomerism

A. Structural Isomerism:

The structural isomerism is not confined to hydrocarbons only. In fact, all classes of organic compounds and their derivatives show the phenomenon of structural isomerism. The structural isomerism arises due to the difference in the arrangement of atoms within the molecule. The structural isomerism can be exhibited in five different ways.



Rack Your Mind!

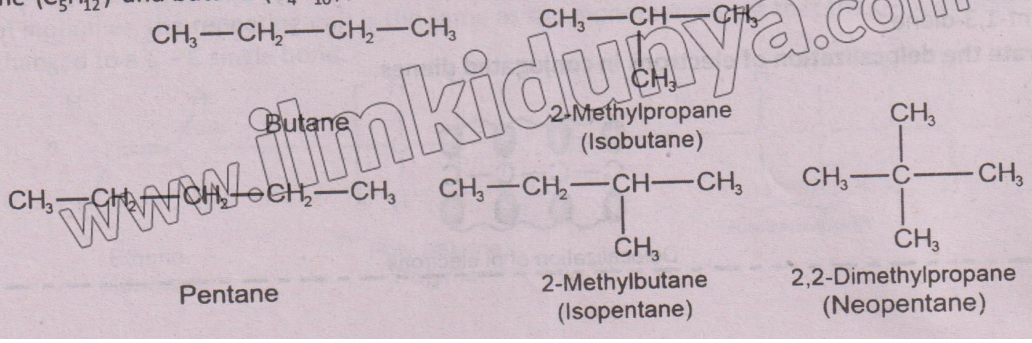
7. Number of isomers of C_4H_{10} is:
(A) 1 (B) 2
(C) 3 (D) 4

Rack Your Mind!

8. Five carbon compound, pentane has number of isomers:
(A) Five (B) Four
(C) Three (D) One

1. The Chain or Skeletal or Nucleus Isomerism

This type of isomerism arises due to the difference in the nature of the carbon chain. For example, for pentane (C_5H_{12}) and butane (C_4H_{10}), the following arrangements are possible.



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Alkanes	No. of Isomers	Alkanes	No. of Isomers
Methane, Ethane, Propane	No. of Isomers	Methane, Ethane, Propane	No. of Isomers
Butane (C_4H_{10})	2	Pentane (C_5H_{12})	3
Hexane (C_6H_{14})	5	Heptane (C_7H_{16})	9
Octane (C_8H_{18})	18	Nonane (C_9H_{20})	35
Decane ($C_{10}H_{22}$)	75	Icosane ($C_{20}H_{42}$)	366319
Triacontane ($C_{30}H_{62}$)	More than 4 billions	Tetracontane ($C_{40}H_{82}$)	625 Trillions

2. Position Isomerism

This type of isomerism arises due to the difference in the position of the same functional group or multiple bonds on the carbon chain. The arrangement of carbon atoms remains the same.

Examples:

C_3H_7Cl

$CH_3 - CH_2 - CH_2 - Cl$ — **1-Chloropropane**

$CH_3 - \underset{\displaystyle Cl}{\underset{|}{CH}} - CH_3$ — **2-Chloropropane**

Pentane and 2-methyl butane have the same percentage composition.

C_3H_7OH

$CH_3 - CH_2 - CH_2 - OH$ — **1-Propanol**

$CH_3 - \underset{\displaystyle OH}{\underset{|}{CH}} - CH_3$ — **2-Propanol**

Ethanal (acetaldehyde) does not show position isomerism.

C_4H_8 $CH_3 - CH_2 - CH = CH_2$ — **1-Butene**; $CH_3 - CH = CH - CH_3$ — **2-Butene**

Rack Your Mind!

9. Write down three position isomers of xylene.

3. Functional Group Isomerism

The compounds having the same molecular formula but different functional groups are said to exhibit functional group isomerism.

Examples

In the following examples, there are two or more compounds having the same molecular formulae but different arrangement of atoms.

C_2H_6O

$CH_3 - O - CH_3$ — **Dimethyl ether**

$CH_3 - CH_2 - OH$ — **Ethyl alcohol**

C_3H_6O

$CH_3 - CH_2 - \overset{\displaystyle O}{\overset{\|}{C}} - H$ — **Propionaldehyde (Propanal)**

$CH_3 - \overset{\displaystyle O}{\overset{\|}{C}} - CH_3$ — **Acetone (Propanone)**

C_3H_8O

$CH_3 - CH_2 - CH_2 - OH$ — **I-Propanol**

$CH_3 - O - CH_2 - CH_3$ — **Methoxy ethane**

Rack Your Mind!

10. Both CH_3COOH and $HCOOCH_3$ show isomerism:

(A) Position (B) Chain

(C) Geometric (D) Functional group

Sr.No.	Formula	Functional Group Isomers
(i)	C_nH_{2n}	Alkene and cycloalkane
(ii)	C_nH_{2n-2}	Alkadiene, Alkyne and cycloalkene
(iii)	$C_nH_{2n+2}O$	Alcohol, ether
(iv)	$C_nH_{2n}O$	Aldehyde, ketone
(v)	$C_nH_{2n}O_2$	Carboxylic Acid, ester
(vi)	$C_6H_{12}O_6$	Glucose (aldohexose), Fructose (Ketohexose)
(vii)	$C_nH_{2n+1}CN$	Cyanides and iso-cyanides e.g., CH_3CN = Ethane nitrile, CH_3NC = Methane isonitrile

4. Metamerism

This type of isomerism arises due to the unequal distribution of carbon atoms on either side of the functional group. Such compounds belong to the same homologous series.

- Such compounds belong to the same homologous series or class of compounds.
- It is due to the presence of different alkyl groups attached to the same polyvalent functional group or atom.

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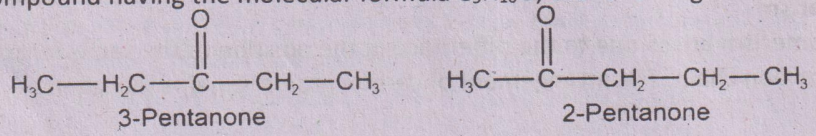
i.e., $-O-$, $-S-$, $-NH-$, $-\overset{O}{\overset{\|}{C}}-$, $-\overset{O}{\overset{\|}{C}}-O-$.

- It is shown by ethers, thioether, ketones, esters, secondary amines, tertiary amines.
- Metamerism is due to the difference in alkyl groups joined with same divalent functional group present in the molecule.
- **Examples:** Diethyl ether and Methoxy methane.

> • Alkenes do not show metamerism.
> • Butanone do not show metamerism.

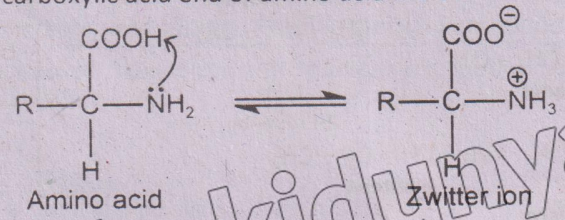
$$\underset{\text{Ethoxy ethane}}{H_3C-H_2C-O-CH_2-CH_3} \qquad \underset{\text{Methoxy propane}}{H_3C-O-CH_2-CH_2-CH_3}$$

For a ketonic compound having the molecular formula $C_5H_{10}O$, the following two metamers are possible.



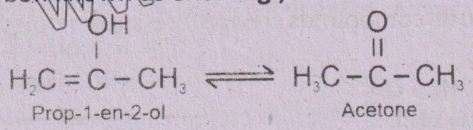
5. Tautomerism

This type of isomerism arises due to shifting of proton (H^+) from one atom to another in the same molecule. This is commonly seen in amino acids. They exist as zwitter ions which are formed when a proton is shifted from the carboxylic acid end of amino acid molecule to the amine group.



➢ **Keto-Enol Isomerism:**

Keto-enol isomerism is exhibited only by such aldehydes and ketones which contain at least one α-hydrogen. Here one isomer has the carbonyl group and the other has an – OH group attached to a doubly bonded carbon known as enol. **E.g.,**



Rack Your Mind!

11. Which type of structural isomerism involves differences in the arrangement of the carbon skeleton?
(A) Chain isomerism
(B) Positional isomerism
(C) Metamerism
(D) Stereoisomerism

B. Stereoisomerism:

Stereoisomers are such compounds which possess the same structural formula, but differ with respect to the positions of the identical groups in space.

There are two types of stereoisomerism:

i. Geometrical or cis trans isomerism
ii. Optical isomerism

Note: It is part of class 12 syllabus and will be covered there.

ORGANIC REDOX REACTIONS

Oxidation-Reduction reactions that involve organic compounds are called organic **redox reactions**. These reactions are characterized by the addition or removal of atoms/bonds. Normally, during organic oxidation, oxygen is added or hydrogen is removed. During organic reduction, hydrogen is added or oxygen is removed. Some examples of oxidation and reduction reactions are given below:

➲ **Oxidation**

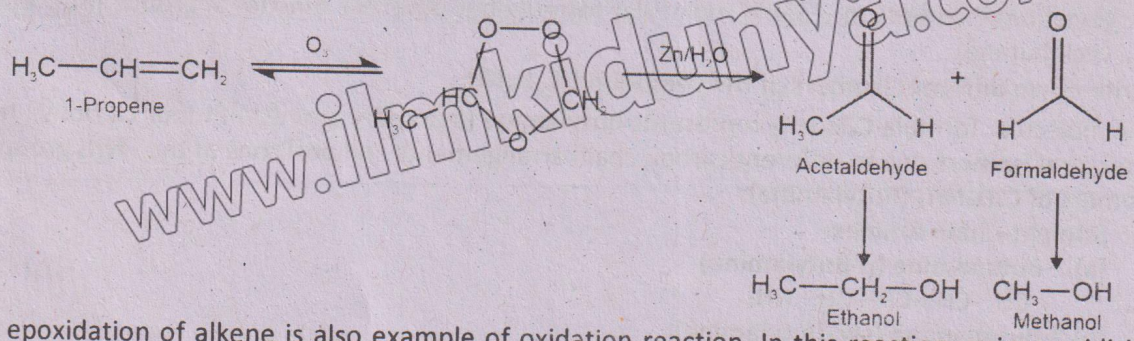
Oxidation of organic compounds involving reaction with oxygen is usually the combustion reaction:

$$2C_2H_6 + 7O_2 \longrightarrow 4CO_2 + 6H_2O$$

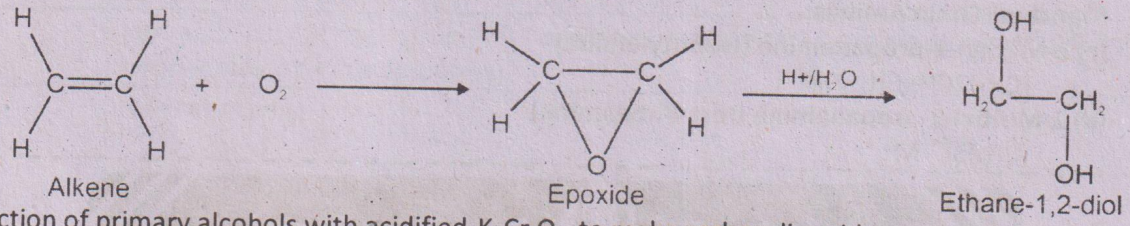
Reactions of organic compounds with oxidizing agents. e.g.,

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i) Ozonolysis is a method of oxidatively cleaving alkenes using ozone (O_3).



ii) The epoxidation of alkene is also example of oxidation reaction. In this reaction various oxidizing agents can be used like molecular oxygen and metal catalysts.

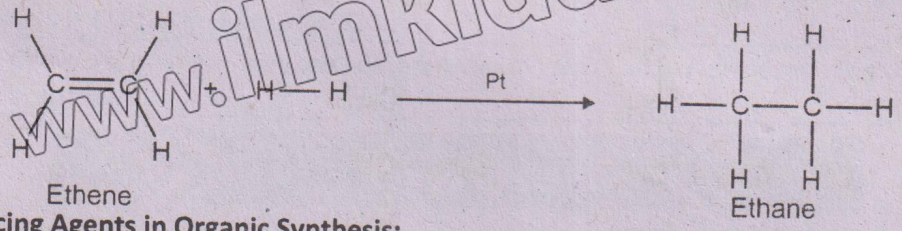


iii) Reaction of primary alcohols with acidified $K_2Cr_2O_7$ to make carboxylic acids,
(**Note:** Detail will be discussed in class 12 syllabus).

$$C_2H_5OH + 2[O] \xrightarrow[H_2SO_4]{K_2Cr_2O_7} CH_3COOH + H_2O$$

➢ **Reduction**

Addition of hydrogen to carbon-carbon double bond to form alkane is an example of organic reduction reaction.



Role of Reducing Agents in Organic Synthesis:

Various reducing agents are used in Organic synthesis. e.g,; $LiA\ell H_4$, $NaBH_4$, .

(**Note:** Reduction of nitriles to amines, amides to amines, carboxylic acid to primary alcohols, nitrobenzene to phenylamine are all examples of reduction and will be studied in class 12 syllabus).

$$CH_3-\overset{\overset{O}{\|}}{C}-H + 2[H] \xrightarrow[\Delta]{LiA\ell H_4} CH_3-CH_2-OH$$

QUICK CHECK 11.11

a) Draw the displayed formula and name an isomer of C_4H_8 that could be an example of positional isomerism?

Ans.

C_4H_8 $CH_3-CH_2-CH=CH_2$ (1-Butene) $CH_3-CH=CH-CH_3$ (2-Butene)

b) What type of isomers are ethoxy methane ether and propanol?

Ans.

C_3H_8O $CH_3-CH_2-O-CH_3$ (Ethoxy Methane (Methoxy ethane)) $CH_3-CH_2-CH_2-OH$ (1–propanol)

c) What are the different types of structural isomerism in alkenes?

Ans. The types of structural isomerism in alkenes are:

1. **Chain Isomerism** – Different carbon skeletons (e.g., 1-butene and 2-methylpropene).

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2. **Position Isomerism** – Double bond at different positions (e.g., 1-butene and 2-butene).
3. **Functional Isomerism** – Same molecular formula but different functional groups (e.g., butene and cyclobutane).

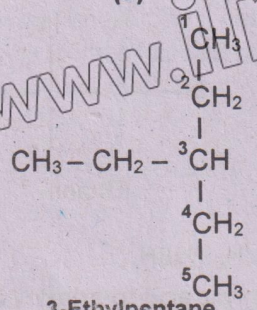
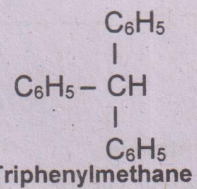
d) Write down different isomers of the compound $C_4H_9NH_2$.

Ans. The molecular formula **$C_4H_9NH_2$** represents **butylamine** (a primary amine with four carbons). It has **four structural isomers** due to different carbon chain arrangements and positions of the **$-NH_2$** group.

Isomers of $C_4H_9NH_2$ (Butylamine):

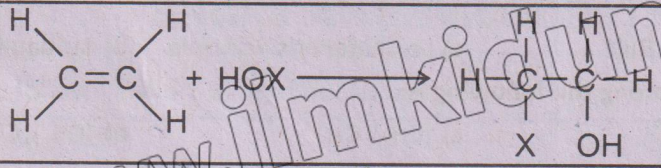
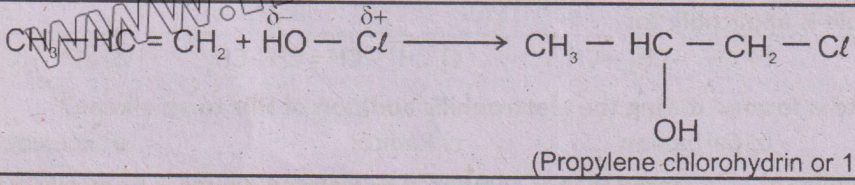
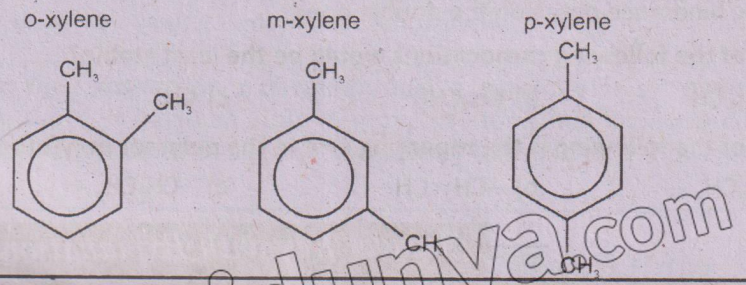
1. **Straight-Chain Amines:**
   - **(a) 1-Butanamine (n-Butylamine)**
     $CH_3–CH_2–CH_2–CH_2–NH_2$
   - **(b) 2-Butanamine (sec-Butylamine)**
     $CH_3–CH_2–CH(NH_2)–CH_3$
2. **Branched-Chain Amines:**
   - **(c) 2-Methyl-1-propanamine (Isobutylamine)**
     $(CH_3)2CH–CH_2–NH_2$
   - **(d) 2-Methyl-2-propanamine (tert-Butylamine)**
     $(CH_3)3C–NH_2$

Solution File — Rack Your Brain!

Sr. #	Option	Explanation
1.	B	Toluene is the common name for methyl benzene, which is a benzene ring with one methyl group attached.
2.	S.Q	**(a)**  3-Ethylpentane **(b)**  Triphenylmethane
3.	S.Q	**Differences between Nucleophile and Electrophile:**

Nucleophile	Electrophile
• Nucleophile means nucleus loving. This is the reagent which seeks for a nucleus. • It has an unshared electron pair available for bonding. • In most cases it is basic in character. • It may be negatively charged or neutral. • Nucleophile is also called Lewis base. **Examples:** • It may be negatively charged **e.g.,** $C_2H_5O^-$ Ethoxide, H_2S^- Hydrogen Sulphide ion, SCN^- Thiocyanate ion, Cl^- Chloride ion, Br^- Bromide ion, I^- Iodine ion, It may be neutral e.g. $H_2\ddot{O}:$, NH_3 • π-electron system $H_2C = CH_2$, $HC \equiv CH$	• It is a specie which attracts electrons (electron loving). • In most cases, it is acidic in character. • The carbon atom of an alkyl group attached with the halogen atom and bearing a partial positive charge is called an electrophile or electrophilic center. • An electrophile may be neutral or positively charged. • Electrophile is also called Lewis acid. **Examples:** • It may be neutral or electron deficient e.g. $AlCl_3$, SO_3, BF_3, • It may be positively charged **e.g.,** NH_4^+, Cl^+, Br^+, NO_2^+, R^+ etc.

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4.	C	BF_3 is not a nucleophile because it is electron–deficient and acts as an electrophile.
5.	S.Q	
6.	S.Q	 (Propylene chlorohydrin or 1-Chloro-2-propanol)
7.	B	C_4H_{10} has two chain isomers, n-butane and iso-butane
8.	C	Pentane has three structural isomers: n-pentane, isopentane (methylbutane), and neopentane (dimethylpropane).
9.	S.Q	**Xylenes (C_8H_{10})** 
10.	D	They have the same molecular formula ($C_2H_4O_2$) but different functinal group: carboxylic acid (–COOH) and ester (–COO–).
11.	A	Chain isomerism involves differences in the carbon skeleton (e.g., straight-chain vs. branched).

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Exercise

MULTIPLE CHOICE QUESTIONS (MCQs)

Q.1 Four choices are given for each question. Select the correct choice.

I. An alkene undergoes ozonolysis followed by reduction with zinc dust and water to yield propanone and methanal. The alkene is:

a) 1-Butene b) 2-Butene c) 2-Methylpropene d) 2-Methyl-2-butene

II. Which of the following reagents is typically used for the acid-catalyzed hydration of alkenes to form alcohols?

a) H_2 / Ni b) O_3 followed by Zn / H_2O

c) Dilute H_2SO_4 d) Br_2 in $CC\ell_4$

III. Halogenation of alkanes is an example of:

a) Electrophilic substitution b) Nucleophilic substitution

c) Free-radical substitution d) Oxidation

IV. Which of the following reactions can an alkane undergo?

a) Addition b) Substitution c) Polymerization d) Nitration

V. What is the first step in the electrophilic addition reaction of alkenes?

a) Formation of a carbocation b) Attack by a nucleophile

c) Attack by an electrophile on the double bond d) Formation of a free radical

VI. **The addition of unsymmetrical reagent to an unsymmetrical alkene is in accordance with the rule/principle?**
a) Markovnikov's Rule b) Hund's Rule c) Le Chatelier's Principle d) Aufbau Principle

VII. **The most stable carbonium ion among the following is:**
a) CH_3^+ b) $CH_3CH_2^+$ c) $(CH_3)_2CH^+$ d) $(CH_3)_3C^+$

VIII. **Markownikov's rule is applicable to:**
a) $CH_2=CH_2$ b) $CH_3-CH_2-CH_3$ c) $CH_3-CH=CH-CH_3$ d) $(CH_3)_2C=CH_2$

IX. **What intermediate is formed during the electrophilic addition of HBr to an alkene?**
a) Carbocation b) Carbanion c) Radical d) Epoxide

X. **The enhanced stability of conjugated dienes compared to isolated dienes is primarily attributed to:**
a) Inductive effects of the double bonds.
b) Increased s-character of the hybridised orbitals.
c) Delocalisation of π electrons across the conjugated system.
d) Steric hindrance between the double bonds.

XI. **Which of the following carbocations would be the least stable?**
a) $(CH_3)_2CH^+$ b) $CH_3CH_2^+$ c) CH_3^+ d) $(CH_3)_3C^+$

XII. **Which of the following is the repeating unit in the polymer poly(ethene) (polyethylene)?**
a) $-CH_2CH_3-$ b) $-CH=CH-$ c) $-CH_2CH_2-$ d) $-CH(CH_3)CH_2-$

Answer Key with Explanations

Sr.No.	Option	Answer	Explanation
I.	c	2-Methylpropene	• Ozonolysis of 2-methylpropene ($(CH_3)_2C=CH_2$) gives propanone (CH_3COCH_3) and methanol (HCHO).
II.	c	Dilute H_2SO_4	• Dilute H_2SO_4 catalyzes the hydration of alkenes to form alcohols.
III.	c	Free-radical substitution	• Halogenation of alkanes (e.g., $CH_4 + Cl_2 \xrightarrow{UV} CH_3Cl$) proceeds via free-radical chain mechanism.
IV.	b	Substitution	• Alkanes undergo substitution (e.g., halogenation) but not addition (no π bonds) or polymerization.
V.	c	Attack by an electrophile on the double bond	• The first step is electrophilic attack (e.g., H^+ in HBr) on the π electrons of the alkene.
VI.	a	Markovnikov's Rule	• Unsymmetrical reagents (e.g., HBr) add to unsymmetrical alkenes such that the H attaches to the less substituted carbon.
VII.	d	$(CH_3)_3C^+$	• Tertiary carbocations (3°) are most stable due to hyperconjugation and inductive effects.
VIII.	d	$(CH_3)_2C=CH_2$	• Markovnikov's rule applies to unsymmetrical alkenes (e.g., $(CH_3)_2C=CH_2$.
IX.	a	Carbocation	• Electrophilic addition of HBr forms a carbocation intermediate (e.g., CH_3CH+CH).
X.	c	Delocalisation of π electrons across the conjugated system	• Conjugated dienes (e.g., buta-1,3-diene) are stabilized by π-electron delocalization over 4+ carbons.
XI.	c	CH_3^+	• Methyl cation (CH_3^+) is least stable (no alkyl groups to stabilize the positive charge).
XII.	c	$-CH_2CH_2-$	• Poly(ethene) is formed by polymerization of ethene ($CH_2=CH_2$), with repeating unit $-CH_2-CH_2-$.

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SHORT ANSWER QUESTIONS

Q.2 Attempt the following short-answer questions:

a. Define the following:
i) Cycloalkanes ii) Isomerism iii) Conjugated dienes iv) Inductive effect

Ans.

(i) Cycloalkanes: Cycloalkanes are saturated hydrocarbons with carbon atoms arranged in a ring structure, containing only single bonds.
General formula: C_nH_{2n}

ii) Isomerism
Two or more compounds having the same molecular formula but different structural formulas and properties are said to be isomers and the phenomenon is called isomerism.

iii) Conjugated dienes
Conjugated dienes are organic compounds that contain two double bonds separated by a single bond. The double bonds are alternating (i.e., conjugated) in the carbon chain.

iv) Inductive effect
The inductive effect refers to the transmission of charge through a chain of atoms in a molecule by the polarization of sigma bonds. It occurs when an atom or group of atoms in a molecule either donates electron density (electron-donating) or withdraws electron density (electron-withdrawing) through the sigma bonds.

b. Differentiate between:
i) Aliphatic and Aromatic hydrocarbons ii) Homolytic and Heterolytic Fission
iii) Electrophile and Nucleophile

Ans.

i) Aliphatic and Aromatic hydrocarbons

Property	Aliphatic Hydrocarbons	Aromatic Hydrocarbons
Structure	Open-chain (straight or branched) or non-aromatic rings	Contain one or more **benzene rings** (aromatic rings)
Bonding	May have single, double, or triple bonds	Contain **delocalized π-electrons** in a ring structure
Stability	Less stable than aromatics	Highly stable due to resonance
Types	Alkanes, alkenes, alkynes, and cycloalkanes	Benzene, toluene, naphthalene, etc.
Reactivity	Generally more reactive	Less reactive toward addition reactions
Examples	Ethane (C_2H_6), Propene (C_3H_6), Butyne (C_4H_6)	Benzene (C_6H_6), Toluene (C_7H_8)

ii) Homolytic and Heterolytic Fission

Feature	Homolytic Fission	Heterolytic Fission
Bond breaking	Bond breaks evenly	Bond breaks unevenly
Electron distribution	Each atom gets one electron	One atom gets both bonding electrons
Produces	**Free radicals**	**Ions (cation and anion)**
Occurs in	Non-polar solvents or under high energy (e.g. UV light)	Polar solvents or in presence of electrophiles/nucleophiles
Example	$Cl–Cl \rightarrow Cl^{\bullet} + Cl^{\bullet}$	$H–Cl \rightarrow H^{+} + Cl^{-}$

iii) Electrophile and Nucleophile

Property	Electrophile	Nucleophile
Definition	Electron-deficient species	Electron-rich species
Electron behavior	Accepts electron pairs	Donates electron pairs
Charge	Often positively charged or neutral	Often negatively charged or neutral
Affinity	Attracted to electron-rich centers	Attracted to electron-deficient centers
Role in reactions	Acts as a Lewis acid	Acts as a Lewis base
Examples	H^+, NO_2^+, $AlCl_3$, BF_3	OH^-, NH_3, Cl^-, CN^-

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c. Explain why alkanes do not undergo addition reactions.

Ans. Alkanes do **not undergo addition reactions** because:

- They are **saturated hydrocarbons**, meaning all carbon-carbon bonds are **single (σ) bonds**.
- These σ-bonds are **strong and stable**, and there are **no regions of high electron density** like double or triple bonds for an electrophile to attack.
- Addition reactions typically occur with **unsaturated compounds** (like alkenes or alkynes), which have **π-bonds** that are more reactive.

In short, Alkanes lack π-bonds, making them chemically inert toward addition reactions and more likely to undergo substitution reactions instead.

d. How elimination reaction is considered the opposite of an addition reaction.

Ans. An elimination reaction is considered the opposite of an addition reaction because:

- In an addition reaction, atoms or groups are added to a molecule, typically converting a double or triple bond into a single bond.
- In an elimination reaction, atoms or groups are removed from a molecule, typically forming a double or triple bond from a single bond.

Alkanes do not undergo elimination reactions under normal conditions because:

- Elimination reactions require a molecule to have a leaving group (like –OH, –Br, –Cℓ) on one carbon and a β-hydrogen (on an adjacent carbon).
- Alkanes consist of only C–C and C–H single bonds and do not have good leaving groups naturally.
- They are also non-polar and chemically stable, making it hard to break bonds without strong reagents or high energy.

In short, Alkanes lack both the leaving groups and reactive centres needed for elimination, so they do not undergo elimination reactions unless first converted to more reactive derivatives (like alkyl halides).

e. Compare the carbocation stability in propene and 2-butene.

Ans.

(i) Propene (CH_3–CH=CH_2)

- If a proton is removed from the double bond, the most likely carbocation formed is the allyl carbocation ($CH_2 = CH–CH_2^+$).
- This allylic carbocation is resonance-stabilized, meaning the positive charge is delocalized over two carbon atoms.
- **Stability:** Relatively stable due to resonance.

(ii) 2-Butene (CH_3–$CH = CH$–CH_3)

- Ionization typically leads to a secondary carbocation ($CH_3–C^+H–CH=CH_3$).
- There is no resonance stabilization unless rearrangement occurs.
- **Stability:** Less stable than the allylic carbocation of propene.

f. Given the molecular formula C_5H_{10}, list all possible structural isomers that are alkenes.

Ans. C_5H_{10} Alkene Isomers:

(i) Pent-1-ene
$CH_2=CH–CH_2–CH_2–CH_3$

(ii) Pent-2-ene
$CH_3–CH=CH–CH_2–CH_3$

(iii) 2-Methylbut-1-ene
$CH_2=C(CH_3)–CH_2–CH_3$

(iv) 3-Methylbut-1-ene
$CH_2=CH–CH(CH_3)–CH_3$

(v) 2-Methylbut-2-ene
$CH_3–C(CH_3)=CH–CH_3$

g. When propene (C_3H_6) undergoes electrophilic addition with HBr, it forms 2-bromopropane as the major product. Explain why 2-bromopropane is favored over 1-bromopropane, using the concept of carbocation stability.

Ans. When propene ($CH_3–CH=CH_2$) reacts with HBr, the reaction proceeds via an electrophilic addition mechanism. The major product is 2-bromopropane, and this can be explained using carbocation stability:

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➢ **Explanation:**

1. **Electrophilic attack:**
   The **π electrons** of the double bond attack the $H^{\delta+}$ from HBr.
   This can lead to two possible carbocations:
   - Path A (less stable): H^+ adds to the CH_2 end, forming a primary carbocation ($CH_3–CH–CH_2^+$)
   - Path B (more stable): H^+ adds to the CH end, forming a secondary carbocation ($CH_3–C^+H–CH_3$)
2. **Carbocation stability:**
   - Primary carbocations are less stable
   - Secondary carbocations are more stable due to hyperconjugation and inductive effects from surrounding alkyl groups
3. **Nucleophilic attack:**
   - Br^- then attacks the more stable secondary carbocation, leading to 2-bromopropane.

Conclusion:

2-bromopropane is the major product because its formation proceeds through a more stable secondary carbocation, following Markovnikov's rule.

h. Explain why conjugated alkenes may show different reactivity compared to isolated alkenes.

Ans. Conjugated alkenes show different reactivity compared to isolated alkenes due to delocalization of π-electrons across alternating double and single bonds.

Aspect	Conjugated Alkenes	Isolated Alkenes
Structure	Alternating double and single bonds.	Double bonds separated by two or more single bonds.
Electron delocalization	π-electrons are **delocalized** across the system.	π-electrons are **localized** between two atoms.
Stability	More stable due to **resonance.**	Less stable.
Reactivity	Can undergo **special reactions** (e.g. 1, 4-addition).	React through **normal electrophilic addition** only.
UV/Visible absorption	Often absorb at **longer wavelengths.**	Less likely to absorb in the visible range.

i. Explain how inductive effects from alkyl groups stabilize carbocations in alkenes.

Ans. Inductive effects from alkyl groups help stabilize carbocations in alkenes by donating electron density through sigma (σ) bonds toward the positively charged carbon.

- Carbocations are electron-deficient species (positively charged carbon).
- Alkyl groups (like $–CH_3$ or $–CH_2CH_3$) have a slight electron-releasing character.
- Through the inductive effect, they push electron density toward the carbocation, reducing its positive charge and making it more stable.

Relative stability of carbocations due to inductive effects:

- **Tertiary carbocation** (3 alkyl groups) → Most stable
- **Secondary carbocation** (2 alkyl groups)
- **Primary carbocation** (1 alkyl group)
- **Methyl carbocation** (no alkyl groups) → Least stable

j. Write the equation for each reaction.

i. $CH_3CH_2CH = CH_2$ **with** H_2 **(Ni catalyst)**

ii. $CH_3CH = CH_2$ **with** $C\ell_2$

iii. $CH_3CH_2CH = CHCH_2CH_3$ **with** $H_2O(H_2SO_4$ **catalyst)**

Ans.

i. $CH_3CH_2CH = CH_2$ **with** H_2 **(Ni catalyst)**

This is a hydrogenation reaction of an alkene.

$$CH_3CH_2CH = CH_2 + H_2 \xrightarrow{Ni} CH_3CH_2CH_2CH_3$$

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ii. **$CH_3CH = CH_2$ with Cl_2**

This is an **electrophilic addition** of chlorine to an alkene.

$$CH_3CH = CH_2 + Cl_2 \longrightarrow CH_3CHClCH_2Cl$$

iii. **$CH_3CH_2CH = CHCH_2CH_3$ with H_2O(H_2SO_4 catalyst)**

It is Hydration of hex-2-ene with H_2O in the presence of H_2SO_4 catalyst

$$CH_3CH_2CH = CHCH_2CH_3 + H_2O \xrightarrow{H_2SO_4} CH_3CH_2CH(OH) - CH_2CH_2CH_3$$

k. Write structural formulas for each of the following compounds.

(i) Isobutylene **(ii) 2,3,4,4-Tetramethyl-2-pentene** **(iii) 2,5-Heptadiene**
(iv) 4,5-Dimethyl-2-hexene **(v) Vinyl acetylene** **(vi) 1,3-Pentadiene**
(vii) 1-Butyne **(viii) 3-n-Propyl-1,4-pentadiene** **(ix) Vinyl bromide**
(x) But-1-en-3-yne **(xi) 4-Methyl-2-pentyne** **(xii) Isopentane**

Ans. Structural Formulae

(i) Isobutylene

$$CH_3 - \underset{\displaystyle CH_3}{\overset{\displaystyle |}{C}} = CH_2$$

(IUPAC Name = 2-Methylpropene)

(ii) 2,3,4,4-Tetramethyl-2-pentene

$$^5CH_3 - \overset{\displaystyle CH_3}{\overset{\displaystyle |}{^4C}} - {}^3C = {}^2C - {}^1CH_3$$
$$\qquad\qquad\quad | \quad | \quad |$$
$$\qquad\qquad\quad CH_3 \; CH_3 \; CH_3$$

(iii) 2,5-Heptadiene

$$^7CH_3 - {}^6CH = {}^5CH - {}^4CH_2 - {}^3CH = {}^2CH - {}^1CH_3$$

(iv) 4,5-Dimethyl-2-hexene

$$^6CH_3 - \underset{\displaystyle CH_3}{\overset{\displaystyle |}{^5CH}} - \underset{\displaystyle CH_3}{\overset{\displaystyle |}{^4CH}} - {}^3CH - {}^2CH - {}^1CH_3$$

(v) Vinyl acetylene

$$H_2C = CH - C \equiv CH$$

(vi) 1,3 – Pentadiene

$$^5CH_3 - {}^4CH = {}^3CH - {}^2CH = {}^1CH_2$$

(vii) 1-Butyne

$$^4CH_3 - {}^3CH_2 - {}^2C \equiv {}^1CH$$

(viii) 3-n-Propyl-1,4-pentadiene

$$^5CH_2 = {}^4CH - \underset{\displaystyle CH_2 - CH_2 - CH_3}{\overset{\displaystyle |}{^3CH}} - {}^2CH = {}^1CH_2$$

(ix) Vinyl bromide

$$H_2C = CH - Br$$

(x) But-1-en-3-yne

$$^1CH_2 = {}^2CH - {}^3C \equiv {}^4CH$$

(xi) 4-Methyl-2-pentyne

$$^5CH_3 - \underset{\displaystyle CH_3}{\overset{\displaystyle |}{^4CH}} - {}^3C \equiv {}^2C - {}^1CH_3$$

(xii) Isopentane

$$^4CH_3 - {}^3CH_2 - \underset{\displaystyle CH_3}{\overset{\displaystyle |}{^2CH}} - {}^1CH_3$$

l. Write down names of the following compounds according to IUPAC-System.

(i) $H_3C - CH = CH(CH_2)_2CH_3$

(ii) $(CH_3)_2C = CH_2$

(iii) $CH_3 - CH_2 - CH_2 - \underset{\displaystyle CH(CH_3)_2}{\overset{\displaystyle |}{C}} = CH_2$

(iv) $CH_2 = CH - CH = CH_2$

(v) $CH_2 = \underset{\displaystyle C_2H_5}{\overset{\displaystyle |}{C}} - CH_2CH_2CH_3$

(vi) $(CH_3CH_2)_3CH$

(vii) $CH_3CH_2C(CH_3)2CH(CH_2CH_3)CH_3$

(viii) $CH_2 = CH - C \equiv C - CH = CH_2$

(ix) $(CH_3)_3C - CH_2 - C(CH_3)_3$

(x) $CH_2 = CH - C \equiv CH$

(xi) $CH_3C(CH_3)_2(CH_2)CH_3$

(a)

$$H_3C - CH_2 - \underset{\displaystyle CH_2 - CH_3}{\overset{\displaystyle |}{CH}} - CH_2 - CH_2 - CH_3$$

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(b)

$(CH_3)_2CH - \underset{\displaystyle CH_3}{\underset{|}{CH}} - CH(CH_3)_2$

(c)

$H_3C - CH_2 - CH_2 - \underset{\displaystyle CH_3}{\overset{\displaystyle CH_3}{\overset{|}{\underset{|}{CH}}}}$

Ans. IUPAC Names

(i) $H_3C^1 - {}^2CH = {}^3CH - {}^4CH_2 - {}^5CH_2 - {}^6CH_3$

2-Hexene

(ii)

$CH_3 - \underset{\displaystyle CH_3}{\underset{|}{C}} = CH_2$

2-Methylpropene

(iii)

$^5CH_3 - {}^4CH_2 - {}^3CH_2 - {}^2C = {}^1CH_2$

$CH_3 - HC - CH_3$

2-Isopropyl-1-pentene

(iv) $CH_2 = CH - CH = CH_2$

1,3 – Butadiene

(v) $^1CH_2 = {}^2C - {}^3CH_2 {}^4CH_2 {}^5CH_3$

C_2H_5

2-Ethyl-1-pentene

(vi)

$CH_3 - CH_2 - CH(CH_3) - CH_2 - CH_3$

3-Ethylpentane

(vii)

$H_3C - CH_2 - C(CH_3)_2 - CH(CH_3) - CH_2 - CH_3$

3,3,4-Trimethylhexane

(viii) $^1CH_2 = {}^2CH - {}^3C \equiv {}^4C - {}^5CH = {}^6CH_2$

1,5-Hexadien-3-yne

(ix)

$H_3C - C(CH_3)_2 - CH_2 - C(CH_3)_2 - CH_3$

2,2,4,4 - tetramethylPentane

(x) $^1CH_2 = {}^2CH - {}^3C \equiv {}^4CH$

1-Buten-3-yne

(xi)

$H_3C - C(CH_3)_2 - CH_2 - CH_3$

2,2 - dimethylbutane

(a)

$H_3{}^1C - {}^2CH_2 - {}^3CH - {}^4CH_2 - {}^5CH_2 - {}^6CH_3$

$CH_2 - CH_3$

3-etthylhexane

(b)

$^1CH_3 - {}^2CH - {}^3CH - {}^4CH - {}^5CH_3$

$CH_3 \quad CH_3 \quad CH_3$

2, 3, 4 - trimethylpentane

(c)

$H_3{}^5C - {}^4CH_2 - {}^3CH_2 - {}^2CH - {}^1CH_3$

CH_3

2-MethylPentane

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DESCRIPTIVE QUESTIONS

Q.3 Describe the free radical halogenation of methane using Cl_2 as an example.

Ans. See Page No. (385)

Q.4 Describe the following methods for the preparation of alkenes:
i) Dehydrohalogenation of alkyl halides ii) Dehydration of alcohols

Ans. See Page No. (389)

Q.5 Describe the mechanism of electrophilic addition of hydrogen halides to alkenes. Discuss Markovnikov's Rule in the context of hydrogen halide addition.

Ans. See Page No. (395)

Q.6 Explain the following reactions of alkenes with examples:
a) Halogenation b) Ozonolysis c) Epoxidation d) Polymerization

Ans. See Reactions of Alkenes (Point No. 1, 7, 6, 8) in theory.

ADDITIONAL SLOs BASED MCQs

1. The most likely reaction alkanes undergo is:
A. electrophilic addition
B. free radical substitution
C. nucleophilic addition
D. electrophilic substitution

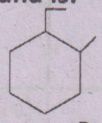
2. The condensed structural formula of the major product obtained by hydrobromination of 2-methylpent-2-ene is:
A. $CH_3CH(Br)CH(CH_3)CH_2CH_3$
B. $(CH_3)_2C(Br)(CH_2)_2CH_3$
C. $(CH_3)_2CHCH(Br)CH_2CH_3$
D. $CH_2(Br)CH(CH_3)(CH_2)_2CH_3$

3. Which one of the following is a possible propagation step in chlorination of ethane?
A. $C_2H_6 + Cl \rightarrow C_2H_5Cl + H$
B. $C_2H_5Cl + Cl \rightarrow C_2H_4Cl + HCl$
C. $C_2H_5 + Cl \rightarrow C_2H_5Cl$
D. $C_2H_4Cl_2 + Cl \rightarrow C_2H_4Cl + Cl_2$

4. Which one of the following is the most stable (least reactive) hydrocarbon?
A. hex-1-ene B. propene C. penta-1,2-diene D. hepta-1,3,5-triene

5. The most striking factor held responsible for the less reactivity of alkanes is:
I. their non-polar bonds
II. absence of functional group
III. their strong sigma (δ) bonds
IV. Long C – C bond lengths
A. I &II only B. II & III only C. I, II & III only D. III & IV only

6. The systematic name of the following compound is:



A. 2-ethylmethylcyclohexane
B. 2-methyethylcyclohexane
C. 1-ethylmethylcyclohexane
D. 1-ethyl-2-methylcyclohexane

7. Dehydration of propan-1-ol gives:
A. propene B. propane C. propanone D. propanal

8. Which one of the following compounds can show geometric isomerism?
A. 2,2-dimethylbut-2-ene B. 2-methylhex-1-ene C. hex-3-ene D. 2-methylpropene

9. A racemic mixture must contain:
A. 90 levorotatory isomers
B. equimolar quantities of levorotatory and dextrorotatory isomers
C. meso isomers and levorotatory isomers
D. 80 dextrorotatory and 20% levorotatory isomers

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10. **Which set of compounds are consecutive members of same homologous series?**
A. CH_3OH, CH_3CHO, HCHO
B. CH_3COOH, C_2H_5COOH, C_3H_7COOH
C. CH_4, CH_2Cl, CH_2Cl_2
D. C_2H_2, C_2H_4, C_2H_6

11. **The molecule of ethane possesses which hybridization;**
A. sp^3 B. sp^2 C. sp D. sp^2d

12. **The sp^2 hybrid orbitals are oriented in space at one angle;**
A. 109.5° B. 180° C. 100° D. 120°

13. **The geometry of acetylene is:**
A. angular B. bent C. trigonal D. linear

14. **Which reaction is used as test for the presence of alkene;**
A. reaction of cold diluted alkaline $KMnO_4$
B. combustion
C. polymerization
D. catalytic hydrogenation

15. **The general formula of alkane is;**
A. C_nH_{2n+2} B. C_nH_n C. C_nH_{2n} D. C_nH_{2n-2}

Answer Key with Explanations

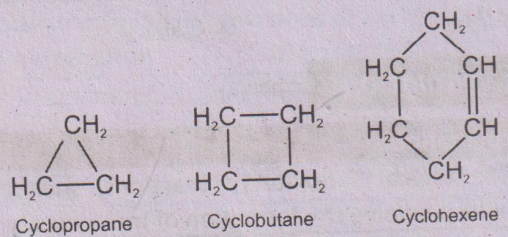
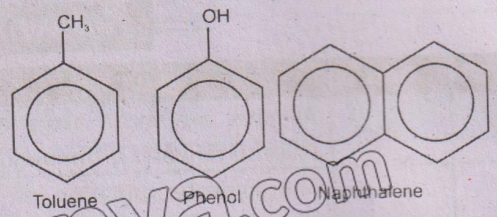
Sr. #	Ans.	Explanations
1.	B	Alkanes are most likely to undergo free radical substitution reactions, such as the chlorination and bromination of alkanes, which involve the formation of free radicals.
2.	C	The hydrobromination of 2-methylpent-2-ene follows Markownikov's rule, where the bromine atom attaches to the more substituted carbon atom, resulting in 3-bromo-2-methylpentane.
3.	C	During the chlorination of ethane, a propagation step involves the ethyl radical (C_2H_5) reacting with a chlorine atom to form chloroethane (C_2H_5Cl).
4.	B	Stability decreases with increasing number of double bonds and conjugation. Propene, with a single double bond, is more stable than dienes or trienes.
5.	C	Alkanes are less reactive due to their non-polar bonds, absence of functional groups, and strong sigma bonds.
6.	D	The correct IUPAC name indicates the substituents' positions and follows the alphabetical order of naming.
7.	A	Dehydration of propan-1-ol results in the formation of propene through the elimination of water.
8.	C	Geometric isomerism (cis-trans) can occur in compounds with double bonds that have different substituents on each carbon of the double bond. Hex-3-ene fits this criterion.
9.	B	A racemic mixture contains equal amounts of both enantiomers, which cancel out each other's optical activity.
10.	B	These compounds are carboxylic acids and differ by a CH_2 unit, fitting the definition of a homologous series.
11.	A	In ethane, there is C – C so each carbon is sp^3 hybridized.
12.	D	Angle b/w each orbital is 120º.
13.	D	
14.	A	When alkenes are treated with mild oxidizing reagents like dilute (1%) alkaline $KMnO_4$ solution (Baeyer's Reagent) at low temperature, hydroxylation of double bond occurs resulting in the formation of dihydroxy compounds known as vicinal glycols. The pink colour of $KMnO_4$ solution is discharged during the reaction.
15.	A	The general formula of alkane is C_nH_{2n+2}.

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ADDITIONAL SHORT ANSWER QUESTIONS

Q.1 Differentiate between Alicyclic and Aromatic compounds.

Ans.

Alicyclic Compounds	Aromatic Compounds
• The homocyclic compounds which contain ring of three or more carbon atoms and resembling the aliphatic compounds are called alicyclic compounds.	• The homocyclic compounds which contain atleast one benzene ring are called aromatic compounds.
• They may be saturated or unsaturated.	• They may contain one or more benzene rings.
• They have low percentage of carbon.	• They have high percentage of carbon.
Examples: 	**Examples:** 

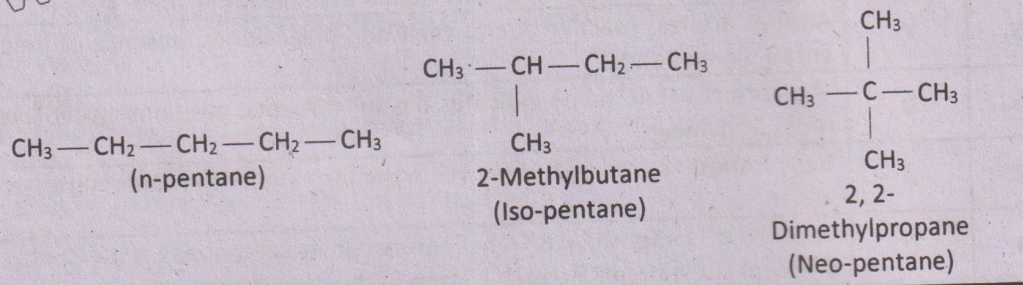
Q.2 Define the term isomerism. Give examples.

Ans. Isomerism:

"Two or more compounds having the same molecular formula but different structural formulas and properties are said to be isomers and the phenomenon is called isomerism."

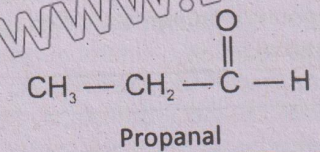
Examples:

C_5H_{12}:



Q.3 How functional group isomerism differs from metamerism? Give examples.

Ans.

Functional Group Isomerism	Metamerism
• The compounds having the same molecular formula but different functional groups are said to exhibit functional group isomerism.	• This type of isomerism arises due to the unequal distribution of carbon atoms on either side of the functional group.
• Such compounds belong to different homologous series.	• Such compounds belong to the same homologous series.
Examples: **C_3H_6O:**  Propanal	**Example:** **$C_4H_{10}O$:** $CH_3 - CH_2 - O - CH_2 - CH_3$ Diethyl ether $CH_3-O-CH_2-CH_2-CH_3$ Methyl–n–propyl ether

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C_3H_8O:	$C_5H_{10}O$:
$CH_3-\overset{\overset{O}{\|}}{C}-CH_3$ Propanone $CH_3CH_2-CH_2-OH$ 1-Propanol $CH_3-O-CH_2-CH_3$ Methoxy Ethane	$CH_3-CH_2-\overset{\overset{O}{\|}}{C}-CH_2-CH_3$ Diethyl ketone (Pentan-3-one) $CH_3-\overset{\overset{O}{\|}}{C}-CH_2-CH_2-CH_3$ Methyl–n–propyl ketone (Pentan-2-one)

Q.4 Define Tautomerism with an example.

Ans. Tautomerism:

This type of isomerism arises due to shifting of proton (H^+) from one atom to other in the same molecule.

Examples:

$$R-\underset{\underset{H}{|}}{\overset{\overset{COOH}{|}}{C}}-NH_2 \rightleftharpoons R-\underset{\underset{H}{|}}{\overset{\overset{COO^-}{|}}{C}}-\overset{+}{N}H_3$$

Amino acid ⇌ Zwitter ion

$$CH_3-\overset{\overset{O}{\|}}{C}-H \rightleftharpoons CH_2=\overset{\overset{OH}{|}}{C}-H$$

Acetaldehyde ⇌ Vinylalcohol

Q.5 Justify that in alkanes sigma bonds are inert.

Ans. Inertness of σ-bond:

In a σ–bond, the electrons are very tightly held between the two nuclei which makes it a very stable bond. A lot of energy is required to break it. Moreover, the electrons present in a σ–bond can neither attack on any electrophile nor a nucleophile can attack on them. Due to the inertness of σ–bonds, alkanes are unreactive.

Q.6 Why alkanes are called paraffins?

Ans. Alkanes are Paraffins:

The word "paraffins" is derived from Latin words 'parum' = little, 'affins' = affinity. Alkanes are called paraffins due to:

(i) Non-polar Nature:

The electronegativity values of carbon **(2.5)** and hydrogen **(2.1)** do not differ appreciably and the bonding electrons between C – H and C – C are equally shared making them almost non-polar. In view of this, the ionic reagents such as acids, alkalies, oxidizing agents, etc. find no reaction site in the alkane molecules to which they could be attached.

(ii) Inertness of σ-bond:

In a σ–bond, the electrons are very tightly held between the nuclei which makes it a very stable bond. A lot of energy is required to break it. Moreover, the electrons present in a σ–bond can neither attack on any electrophile nor a nucleophile can attack on them.

Q.7 Differentiate between hydrogenolysis and hydrogenation.

Ans.

Hydrogenolysis	Hydrogenation
1. The addition of hydrogen accompanied by bond cleavage is called hydrogenolysis."	1. The addition of hydrogen to an unsaturated compound in the presence of a catalyst is called hydrogenation."
2. It is carried out in Pd-charcoal cavity.	2. It is carried out in the presence of Ni, Pt or Pd etc.
Examples: (i) $R-X+H-H \xrightarrow[\Delta]{Pd-Charcoal} R-H+HX$ Alkane (ii) $CH_3-Cl+H-H \xrightarrow[\Delta]{Pd-Charcoal} CH_4+HCl$	**Examples:** (i) $CH_2=CH_2+H_2 \xrightarrow[200°C]{Ni} CH_3-CH_3$ Ethene → Ethane (ii) Vegetable oil $+H_2 \xrightarrow[200°C]{Ni}$ vegetable Ghee

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Q.8 Give general mechanism of electrophilic addition reactions of alkene.

Ans. General Mechanism of Electrophilic Addition Reactions of Alkene:

It involves three steps:

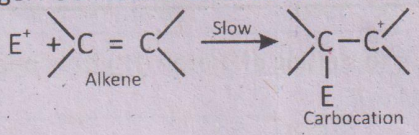
Step 1: To Generate Electrophile:

The reagent E – Nu ionizes to give an electrophile and nucleophile.

$$E - Nu \longrightarrow E^+ + :Nu^-$$

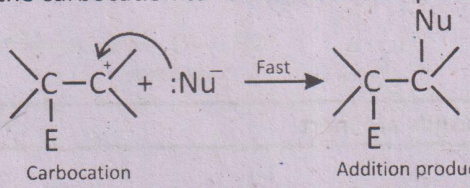
Step 2: Attack of Electrophile and Formation of Carbocation:

The electrophile attacks the carbon – carbon double bond and forms a covalent bond with one carbon and other carbon bears positive charge. As a result a carbocation is formed.



Step 3: Attack of Nucleophile:

The nucleophile now attacks the carbocation to form an addition product.



Since the reaction is initiated by addition of electrophile, so it is called electrophilic addition reaction.

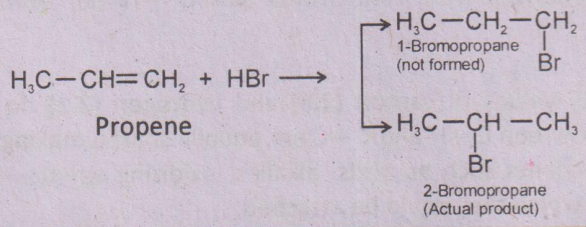
Q.9 What is Markownikov's rule? Give example also.

Ans. Markownikov's Rule:

Statement:

"In the addition of an unsymmetrical reagent to an unsymmetrical alkene, the negative part of the adding reagent goes to that carbon, constituting the double bond, which has least number of hydrogen atoms."

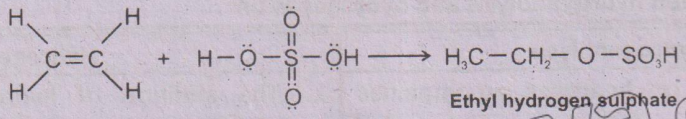
Example:



Q.10 How would you convert ethene into ethyl alcohol?

Ans. Conversion of Ethene into Ethyl Alcohol:

When ethene is treated with cold concentrated sulphuric acid (H_2SO_4), it is dissolved because it forms ethyl hydrogen sulphate.



The ethyl hydrogen sulphate on boiling with water decomposes to give ethyl alcohol.

$$H_3C - CH_2 - O - SO_3H + H_2O \xrightarrow{100^\circ C} H_3C - CH_2 - OH + H_2SO_4$$

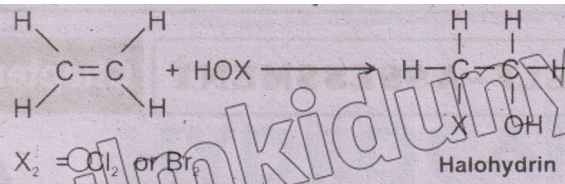
Q.11 Convert ethene to (a) Halohydrin (b) Ethylene oxide

Ans. (a) Ethene to Halohydrin:

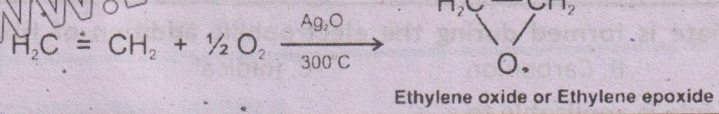
If the halogenation of an alkene is carried out in an aqueous solution, haloalcohol is formed called a Halohydrin.In this reaction, molecules of the solvent become reactants too.

$$X_2 + H_2O \longrightarrow HOX + HX$$

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(b) Ethene to Ethylene Oxide:



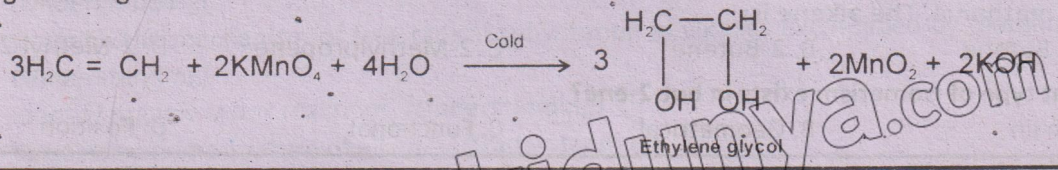
Q.12 How Ethylene Glycol is prepared from ethene?

Ans. Baeyer's Test:

- Dilute 1% alkaline $KMnO_4$ solution is called Baeyer's reagent.
- It is pink in colour and acts as mild oxidizing agent.
- Baeyer's reagent is used to test the presence of unsaturation in the molecules.

Reaction:

When alkenes are treated with Baeyer's reagent at low temperature, hydroxylation of double bond occurs resulting in the formation of dihydroxy compounds known as vicinal glycols. The pink colour of $KMnO_4$ is discharged during the reaction.



Q.13 What is ozonolysis? Describe it giving example. Also give its mechanism.

Ans. Ozonolysis:

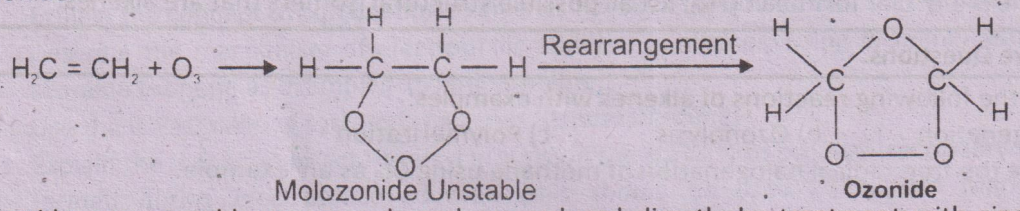
"The cleavage of an unsaturated molecule by reacting with ozone is called ozonolysis."

Ozone (O_3) is a highly reactive allotropic form of oxygen. It reacts vigorously with ethene (or other alkenes) to form formaldehyde (or other **carbonyl compounds.)**

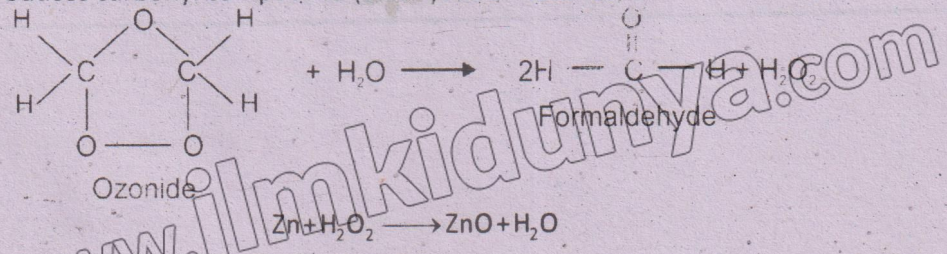
$$CH_2 = CH_2 + O_3 \xrightarrow{Zn} 2HCHO$$

Mechanism:

(i). Ozone reacts with ethene to form molozonide. Molozonoide rearranges spontaneously to form an ozonide.



(ii) Ozonides are unstable compounds and are reduced directly by treatment with zinc and H_2O. The reduction produces carbonyl compounds (aldehydes or ketones).



$$Zn + H_2O_2 \longrightarrow ZnO + H_2O$$

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SELF-ASSESSMENT Chapter # 11

Total Mark: 30 $\frac{27}{27}$

Q.1 Encircle the correct option. (1 × 6 = 6)

(i) **What intermediate is formed during the electrophilic addition of HBr to an alkene?**
A. Carbocation B. Carbanion C. Radical D. Epoxide

(ii) **Markownikov's rule is applicable to :**
A. $CH_2 = CH_2$ B. $CH_3 - CH_2 - CH_3$ C. $CH_3 - CH = CH - CH_3$ D. $(CH_3)_2 - C = CH_2$

(iii) **Which of the following reagents is typically used for the acid-catalyzed hydration of alkenes to form alcohols?**
A. H_2/Ni B. O_3 followed by Zn/H_2O C. Dilute H_2SO_4 D. Br_2 in $CC\ell_4$

(iv) **Alkanes are generally unreactive toward polar reagents because:**
A. They have double bonds B. They are aromatic
C. Their bonds are non-polar D. They are ionic

(v) **An alkene undergoes ozonolysis followed by reduction with zinc dust and water to yield propanone and methanal. The alkene is:**
A. 1-Butene B. 2-Butene C. 2-Methylpropene D. 2-Methyl-2-butene

(vi) **What type of isomerism exists in but-2-ene?**
A. Chain B. Geometrical C. Functional D. Position

Q.2 Write short answers of the following questions. (2 × 8 = 16)

(i) Differentiate between aliphatic and aromatic hydrocarbons with one example each.
(ii) Write the IUPAC name of the following:
a) $CH_2 = CH - CH = CH_2$ b) $CH \equiv C - CH = CH - C \equiv CH$
(iii) Why do branched alkanes have lower boiling points than the straight-chain alkanes?
(iv) What is homolytic and heterolytic bond fission?
(v) Why the order of stability of carbocation is $3^\circ > 2^\circ > 1^\circ$?
(vi) Write down the structural formulas for 2-methylbutane and 2, 2-dimethylpropane.
(vii) Give the dehydrohalogenation reaction of bromopropane?
(viii) Given the molecular formula C_5H_{10}, list all possible structural isomers that are alkenes.

Q.3 Extensive Questions. (2 × 4 = 8)

(a) Explain the following reactions of alkenes with examples:
a) Halogenation b) Ozonolysis c) Polymerization
(b) Describe the free radical halogenation of methane using $C\ell_2$ as an example.

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