

Hydrocarbons

25.1 INTRODUCTION

We are familiar with the use of petroleum compounds and compounds obtained from coal and coaltar like petrol, kerosene oil, lubricating oil, vaseline, paraffin wax, benzene, toluene etc. in our daily life. All these compounds are organic compounds and contain carbon and hydrogen. Being a student of Chemistry you will be curious to know about the systematic method of naming these compounds. In this unit, you will be provided with the definition of the compounds containing carbon and hydrogen (hydrocarbons). Their classification, types and nomenclature will also be explained so that you can name them systematically through a system accepted all over the world.

25.2 OBJECTIVES

After reading this lesson, you will be able to:

- define hydrocarbons
- classify hydrocarbons as acyclic and cyclic
- name hydrocarbons using IUPAC system of nomenclature
- write the structures of hydrocarbons using the given IUPAC names.

25.3 HYDROCARBONS

Carbon forms a large number of compounds with hydrogen. These compounds containing carbon and hydrogen are known as hydrocarbons. The important sources of these compounds are petroleum, natural gas and coal. These compounds are considered to be the parent compounds since other organic compounds are supposed to be derived from them by replacing one or more hydrogen atoms by other substituents.

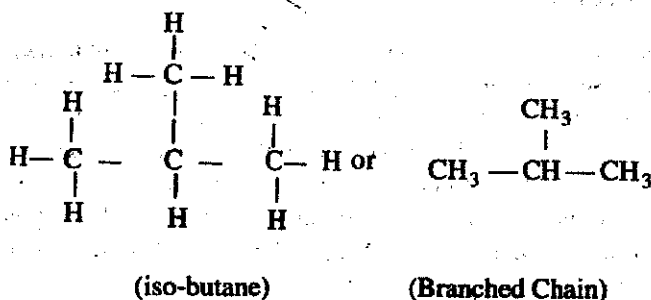
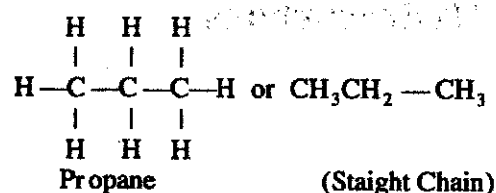
The compounds which are made up of only carbon and hydrogen are known as hydrocarbons.

25.3.1 Types of Hydrocarbons

Hydrocarbons contain carbon atoms which are joined to each other. These carbon atoms have ability to form long chain by joining with other carbon atoms. Depending upon the nature of carbon atom chains, hydrocarbons can be divided into two main classes i.e.

- (i) *Open chain or Acyclic or Aliphatic Hydrocarbons*
- (ii) *Closed chain or Cyclic or Carbocyclic hydrocarbons.*

(i) **Open chain hydrocarbons** : In this type of hydrocarbons, the carbon atoms are arranged in open chain. This chain may be straight or branched, but not closed, These hydrocarbons are also called acyclic. Let us take some examples



These open chain hydrocarbons are also called aliphatic hydrocarbons.

Aliphatic hydrocarbons are further divided into three types i.e. alkanes, alkenes and alkynes.

(a) **Alkanes** are saturated hydrocarbons. They contain only carbon and carbon-hydrogen single bond.g. CH_4 and C_2H_6 .

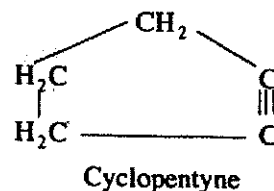
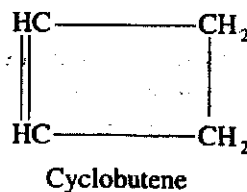
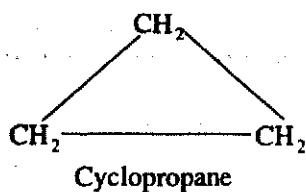
(b) **Alkenes** are unsaturated hydrocarbons. They contain at least one carbon carbon double bond e.g. Ethene ($\text{CH}_2 = \text{CH}_2$)

(c) **Alkynes** are also unsaturated hydrocarbons. They contain at least one carbon-carbon triple bond e.g. Ethyne ($\text{CH} \equiv \text{CH}$)

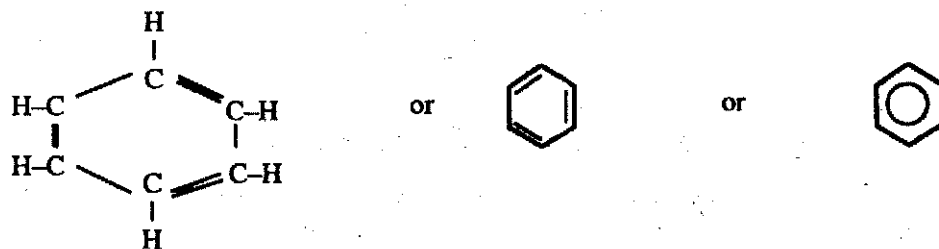
(ii) **Closed chain or cyclic hydrocarbons**: In this type of hydrocarbons, the chain is closed and form carbocyclic rings in their molecules. They are further divided into two categories:

(a) alicyclic hydrocarbons and (b) aromatic hydrocarbons.

(a) **Alicyclic hydrocarbons**: These compounds contain ring or closed chain of carbon atoms but they resemble open chain hydrocarbons. They can be further classified into cyclo alkanes, cycloalkenes, cycloalkynes. Some examples are as follows:

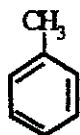


(b) **Aromatic hydrocarbons:** These hydrocarbons are collectively known as **arenes**. They contain one or more hexagonal carbocyclic rings. The name aromatic is derived from the Greek word 'aroma' meaning sweet smell because most of the compounds belonging to this class have sweet fragrance. One of the earliest aromatic hydrocarbons known is benzene. The benzene ring has six carbon cyclic chain with single and double bonds.



Benzene

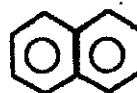
Other aromatic Compounds are derived from benzene. Some of the examples are:



Toluene

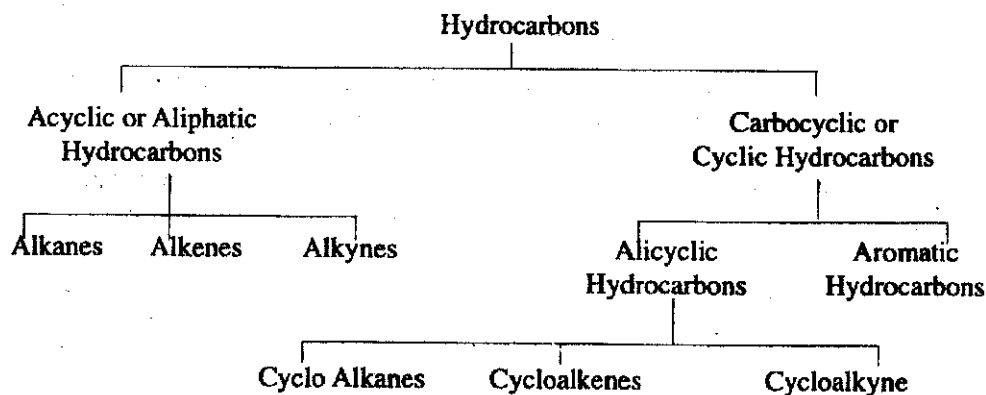


Xylene



Naphthalene

In brief, the classification of hydrocarbons can be given as follows:



INTEXT QUESTIONS 25.1

1) Write three categories of Aliphatic Hydrocarbons.

.....

2) Give one example of

- i) Alicyclic hydrocarbon
 - ii) Aromatic hydrocarbon
-

25.4 IUPAC NOMENCLATURE

The term nomenclature means the system of naming of organic compounds. In the beginning

of organic chemistry, the organic compounds were named after the source from which they were prepared e.g. methane was named as marsh gas as well as damp fire. These names of organic compound are called common names or trivial names. There was no systematic basis for naming them. In order to bring uniformity and rationality in naming the organic compounds throughout the world, International Union of Chemists came out with a system of nomenclature known as International Union of Pure and Applied Chemistry (IUPAC) system. This system is widely accepted and has rules for naming organic compounds. Let us discuss the nomenclature of hydrocarbons.

25.4.1 Nomenclature of Acyclic Hydrocarbons

a) **Straight chain Hydrocarbons:** To name these types of Hydrocarbons, we generally take care of two aspects. The first one is word root and second one is suffix. Word root designate the number of carbon atoms in the chain. Special word roots are used for chains containing one to four carbon atoms but for chains of five and more carbon atoms, Greek number roots are used. IUPAC word root for a few carbon chains are as follows.

Chain Length	Word root	Chain Length	Word root
C 1	Meth -	C 6	Hex -
C 2	Eth -	C 7	hept -
C 3	Prop -	C 8	Oct -
C 4	But -	C 9	Non -
C 5	Pent -	C10	Dec -

The general word root for any carbon chain is alk.

In order to write IUPAC name, a suffix is added to the word root to indicate saturation or unsaturation in the hydrocarbons. These suffixes are as under.

Class of compound	Suffix	General name
Saturated	-ane	Alkane
Unsaturated ($>C = C<$)	-ene	Alkene
Unsaturated ($-C \equiv C-$)	-yne	Alkyne

Let us take some examples:

CH_4 - Methane i.e., Meth word root, ane suffix

$CH_3 - CH_2 - CH_3$ Propane i.e., prop word root, ane suffix

$CH_2 = CH_2$ Ethene i.e., Eth. word root, ene suffix

$CH_3 - C \equiv CH$ Propyne i.e., Prop word root, yne suffix

b) Nomenclature of branched chain Hydrocarbons

In branched chain hydrocarbons, the carbon atoms are present in the side chain along with the straight chain of carbon atoms. The carbon atoms inside the chain constitute **alkyl groups** or **alkyl radicals** These alkyl groups are expressed as prefixes in the IUPAC name. An alkyl group is obtained from an alkane by removing one hydrogen atom. Since the general formula of alkane is C_nH_{2n+2} , the general formula of alkyl group is C_nH_{2n+1} . The

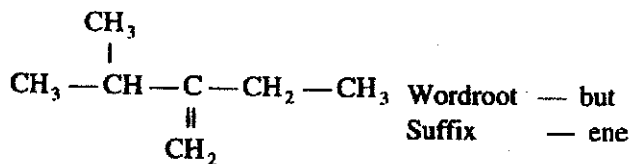
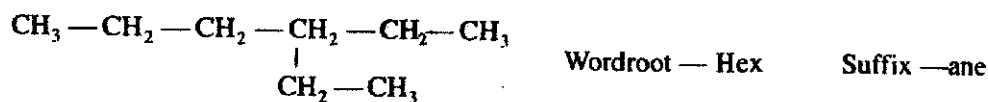
alkyl group is generally represented by R-. The alkyl radicals is named by replacing suffix **ane** from the name of the corresponding alkane by **yl**. Let us see some of the examples of alkyl group in the following tables.

Parent Chain	Formula R - H	Alkyl group R -	Name
Methane	CH ₄	CH ₃ -	Methyl
Ethane	CH ₃ CH ₃	CH ₃ CH ₂ -	Ethyl
Propane	CH ₃ CH ₂ CH ₃	CH ₃ CH ₂ CH ₂ -	1- Propyl (n-Propyl)
		CH ₃ - CH - CH ₃	2-Propyl (Iso-Propyl)
Butane	CH ₃ CH ₂ CH ₂ CH ₃	CH ₃ CH ₂ CH ₂ CH ₂ -	1-Butyl (n-Butyl)
		CH ₃ CH - CH ₂ CH ₃	2-Butyl or Sec Butyl or Iso Butyl
Isobutane	CH ₃ - CH - CH ₂ CH ₃	CH ₃ - C - CH ₃ CH ₃	Tert. Butyl

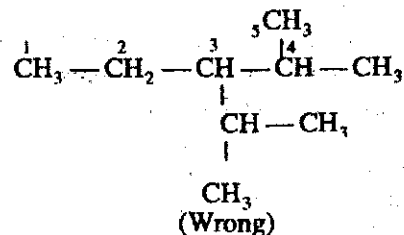
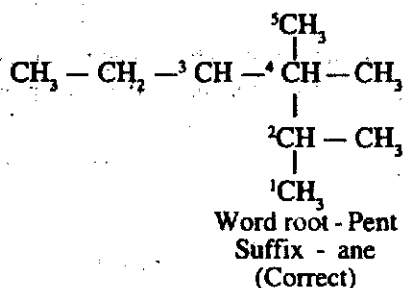
Branched chain hydrocarbons are named using the following rules in IUPAC system.

Rule 1- Longest chain Rule: According to this rule, the longest possible chain of carbon atoms is picked up and the compound is named as derivative of this alkane. If some multiple bond is present, the selected chain must contain the carbon atoms of the multiple bond. The number of carbon atoms in the selected chain determines the word root and the saturation or unsaturation will determine the primary suffix.

For Example :

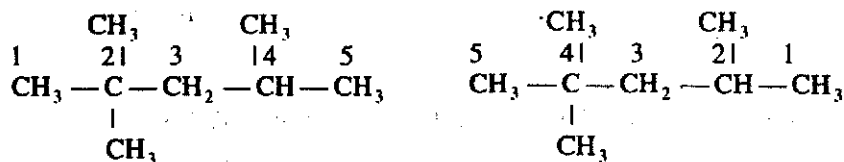
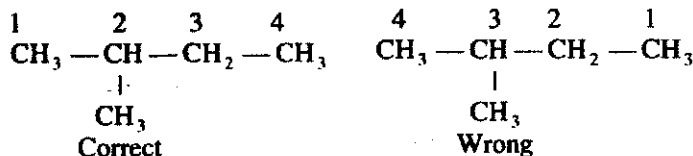


If two equally long chains are possible, the chain with maximum number of side chains is selected.



Rule 2: Lowest number or lowest sum rule : The carbon chain is numbered from one end to another by arabic numerals and the positions of the side chain are indicated by the number of C-atoms to which these are attached. The numbering is done in such a way that :

- The substituted carbon atoms have the lowest possible numbers.
- The sum of numbers used to indicate the positions of various alkyl groups must be the lowest.
- If some multiple bond is present in the chain the carbon atoms involved in the multiple bond should get the lowest possible numbers. For Example :

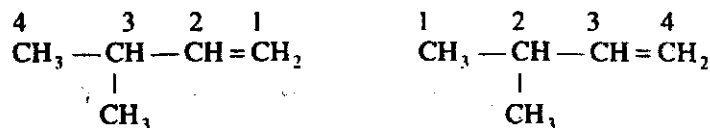


Sum of positions = 2 + 2 + 4 = 8

Correct

Sum of positions = 2 + 4 + 4 = 10

Wrong



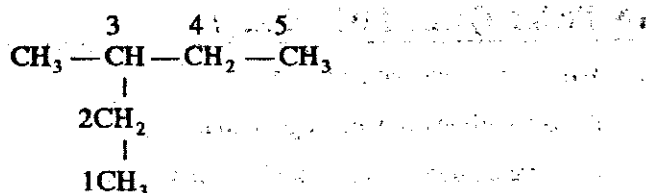
Correct

Wrong

The name of the compound in general is written in the following sequence.

Position of substituent — Name of substituent, Word root, Suffix.

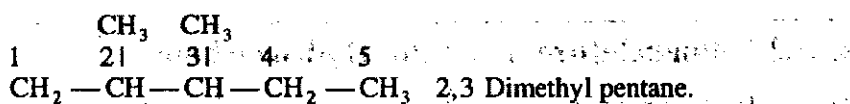
For example the name of the compound



is written as 3-methyl pentane. The substituent is *Methyl* group at position number 3. The word root is *Pent* and suffix is *ane*.

Rule 3: Naming the same Alkyl groups at different positions.

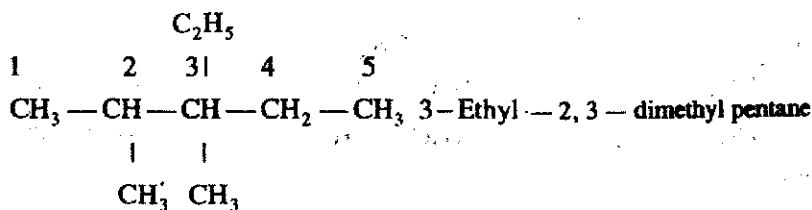
If the compound contains more than one similar alkyl groups, their positions are indicated separately and prefix di (two) tri (three) is attached to the name of the substituents. The position of the substituents is separated by commas (,).



Rule 4: Naming different Alkyl substituent.

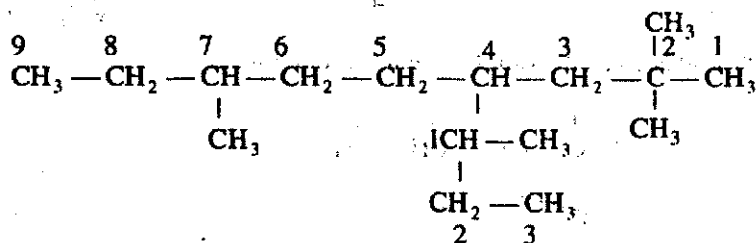
If there are different alkyl substituents present in the compound, their names are written in the alphabetical order. However, prefixes di, tri, etc are not considered in order of preference.

For Example



Rule 5: Naming of complex alkyl substituent.

If alkyl substituent is further branched, it is named as substituted alkyl group. For this purpose, the carbon atoms of the alkyl groups are separately numbered in such a way, that the carbon atom directly attached to the parent chain is given the number. The name of such substituent is enclosed in brackets as shown below.



2,2,7-Trimethyl-4(1-methyl propyl) nonane

IN TEXT QUESTIONS-25.2

- Write word root and suffix of
 - Six carbons and all single bonds
 - Five carbons and one double bond
 - Three carbons and one triple bond

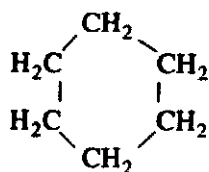
.....
- Name two rules used for naming hydrocarbons in IUPAC System.
.....
- Write the sequence used for naming the branched chain hydrocarbon.
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25.4.2 Nomenclature of Cyclic Hydrocarbons

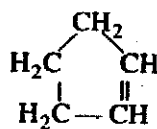
As we already know that cyclic hydrocarbons are divided under two categories of compounds i.e. alicyclic and aromatic compounds. Now let us learn to name these compounds one by one.

a) Naming the alicyclic compounds.

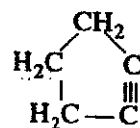
These compounds are cyclic i.e. have closed chain, hence names of alicyclic compounds are derived by putting another prefix 'cyclo' before the word root. The suffix ane, ene or yne are written accordingly to the saturation or unsaturation in the ring structure. Some of the examples are.



Cyclo hexane

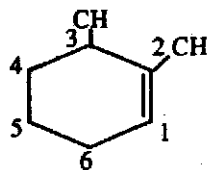


Cyclo pentene

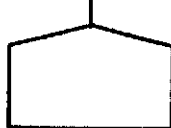
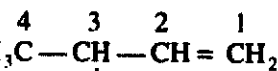
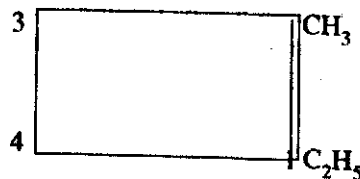


Cyclo pentyne

If some substituent is present, it is indicated by some appropriate prefix or suffix and its position is indicated by numbering the carbon atoms of the ring. The numbering is done in such a way so as to assign the least possible number to the substituent. Some examples are:



2,3 Dimethyl cyclo hexane

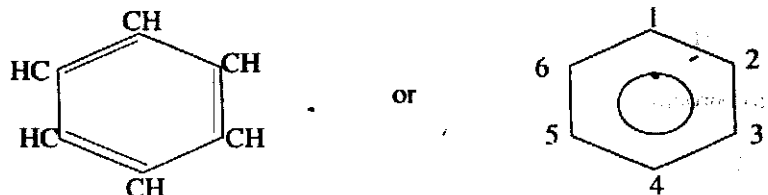


3-Cyclopentyl - 1 - butene

b) Naming the Aromatic compounds:

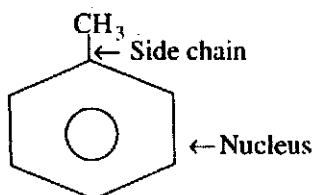
These compounds are cyclic compounds having double bond at alternate positions. Strictly speaking the position of double bond is not fixed at a point but changes all the time, hence double bonds are delocalised in these compounds.

The most important members of this class are benzene and its derivatives.

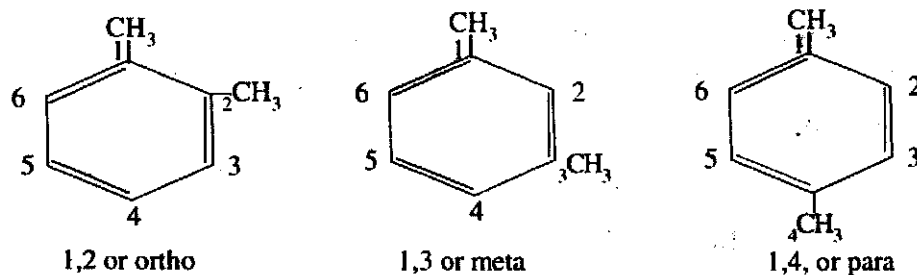


Benzene

The carbon atoms of benzene are numbered from 1 to 6 as shown above. The benzene ring is called nucleus and alkyl groups like $\text{CH}_3, \text{CH}_2\text{CH}_3$ attached to nucleus are called side chains. This can be shown as



Benzene forms only one mono substituted derivative. It can form three disubstituted derivatives namely 1,2; 1,3 and 1,4. These are called ortho (or o-) meta (or m-) and para (or p-) respectively

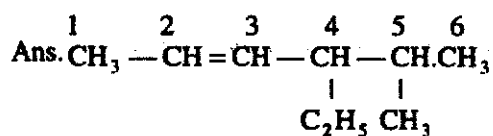


5.5 WRITING STRUCTURE OF HYDROCARBONS FROM IUPAC NAMES

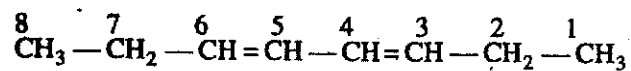
Till now, we have named hydrocarbons from their structures using IUPAC nomenclature. Can we do reverse exercise? The reverse exercise i.e. writing structure of hydrocarbons when their IUPAC names are given. This exercise will confirm our ideas for naming organic compounds systematically. Let us take some examples to do this exercise.

Write the structure of

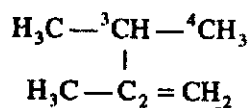
i) 4-ethyl-5-methyl-2-hexene



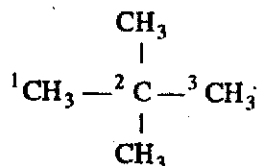
ii) 3,5 Octadiene



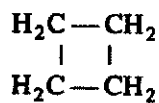
iii) 2,3 Dimethyl-1-butene



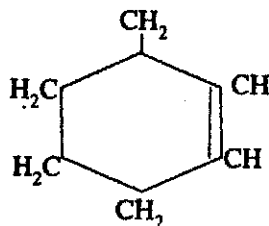
iv) 2,2— Dimethyl propane



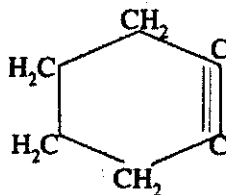
v) Cyclobutane



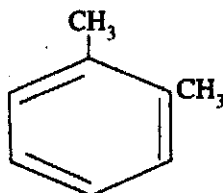
vi) Cyclohexene



vii) Cyclohexyn



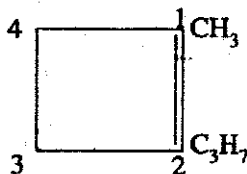
viii) 1,2 dimethyl Benzen



After this reverse exercise, you would have definitely gained confidence to name and write structure of all types of hydrocarbons.

INTEXT QUESTIONS 25.3

1. Write the name of the compound



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2. Why did you number propyl as 2 in the answer of above question.

.....

3. What do you mean by nucleus and side chain.

.....

25.6 WHAT YOU HAVE LEARNT

- Hydrocarbons are the compounds of carbon and hydrogen.
- Hydrocarbons are classified broadly into two categories i.e. open chain (acyclic) and closed chain (cyclic)
- The open chain (acyclic) hydrocarbon contain alkanes, alkenes and alkynes.
- The closed chain hydrocarbons contain alicyclic compounds like cyclo alkyne and aromatic compounds like benzene, toluene.
- Importance of naming hydrocarbons using IUPAC system.
- Important rules i.e. longest chain and lowest numbers to name hydrocarbons using IUPAC system.
- Writing the names of hydrocarbons (open chain alicyclic and aromatic) using IUPAC system.
- Writing structures of hydrocarbons from their IUPAC names.

25.7 TERMINAL EXERCISE

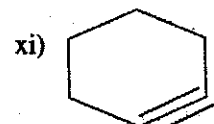
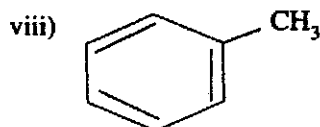
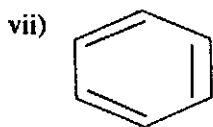
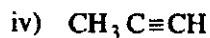
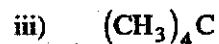
1. What do you mean by hydrocarbons? Give two examples.

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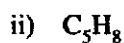
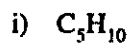
2. Why is benzene called an aromatic hydrocarbon. Give two examples of aromatic hydrocarbons.

.....

3. Classify the following hydrocarbons and write their names



4. Write the possible structures and names of the following



5. Write the structures for the following compounds:

i) Isobutyl benzene

ii) 4-methyl -2- pentyne.

iii) 1,6-heptadiene

iv) Cyclobutene.

CHECK YOUR ANSWERS

INTEXT QUESTION 25.1

- Alkane, alkene and alkyne
- i) Cyclopentane ii) benzene

INTEXT QUESTIONS 25.2

- Hexane
 - Pentene
 - Propyne
- Longest chain rule and lowest number rule.
- The sequence used is-position of substituent, name of the substituent, word root, suffix

INTEXT QUESTIONS 25.3

- 1 - Methyl 2 - Propyl Cyclobutene
- The alphabetical letter P of propyl comes after M of Methyl.
- Nucleus is the benzene ring and alkyl group attached to nucleus is called side chain.

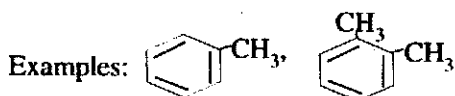
TERMINAL EXERCISE

- The compounds which are made up of carbon and hydrogen elements are known as hydrocarbons

Examples: C_3H_8 (Propane), C_6H_{12} (Hexene)

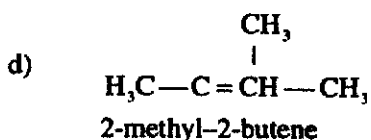
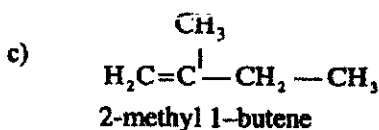
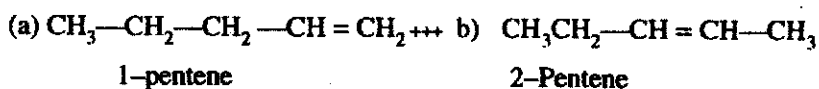
- The name aromatic is derived from the Greek word 'aroma' meaning sweet smell.



Benzene is the first member of this class and has sweet smell.



3.	Classification	Names
i)	acyclic, saturated, alkane	2 methylpropane
ii)	acyclic, unsaturated, alkene	propene
iii)	acyclic saturated, alkane	2,2-dimethyl propane
iv)	acyclic, unsaturated, alkyne	Propyne
v)	acyclic, unsaturated, alkyne	2-butyne
vi)	acyclic, unsaturated, alkene	ethene
vii)	cyclic, arene	Benzene
viii)	cyclic, arene	Toluene
ix)	alicyclic, cyclo alkane	cyclobutane
x)	alicyclic, cycloalkene	cyclopentene
xi)	alicyclic cycloalkyne	cyclopentyne

- (i) C_5H_{10}



- e)  Cyclo pentane
- f) $\begin{array}{c} \text{CH}_3 \\ | \\ \text{CH}_3 - \text{CH} - \text{CH} = \text{CH}_2 \end{array}$
3-methyl-1-butene
- ii) C_5H_8
- (a) $\text{H}_3\text{C} - \text{CH}_2 - \text{CH}_2 - \text{C} \equiv \text{CH}$
1-pentyne
- (b) $\text{H}_3\text{C} - \text{CH}_2 - \text{C} \equiv \text{C} - \text{CH}_3$
2-pentyne
- (c) $\begin{array}{c} \text{CH}_3 \\ | \\ \text{H}_3\text{C} - \text{CH} - \text{C} \equiv \text{CH} \end{array}$
3-methyl-1-butyne
- (d)  cyclopentene
5. (i) $\begin{array}{c} \text{CH}_2 - \text{CH} - \text{CH}_3 \\ | \\ \text{CH}_3 \end{array}$ (ii) $\begin{array}{c} \text{CH}_3 \\ | \\ \text{H}_3\text{C} - \text{C} \equiv \text{C} - \text{CH} - \text{CH}_3 \end{array}$
- (iii) $\text{CH}_2 = \text{CH} - \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{CH} = \text{CH}_2$
- (iv) 