13 ALKANES

Introduction :

Q.1. What are alkanes?

Ans: Alkanes are saturated aliphatic hydrocarbons containing c-c single bond Alkanes are called paraffins (in Latin *parum* means *little* and *affins* means *affinity*) because they have little affinity towards the chemical reactions (i.e. they are less reactive).

Functional group : $\geqslant C - C \leqslant$

Representation : RH

General formula : C_nH_{2n+2}

e.g. Methane (CH_4) , Ethane (C_2H_6).

Homologous series of alkanes :

Alkanes have general formula C_nH_{2n+2} where 'n' is the number of carbon atoms.

Homologous series of alkanes is given below :

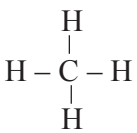
n	Name	Molecular formula
1.	Methane	CH_4
2.	Ethane	C_2H_6
3.	Propane	C_3H_8
4.	Butane	C_4H_{10}
5.	Pentane	C_5H_{12}
6.	Hexane	C_6H_{14}
7.	Heptane	C_7H_{16}
8.	Octane	C_8H_{18}
9.	Nonane	C_9H_{20}
10.	Decane	$C_{10}H_{22}$

Structural formulae

Q.2. Explain the term structural formula.

Ans : *The formula which indicates how the various atoms in a molecule are joined to one another is called structural formula* (or graphic formula).

e.g. Structural formula of methane (CH_4) is

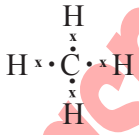


Electronic structure :

Q.3. Explain the term electronic structure.

Ans : *The structure in which electrons are indicated by dot (•) or cross (x) is called electronic structure.*

e.g. The electronic structure of methane is

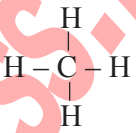


Where, • → electrons of carbon

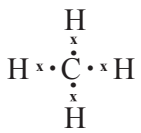
x → electrons of hydrogen

Q.4.Give the structural formula & electronic formula for i) methane ii) ethane iii) propane

i) Methane (CH_4) : Condensed formula : CH_4

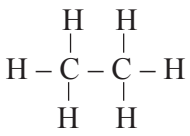


Structural formula

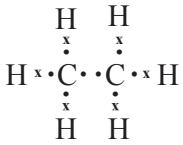


Electronic formula

i) Ethane (C_2H_6) : Condensed formula : $CH_3–CH_3$

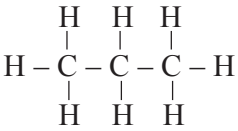


Structural formula

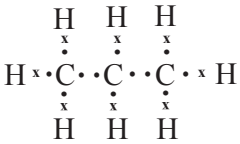


Electronic formula

i) Propane (C_3H_8) : Condensed form. $CH_3–CH_2–CH_3$



Structural formula

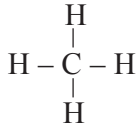


Electronic formula

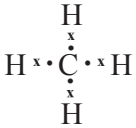
Q.5. Explain the structural & molecular formula of methane.

Ans : i) The molecular formula of methane is CH_4.

ii) Its structural & electronic formulae are



Structural formula



Electronic formula

iii) In methane the carbon atom is joined to four hydrogen atoms by single covalent bonds.

iv) Thus there are four C–H bonds in methane.

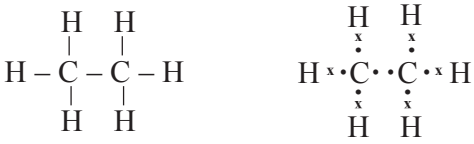
v) Each C–H bond is a covalent bond, formed by sharing of one electron pair between C & H atoms.

vi) Thus carbon atom gets complete octet and each hydrogen atom gets complete duplet (i.e stable configuration) .

Q.6. Explain the structural & electronic formula of ethane. 2

Ans : i) Molecular formula of ethane is C_2H_6.

ii) It's structural & electronic formulae are given below :



Structural formula

Electronic formula

iii) In ethane, the two carbon atoms are joined to each other by a single covalent bond.

iv) Each carbon is joined with three hydrogen atoms by single covalent bonds.

v) The C–C bond is a covalent bond formed by the sharing of one electron pair between the two carbon atoms.

vi) Each C–H bond is also covalent bond formed by sharing of one electron pair between C & H atoms.

vii) Thus each C- atom gets complete octet & each hydrogen atom gets complete duplet (i.e. stable configurations).

Q.7. What are the types of carbon atoms in alkanes ?

Ans: There are four types of carbon atoms in alkanes.

i) Primary C-atom : The carbon atom which is attached to only one other carbon atom (or no other carbon atom) is called a primary carbon

e.g. $\overset{1^\circ}{C}H_3-\overset{1^\circ}{C}H_3$ (Ethane)

ii) Secondary C-atom : The carbon atom which is attached to two other carbon atoms is called a secondary carbon (2°). e.g.

$CH_3-\overset{2^\circ}{C}H_2-CH_3$ (Propane)

iii) Tertiary C-atom : The carbon atom which is attached to three other carbon atoms is called tertiary carbon (3°). e.g.

$CH_3-\overset{3^\circ}{C}H(CH_3)-CH_3$. (iso-butane)

iv) Quaternary C-atom : The carbon atom which is attached to four other carbon atoms is called a quaternary carbon (4°). e.g.

$H_3C-\overset{CH_3}{\underset{CH_3}{\overset{|}{\underset{|}{\overset{4^\circ}{C}}}}}-CH_3$ (neo-pentane)

Q. 8. What are the types of H–atoms in alkanes ?

Ans: There are three types of H atoms in alkanes :

i) Primary H-atom :

The H-atom which is attached to a primary carbon atom is called primary hydrogen.

e.g. ethane CH_3-CH_3

(In this compound there are six primary H- atoms).

ii) Secondary H-atom :

The H-atom which is attached to the secondary carbon atom is called secondary hydrogen.

e.g. Propane $CH_3-CH_2-CH_3$

(In this compound there are two 2^0 H- atoms.)

iii) Tertiary H-atom :

The H-atom which is attached to the tertiary carbon atom is called a tertiary hydrogen.

e.g. iso-butane $CH_3-\overset{3^\circ}{C}H(CH_3)-CH_3$.

(In this compound there is one tertiary H-atom.)

Straight chain & branched chain alkanes

Q.9. What are straight and branched chain alkanes ?

Ans : i) Straight chain alkanes or normal alkanes : *The alkanes in which the carbon atoms are joined to one another to form a continuous straight chain without any branching are called strainght chain alkanes.*

They are called normal alkanes or n - alkanes. They contain only primary & secondary carbon atoms.

e.g.i) n-butane $CH_3–CH_2–CH_2–CH_3$.

ii) n-pentane $CH_3–CH_2–CH_2–CH_2–CH_3$.

ii) Branched chain alkanes : *The alkanes in which one or more alkyl side chains are attached to the main chain are called as branched chain alkanes.*

These alkanes contain tertiary and / or quaternary carbon atoms in addition to the usual 1° and 2° C–atoms..

Branched chain alkanes are of two types

a) Isoalkanes and b) Neoalkanes.

a) Isoalkanes : *The alkane in which a methyl side chain is attached to the next to end carbon of the main chain (i.e. second carbon from the end of the main chain) is called isoalkane.*

It contains a tertiary carbon atom. e.g.

i) $CH_3–\overset{3°}{\underset{\displaystyle CH_3}{\underset{|}{CH}}}–CH_3$. ii) $CH_3–\overset{3°}{\underset{\displaystyle CH_3}{\underset{|}{CH}}}–CH_2–CH_3$

iso-butane iso-pentane

iii) $CH_3–\underset{\displaystyle CH_3}{\underset{|}{CH}}–CH_2–CH_2–CH_3$ iso-hexane

b) Neoalkanes : *The alkane in which two methyl side chains are attached to the next to end carbon of the main chain (i.e.second carbon from the end of the main chain) is called neoalkane.*

It contains a quaternary carbon.

e.g.

i) $H_3C–\underset{\displaystyle CH_3}{\overset{\displaystyle CH_3}{\overset{|}{\underset{|}{\overset{4°}{C}}}}}–CH_3$ ii) $H_3C–\underset{\displaystyle CH_3}{\overset{\displaystyle CH_3}{\overset{|}{\underset{|}{\overset{4°}{C}}}}}–CH_2–CH_3$

neo-pentane neo-hexane

N.B. The prefixes iso and neo are used to designate the branched chain alkanes having six or less number of C – atoms. In naming of the higher alkanes we make the use of IUPAC system.

Q.10. Define and give suitable examples of

i) n-alkane ii) iso-alkane iii) neo-alkane .. 3

Chain isomerism in alkanes

Q.11. Define & explain the term chain isomerism.

OR What do you mean by isomerism ? Explain the same in butane.

Ans: The compounds having same molecular formula but different structural formulae are called isomers of each other & this phenomenon is called isomerism.

The isomerism in alkanes is due to difference in the structure or nature of the carbon chains therefore it is called chain isomerism.

The first three alkanes (methane, ethane & propane) can not have branching hence they exist only as normal alkanes. The isomerism in alkanes starts from butane onwards.

Butane (C_4H_{10}) can have two types of arrangements of carbon atoms hence it has two chain isomers.

$CH_3–CH_2–CH_2–CH_3$ $CH_3–\underset{\displaystyle CH_3}{\underset{|}{CH}}–CH_3$.

n-Butane Isobutane

Q.12. Give the chain isomers of pentane. 3

Ans: Pentane (C_5H_{12}) has three chain isomers as it can have three types of arrangements of C-atoms.

i) $CH_3–CH_2–CH_2–CH_2–CH_3$ (n-Pentane)

ii) $CH_3–\underset{\displaystyle CH_3}{\underset{|}{CH}}–CH_2–CH_3$ iii) $H_3C–\underset{\displaystyle CH_3}{\overset{\displaystyle CH_3}{\overset{|}{\underset{|}{C}}}}–CH_3$

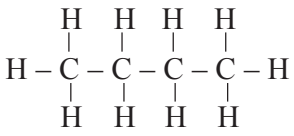
Isopentane Neopentane

N.B. The number of isomers of an alkane increases rapidly with increase in number of carbon atoms. e.g. hexane has 5 isomers, heptane has 9, octane 18, decane 75.

Q.13. Give the structural and condensed formulae of all the isomers of butane and pentane.

i) Butane (C_4H_{10}) : It has 2 isomers.

a) n-Butane :

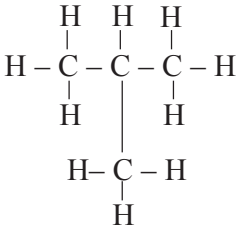


Structural formula

$CH_3–CH_2–CH_2–CH_3$

Condensed formula

a) Isobutane :



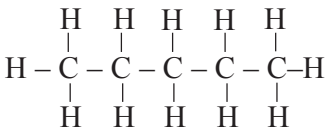
Structural formula

$CH_3–\underset{\displaystyle CH_3}{\underset{|}{CH}}–CH_3$.

Condensed formula

ii) Pentane (C_5H_{12}) : It has 3 isomers.

a) n - Pentane :

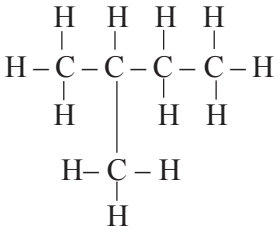


Structural formula

$CH_3–CH_2–CH_2–CH_2–CH_3$

Condensed formula

b) Isopentane :

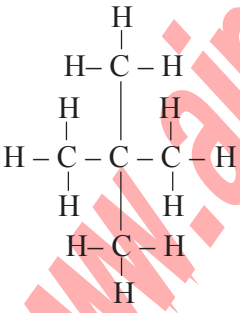


Structural formula

$CH_3–\underset{\displaystyle CH_3}{\underset{|}{CH}}–CH_2–CH_3$

Condensed formula

c) Neopentane :



Structural formula

$H_3C–\underset{\displaystyle CH_3}{\overset{\displaystyle CH_3}{\overset{|}{\underset{|}{C}}}}–CH_3$

Condensed formula

Q.14. Give the condensed structural formulae of the normal alkanes containing 6, 7, 8, 9 and 10 carbon atoms.

i) n - Pentane (C_5H_{12}) :

$CH_3–CH_2–CH_2–CH_2–CH_3$

ii) n- Hexane(C_6H_{14}) :

$CH_3–CH_2–CH_2–CH_2–CH_2–CH_3$

iii) n-Heptane (C_7H_{16}) :

$CH_3–CH_2–CH_2–CH_2–CH_2–CH_2–CH_3$

or $CH_3–(CH_2)_5–CH_3$

iv) n- Octane (C_8H_{18}) :

$CH_3–CH_2–CH_2–CH_2–CH_2–CH_2–CH_2–CH_3$

or $CH_3–(CH_2)_6–CH_3$

v) n-Nonane(C_9H_{20}) :

$CH_3–CH_2–CH_2–CH_2–CH_2–CH_2–CH_2–CH_2–CH_3$

or $CH_3–(CH_2)_7–CH_3$

vi) n - Decane ($C_{10}H_{22}$) :

$CH_3–CH_2–CH_2–CH_2–CH_2–CH_2–CH_2–CH_2–CH_2–CH_3$

or $CH_3–(CH_2)_8–CH_3$

ALKYL GROUPS

Q.15.Explain the term alkyl group.

Alkyl group is a monovalent group or radical obtained by removing one H-atom from alkanes.

The general formula of alkyl group is C_nH_{2n+1}

The name of alkyl group is obtained by replacing the suffix – *ane* of alkane by –*yl* .

$$RH \xrightarrow{-H} R–$$

Alkane Alkyl group

e.g. $CH_4 \xrightarrow{-H} CH_3–$

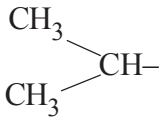
Methane Methyl

Learn the alkyl groups : ***A student must memorise the names of alkyl groups and learn to recognise these groups at a glance in whatever way they may be represented .***

	Alkane		Alkyl group
1)	CH_4	$\xrightarrow{-1^0 H}$	$-CH_3$
	Methane		Methyl group
2)	C_2H_6	$\xrightarrow{-1^0 H}$	$-C_2H_5$ or CH_3-CH_2-
	Ethane		Ethyl group

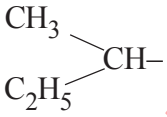
3) $CH_3-CH_2-CH_3 \xrightarrow{-1^0 H} CH_3-CH_2-CH_2-$
Propane — n-Propyl

4) $CH_3-CH_2-CH_3 \xrightarrow{-2^0 H} CH_3-\underset{|}{CH}-CH_2-CH_3$
Propane — Isopropyl or

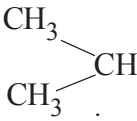


4) $CH_3-CH_2-CH_2-CH_3 \xrightarrow{-1^0 H}$
n-Butane — $CH_3-CH_2-CH_2-CH_2-$
n-Butyl

$CH_3-CH_2-CH_2-CH_3 \xrightarrow{-2^0 H} CH_3-\underset{|}{CH}-CH_2-CH_3$
n-Butane — sec-butyl or

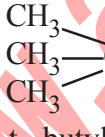


5) $CH_3-\underset{|}{\underset{CH_3}{CH}}-CH_3 \xrightarrow{-1^0 H} CH_3-\underset{|}{\underset{CH_3}{CH}}-CH_2-$
Isobutane — iso-butyl or



or $(CH_3)_2CH\,CH_2-$
iso-butyl — iso-butyl

$CH_3-\underset{|}{\underset{CH_3}{CH}}-CH_3 \xrightarrow{-3^0 H} CH_3-\underset{|}{\underset{CH_3}{C}}-CH_3.$
Isobutane — tert.butyl or



or $(CH_3)_3C-$
t - butyl — t - butyl

Q.16.Give the alkyl groups obtained from pentane

Ans :

$CH_3-CH_2-CH_2-CH_2-CH_3$
n - pentane

$\xrightarrow{-1^0 H} CH_3-CH_2-CH_2-CH_2-CH_2-$
n - pentyl or n-amyl

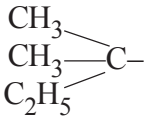
$\xrightarrow{-2^0 H} CH_3-\underset{|}{CH}-CH_2-CH_2-CH_3$
sec-pentyl or sec-amyl

$CH_3-\underset{|}{\underset{CH_3}{CH}}-CH_2-CH_3$
Isopentane

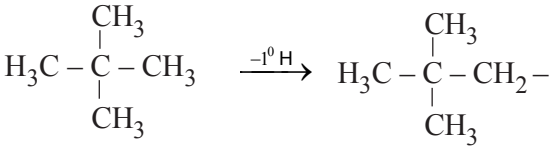
$\xrightarrow{-1^0 H} CH_3-\underset{|}{\underset{CH_3}{CH}}-CH_2-CH_2-$
Isopentyl or Isoamyl

$\xrightarrow{-3^0 H} CH_3-\underset{|}{\underset{CH_3}{\overset{|}{C}}}-CH_2-CH_3.$
t -pentyl or t - amyl

or



t -pentyl or t - amyl



neo-pentane — neo-pentyl

NOMENCLATURE OF ALKANES

It is the naming system. There are two methods of nomenclature.

i) *Common system* (or trivial system.)

ii) *IUPAC system* (or systematic names).

i) Common system or Trivial system :

a) The first four alkanes methane, ethane, propane & butane are called by their common names.

b) From fifth alkane the Greek numerals are used to indicate the number of carbon atoms e.g. pent (5), hex (6) , hept (7) ,oct (8), non (9)

and dec (10) etc.

c) The names of alkanes end with the suffix - ane which indicates the saturated hydrocarbons - alkanes.

d) The various isomers of alkanes are denoted by the prefixes like n -, iso - & neo-.

Limitations of common system :

Common system can name only three isomers of the alkanes i.e. n - , iso - and neo - .

But as the number of carbon atoms in alkanes increases the number of isomers increases rapidly e.g. there are 5 hexanes, 9 - heptanes, 75 decanes etc.

Common system fails to name all these isomers of higher alkanes. Hence there was a need for some systematic method of nomenclature.

IUPAC system fulfills this need.

IUPAC system : Various committees and commissions of chemists of the world have devised a systematic method of nomenclature. It is called IUPAC system i.e.International Union of Pure & Applied Chemistry.

Rules for IUPAC nomenclature :

i) Longest chain rule : Select the longest continuous carbon chain as the parent alkane and the compound is said to be derivative of this alkane.

Note :

a) The alkyl groups which are not included in the parent chain are taken as side chains or substituents.

b) The longest chain may or may not be staight but it should be continuous.

c) If two different chains have equal length, then the chain having greater number of substituents is taken as parent chain.

ii) Lowest number rule : Number the carbon atoms in basic chain from the end which is nearer to the side chain.

iii) locant : The position of side chain is indicated by the number of carbon atom to which the side chain is attached. This number is called ***locant***.

iv) Lowest set of locants rule : When two or more substituents (i.e. side chains) are present then start the numbering from that end of the parent chain which gives

a) lowest set of locants and / or

b) lowest sum of locants.

But the lowest set of locants rule is preferred over the lowest sum of locants rule.

v) About side chains or substituents :

a) When the same side chain is present for two or more times then the prefixes like di, tri, tetra etc are used and their positions are indicated separately by numerals.

b) The names of different side chains are written in alphabetical order (the prefixes di, tri etc are ignored while comparing the substituents).

c) When two side chains are present on the same carbon atom then the number of that carbon must be repeated for each side chain.

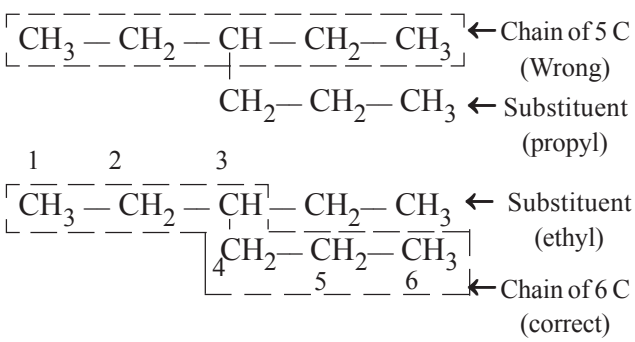
vi) When two different side chains are present at equivalent positions from two ends of a main chain, then the numbering is done in such a way that the alkyl group which comes first in alphabetical order gets lower number.

vii) In the name, the comma is used to separate the numbers from each other and a hyphen is used to separate a number from the name.

The name of last alkyl group and the parent alkane are written as a single word.

Explanation of the rules

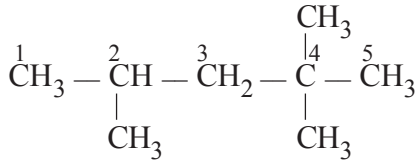
1)



3-Ethylhexane (correct Name)

3-Propylpentane (worng Name)

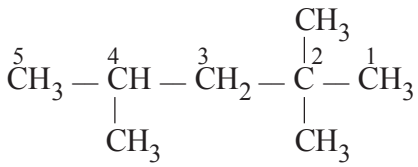
This compound is derivative of hexane and ethyl is taken as substituent or side chain, (rule -1). Numbering is started from the left (as shown) so that the locant (i.e. number which indicates position of side chain) is the minimum (rule 2).

2) 

Counting from left to right.

Set of locants : 2, 4, 4 (wrong)

Sum of locants : 2 + 4 + 4 = 10



Counting from right to left .

Set of locants : 2, 2, 4 (correct)

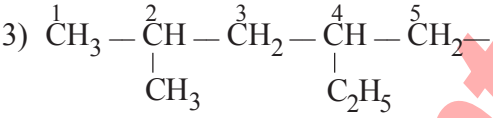
Sum of locants : 2 + 2 + 4 = 8

∴ This compound is

2,2,4- trimethylpentane (correct name)

2,4,4- trimethylpentane (wrong name)

Alphabetical order rule :

3) 

4- Ethyl - 2 - methylhexane (correct name)

2- Methyl - 4 - ethylhexane (wrong name)

Lowest set of locants rule : Number the C atoms of the basic chains in such a way that it should give the lowest set of locants and the lowest sum of locants. But in case of dispute, the lowest set of locants rule is given preference over the lowest sum of locants.

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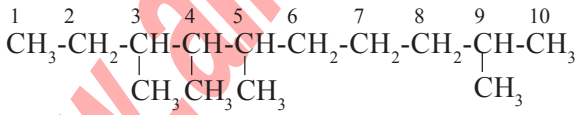
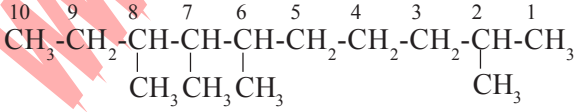
4) 

Set of locants : 3, 4, 5, 9

Sum of locants : 3 + 4 + 5 + 9 = 21



Set of locants : 2, 6, 7, 8

Sum of locants : 2 + 6 + 7 + 8 = 23

In this case the numbering is started from right to left as it gives the lowest set of locants (2,6,7,8), even though it does not give the lowest sum of locants.

2,6,7,8-Tetramethyldecane (correct name)

3,4,5,9-Tetramethyldecane (wrong name)

Thus we prefare the lowest set of locants rule over lowest sum of locants rule.

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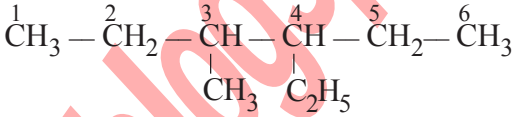
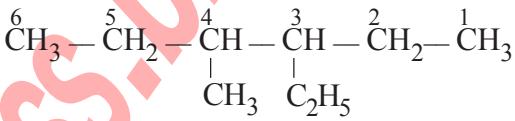
5) 

Methyl group at C_3



Ethyl group at C_3

3-Ethyl-4- Methylhexane (Correct name)

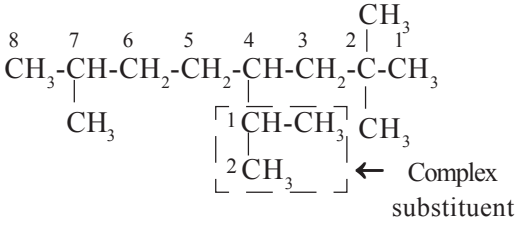
4-Ethyl-3- Methylhexane (Wrong name)

Here counting of the basic chain should be done from left to right so that ethyl gets lower number than methyl (since ethyl comes first in alphabetical order than methyl ; rule no. viii).

For complex substituents : If the side chain is branched then it is named as substituted alkyl group.

i) The C - atom of this group attached to the parent chain is numbered as 1.

ii) The names of such substituents are written in brackets to avoid any confustion with the numbering of parent chain.

1) 

2,2, 7 - trimethyl-4- (1 - methylethyl) octane

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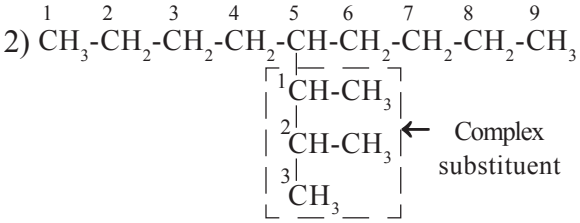
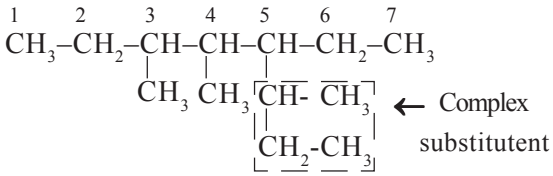
2) 

5- (1,2 - Dimethylpropyl) nonane

3) 

3, 4 - Dimethyl-5- (1- methylpropyl) heptane

Q.17. Give IUPAC names to following alkanes

1) $CH_3-CH_2-\underset{\displaystyle C_2H_5}{\underset{|}{CH}}-CH_3$ (3-methylpentane)

2) $CH_3-\underset{\displaystyle C_2H_5}{\underset{|}{CH}}-\underset{\displaystyle C_2H_5}{\underset{|}{CH}}-CH_3$ (3,4 - dimethylhexane)

3) $CH_3-CH_2-\underset{\displaystyle (CH_3)_2}{C}-CH_2-\underset{\displaystyle C_2H_5}{\underset{|}{CH}}-C_2H_5$

(3,3-Dimethyl - 5- ethyl - heptane)

4) $(CH_3)_3\,C-C_2H_5$ (2,2-diemthylbutane)

Q.18. Give IUPAC name.

i) $CH_3-\underset{\displaystyle CH_3}{\underset{|}{CH}}-CH_3$

ii) $CH_3-CH_2-\underset{\displaystyle CH_3}{\underset{|}{CH}}-CH_3$

iii) $CH_3-CH_2-CH_2-\underset{\displaystyle C_2H_5}{\underset{|}{CH}}-CH_2-CH_3$

iv) $CH_3-\underset{\displaystyle CH_3}{\underset{|}{CH}}-\underset{\displaystyle CH_3}{\underset{|}{CH}}-CH_3$

v) $CH_3-\underset{\displaystyle CH_3}{\overset{\displaystyle CH_3}{\overset{|}{C}}}-\underset{\displaystyle C_2H_5}{\underset{|}{CH}}-CH_2-CH_3$

vi) $CH_3-CH_2-\underset{\displaystyle CH_3}{\underset{|}{CH}}-\underset{\displaystyle CH_3}{\underset{|}{CH}}-\underset{\displaystyle C_2H_5}{\underset{|}{CH}}-CH_2-CH_3$

vii) $CH_3-CH_2-\underset{\displaystyle C_2H_5}{\underset{|}{\overset{\displaystyle CH_3}{\overset{|}{CH}}}}-\underset{\displaystyle C_2H_5}{\overset{\displaystyle CH_3}{\overset{|}{C}}}-CH_2-CH_3$

Answers of Q.No. 18 :

i) 2- Methylpropane
ii) 2-Methylbutane
iii) 3- Ethylhexane
iv) 2,3-Dimethylbutane
v) 3-Ethyl-2,2-dimethylpentane
vi) 3-Ethyl-4,5-dimethylheptane
vii) 3,4-Diethyl-3-methylhexane

Q.19. Common names of some alkanes are given. Write their structures and IUPAC names.

i) n- butane ii) n- pentane
iii) n- hexane iv) iso-butane
v) iso-pentane vi) iso-hexane
vii) neo-pentane viii) neo-hexane.

Ans : Write the answers and compare your answers with those given below in the same sequence.

Structures	**IUPAC names**
i) $CH_3-CH_2-CH_2-CH_3$	Butane
ii) $CH_3-CH_2-CH_2-CH_2-CH_3$	Pentane
iii) $CH_3-CH_2-CH_2-CH_2-CH_2-CH_3$	Hexane
iv) $CH_3-\underset{\displaystyle CH_3}{\underset{|}{CH}}-CH_3$	2- Methylpropane
v) $CH_3-\underset{\displaystyle CH_3}{\underset{|}{CH}}-CH_2-CH_3$	2- Methylbutane
vi) $CH_3-\underset{\displaystyle CH_3}{\underset{|}{CH}}-CH_2-CH_2-CH_3$	2- Methylpentane
vii) $H_3C-\underset{\displaystyle CH_3}{\overset{\displaystyle CH_3}{\overset{|}{C}}}-CH_3$	2,2 -Dimethylpropane
viii) $H_3C-\underset{\displaystyle CH_3}{\overset{\displaystyle CH_3}{\overset{|}{C}}}-CH_2-CH_3$	2,2 -Dimethylbutane

Q.20.Give the structures of following compounds

i) 2- Methylpropane ii) 2-Methylbutane

iii) 3- Ethylhexane
iv) 2,3-Dimethylbutane
v) 3-Ethyl-2,2-dimethylpentane
vi) 3-Ethyl-4,5-dimethylheptane
vii) 3,4-Diethyl-3-methylhexane
viii) 3-Ethyl-3,4,5-trimethyloctane

GENERAL METHODS OF PREPARATION

i) From unsaturated hydrocarbons
ii) Decarboxylation of acids
iii) From alkyl halides (reduction and Wurtz sysnthesis)

i) Hydrogenation of unsaturated hydrocarbons:

Q.21.Explain preparation of alkane from hydrogenation of unsaturated hydrocarbons

Ans:a) From alkenes : When alkenes are heated with H_2 gas is presence of catalyst Ni, Pt or Pd at 523K - 573K alkanes are obtained.

[or alkenes upon catalytic hydrogenation (H_2 / Ni) at 523 K - 573 K give alkanes].

Methane can not be prepared by this method.

e.g i) Ethylene (ethene) upon catalytic hydrogenation (H_2 / Ni at 573 K) gives ethane.

$$\underset{\text{Ethylene}}{CH_2 = CH_2} + H_2 \xrightarrow[573\,K]{Ni} \underset{\text{Ethane}}{CH_3 - CH_3}$$

e.g. ii) propylene (propene) upon catalytic hydrogenation (H_2/Ni at 573K) gives propane.

$$\underset{\text{Propylene}}{CH_3 - CH = CH_2} + H_2 \xrightarrow[573\,K]{Ni} \underset{\text{Propane}}{CH_3 - CH_2 - CH_3}$$

b) From alkynes : When alkynes are heated with H_2 gas is presence of catalyst Ni, Pt or Pd at 523K - 573K alkanes are obtained.

[or alkynes upon catalytic hydrogenation (H_2 / Ni) at 523 K - 573 K give alkanes].

Methane can not be prepared by this method.

e.g. i) Acetylene (an alkyne) upon catalytic hydrogenation (H_2/Ni at 573K) gives ethane.

$$\underset{\text{Acetylene}}{CH \equiv CH} + 2H_2 \xrightarrow[573\,K]{Ni} \underset{\text{Ethane}}{CH_3 - CH_3}$$

e.g. ii) propyne (propene) upon reduction by hydrogen gas in presence of Ni at 573 K gives propane.

$$\underset{\text{Propyne}}{CH_3 - C \equiv CH} + 2H_2 \xrightarrow[573\,K]{Ni} \underset{\text{Propane}}{CH_3 - CH_2 - CH_3}$$

Q.22.How will you prepare ethane from
i) Ethene ii) Ethyne
or
How will you convert :
i) Ethene into ethane
ii) Ethyne into ethane

Q.23.How will you prepare propane from
i) Propene ii) Propyne
or
How will you convert :
i) Propene into propane
ii) Propyne into propane

ii) By decarboxylation of fatty acids (i.e. carboxylic acids) :

Q.24. Explain decarboxylation of carboxylic acids.

Ans : When dry sodium salt of fatty acid is heated with sodalime (NaOH + CaO in 3 : 1 ratio) alkane is obtained.

In this reaction carbon dioxide (CO_2) is eliminated from carboxylic acid therefore the name is decarboxylation.

The product alkane contains one carbon atom less than the starting carboxylic acid.

$$\underset{\text{Sodium carboxylate}}{RCOONa} + \underset{\text{Sodalime}}{NaOH} \xrightarrow[CaO]{\Delta} \underset{\text{Alkane}}{RH} + Na_2CO_3$$

e.g i) When sodium acetate is heated with sodalime methane is obtained by decarboxylation.

$$\underset{\text{Sodium acetate}}{CH_3COONa} + \underset{\text{Sodalime}}{NaOH} \xrightarrow[CaO]{\Delta} \underset{\text{Methane}}{CH_4} + Na_2CO_3$$

ii) When sodium propionate is heated with sodalime ethane is obtained by decarboxylation.

$$\underset{\text{Sod.propionate}}{C_2H_5COONa} + \underset{\text{Sodalime}}{NaOH} \xrightarrow[CaO]{\Delta} \underset{\text{Ethane}}{C_2H_6} + Na_2CO_3$$

Q.25. How is methane prepared by decarboxylation of carboxylic acid?

Or

How is methane prepared from sodium acetate ?

Q.26. How is ethane prepared by decarboxylation of carboxylic acid?

Or

How is ethane prepared from sodium propionate ?

iii) From alkyl halides (RX) : Alkanes can be prepared from alkyl halides by two methods

a) By reduction of RX and

b) Wurtz sysnthesis

a) By reduction of RX :

Q.27.How alkanes are prepared by reduction of alkyl halide?

Ans : When alkyl halide is reduced by Zn / HCl acid or Zn / Cu couple in alcohol, alkanes are obtained.

$$\underset{\text{Alkyl halide}}{RX} + 2[H] \xrightarrow[Zn.Cu\ /Alcohol]{Zn/HCl\ or} \underset{\text{Alkane}}{RH} + HX$$

e.g i) Methane is obtained by reduction of methyl bromide.

$$\underset{\text{Methyl bromide}}{CH_3Br} + 2[H] \xrightarrow[Zn.Cu\ /Alcohol]{Zn/HCl\ or} \underset{\text{Methane}}{CH_4} + HBr$$

ii) ethane is obtained by reduction of ethyl iodide.

$$\underset{\text{Ethyl iodide}}{C_2H_5I} + 2[H] \xrightarrow[Zn.Cu\ /Alcohol]{Zn/HCl\ or} \underset{\text{Ethane}}{C_2H_6} + HI$$

b) Wurtz Synthesis :

Q.28. Write a note on Wurtz synthesis. 2

Ans: When alkyl halide is treated with sodium in dry ether, higher alkanes containing even no. of carbon atoms are obtained .

In this reaction two molecules of alkyl halide condense together to form a symmetrical alkane containing twice the number of C - atoms than the alkyl group.

$$\underset{\text{Alkyl halide}}{2RX} + 2Na \xrightarrow{\text{Dry ether}} \underset{\text{Higher alkane}}{R-R} + 2NaX$$

i) When methyl iodide is treated with sodium in dry ether ethane is obtained.

$$\underset{\text{Methyl iodide}}{2CH_3I} + 2Na \xrightarrow{\text{Dry ether}} \underset{\text{Ethane}}{CH_3-CH_3} + 2NaI$$

ii) When ethyl iodide is treated with sodium in dry ether n-butane is obtained.

$$\underset{\text{Ethyl iodide}}{2C_2H_5I} + 2Na \xrightarrow{\text{Dry ether}} \underset{\text{n-Butane}}{C_2H_5-C_2H_5} + 2NaI$$

Limitations : i) Methane cannot be prepared.

ii) Alkanes containing odd no. of carbon atoms can't be prepared in good yields.

Q.29.Explain Wurtz's reaction with a mixture of different alkyl halides. OR

What is action of Na on a mixture of ethyl iodide and methyl iodide ?

Ans : When a mixture of two different alkyl halides is treated with Na in ether a mixture of higher alkanes is obtained, which is difficult to separate.

In this reaction higher alkanes containing even number of carbon atoms are predominantly formed.

Hence Wurtz reaction cannot be used to prepare higher alkanes containing odd number of carbon atoms.

e.g. Wurtz reaction with ethyl iodide and methyl iodide gives ethane, propane & butane (ethane and butane are major products).

$$\underset{\text{Methyl iodide}}{2CH_3I} + 2Na \xrightarrow{\text{Dry ether}} \underset{\text{Ethane}}{C_2H_6} + 2NaI$$

$$\underset{\text{Ethyl iodide}}{2C_2H_5I} + 2Na \xrightarrow{\text{Dry ether}} \underset{\text{n-Butane}}{C_4H_{10}} + 2NaI$$

$$\underset{\text{Methyl iodide}}{CH_3I} + \underset{\text{Ethyl iodide}}{C_2H_5I} + 2Na \xrightarrow{\text{Dry ether}} \underset{\text{Propane (minor)}}{C_3H_8} + 2NaI$$

Q.30. How will you convert :

i) Ethyl iodide into n-Butane

ii) Methyl iodide into ethane ? 2

3) By reduction of alkyl halide :

Q.31. How is ethane prepared from

a) Ethylene b) Methyl bromide

c) Ethyl iodide d) Acetylene 4

Ans: a) Ethylene upon catalytic hydrogenation (H_2 / Ni at 573K) give ethane.

$$\underset{\text{Ethylene}}{CH_2 = CH_2} + H_2 \xrightarrow[573\,K]{Ni} \underset{\text{Ethane}}{CH_3 - CH_3}$$

b) From methyl bromide by Wurtz synthesis:

$$\underset{\text{Methyl bromide}}{2CH_3Br} + 2Na \xrightarrow{\text{Dry ether}} \underset{\text{Ethane}}{C_2H_6} + 2NaBr$$

c) By reduction of ethyl iodide :

$$\underset{\text{Ethyl iodide}}{C_2H_5I} + 2[H] \xrightarrow{Zn/HCl} \underset{\text{Ethane}}{C_2H_6} + HI$$

d) From acetylene by catalytic hydrogenation.

$$\underset{\text{Acetylene}}{CH \equiv CH} + 2H_2 \xrightarrow[573\,K]{Ni} \underset{\text{Ethane}}{CH_3 - CH_3}$$

CHEMICAL PROPERTIES

i) Halogenation ii) Nitration

iii) Pyrolysis iv) Combustion

Substitution or replacement reaction :

The reaction in which an atom or a group of atoms is replaced by another atom or group is called substitution reaction .

Alkanes under go substitution reaction in which H - atom of alkane is replaced by another atom or group.

1) Halogenation of alkanes.

The reaction in which H-atom of alkane is replaced by a halogen atom is called as halogenation.

Q. 32 .Explain chlorination of methane. 3

Ans : Alkane reacts with halogen (Cl_2 or Br_2) in presence of diffused sunlight (UV light) or at high temperature (573 K - 773 K) to form halogen derivatives of alkanes.

In this reaction all the H-atoms of alkane are replaced one by one with halogen atoms.

e.g. Methane upon chlorination gives a mixture of methyl chloride, methylene dichloride, chloroform and carbon tetrachloride.

$$\underset{\text{Methane}}{CH_4} + Cl_2 \xrightarrow[\text{or UV light}]{\text{Diffused sun light}} \underset{\text{Methyl Chloride.}}{CH_3Cl} + HCl$$

$$\underset{\text{Methyl Chloride.}}{CH_3Cl} + Cl_2 \xrightarrow[\text{or UV light}]{\text{Diffused sun light}} \underset{\text{Methylene dichloride}}{CH_2Cl_2} + HCl$$

$$\underset{\text{Methylene dichloride}}{CH_2Cl_2} + Cl_2 \xrightarrow[\text{or UV light}]{\text{Diffused sun light}} \underset{\text{Chloroform}}{CHCl_3} + HCl$$

$$\underset{\text{Chloroform}}{CHCl_3} + Cl_2 \xrightarrow[\text{or UV light}]{\text{Diffused sun light}} \underset{\text{Carbon tetrachloride}}{CCl_4} + HCl$$

2) Nitration :

The reaction in which H-atom of alkane is replaced by a nitro group (-NO_2) is called nitration.

Q.33. Explain nitration of alkanes. 2

Ans : When alkanes are heated with nitric acid in vapour phase at 673 to 773 K, nitroalkanes are obtained.

e.g. When methane is treated with nitric acid in vapour phase at 723 K,nitromethane is obtained.

$$\underset{\text{Methane}}{CH_4} + \underset{\text{Nitric acid}}{HONO_2} \xrightarrow{773\,K} \underset{\text{Nitro methane}}{CH_3{-}NO_2} + H_2O$$

Q.34. Explain nitration of methane OR

. How will you convert methane into nitromethane. 1

Q.35.Explain nitration of ethane OR

How will you convert ethane into nitroethane. 1

Ans : When ethane is treated with nitric acid in vapour phase at 773 K, nitroethane is obtained.

$$\underset{\text{Ethane}}{C_2H_6} + \underset{\text{Nitric acid}}{HONO_2} \xrightarrow{773\,K} \underset{\text{Nitroethane}}{C_2H_5{-}NO_2} + H_2O.$$

Q.36. Explain nitration of propane.

OR What is the action of nitric acid on propane at high temperature? 2

Ans : Propane reacts with nitric acid in vapour phase at 773K to form a mixture of nitromethane, nitroethane, 1-nitropropane & 2-nitropropane.

$$CH_3CH_2CH_3 + HNO_3 \xrightarrow{773\,K} CH_3NO_2 + CH_3CH_2NO_2$$

nitro methane, nitro ethane

$$CH_3CH_2CH_2NO_2 + CH_3\underset{\underset{NO_2}{|}}{CH}CH_3 + H_2O$$

1-nitropropane; 2-nitropropane

N.B. Nitromethane and nitroethane are formed due to breakage of C-C bond in propane at high temperature.

3) Pyrolysis :

Q. 37. Explain pyrolysis.

Ans : *It is the thermal decomposition of alkanes in the absence of air to form smaller molecules.*

Pyrolysis takes place in two ways

a) Dehydrogenation : *It is the fission of C-H bonds in alkane to form alkene and H_2 gas.*

As hydrogen gas is lost the reaction is called dehydroganation.

$$CH_3CH_3 \xrightarrow{873\,K} CH_2=CH_2 + H_2\uparrow$$

Ethane → Ethylene

$$CH_3CH_2CH_3 \xrightarrow[K/SiO_2AlO_3]{873\ K} CH_3CH=CH_2 + H_2\uparrow$$

Propane → Propylene

b) Cracking : *It is the fission of C-C bond in alkanes to form a pair of alkane and alkene.*

e.g.Propane gives a pair of ethylene and methane.

$$CH_3CH_2CH_3 \rightarrow CH_2=CH_2 + CH_4$$

Q.38. What is the action of heat on

a) Ethane b) Propane

Ans : a) Ethane on pyrolysis gives a mixture of ethylene & H_2 gas

$$CH_3CH_3 \rightarrow CH_2=CH_2 + H_2 \text{ (dehydrogenation)}$$

Ethane → Ethylene

ii) Propane on pyrolysis gives a mixture of products. It undergoes dehydrogenation as well as cracking.

$$CH_3CH_2CH_3 \rightarrow CH_3CH=CH_2 + H_2\uparrow$$

Propane → Propylene

$$CH_3CH_2CH_3 \rightarrow CH_2=CH_2 + CH_4$$

Q.39. Explain catalytic cracking with suitable example. Give its advantages.

Ans : When n-butane is heated at 873 K it undergoes (88%) craking to give methane and propene 50 % and ethane and ethene 38 % and 12 % dehydrogenation.

$$CH_3CH_2CH_2CH_3 \xrightarrow[(SiO_2Al_2O_3)]{873\ K}$$

n - Butane

12% → $CH_3CH=CHCH_3 + H_2$ (but-2-ene)

873 K, $SiO_2Al_2O_3$

50% → $CH_3CH=CH_2 + CH_4$ (propene, methane)

38% → $CH_2=CH_2 + CH_3-CH_3$ (ethene, ethane)

Advantages :

a) It requires lower temperature and pressure.

b) It gives less amount of methane and carbon

4) Combustion :

Q.40.Explain combustion of alkanes.

Ans : When alkanes are heated in excess of air or oxygen, they burn readily to give CO_2 & H_2O. In this process large amount of heat is evolved.Thus reaction is highly exothermic. Combustion is complete oxidation of alkanes Hence alkanes are used as fuels.

e.g.i) $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O + 890\ kJ\ mol^{-1}$

ii) $C_2H_6 + 3.5O_2 \rightarrow 2CO_2 + 3H_2O + 1580\ kJ\ mol^{-1}$

Uses of Alkane :

Q.41.Give uses of alkanes 2

i) Methane is used for making carbon-black

which is used as black pigment in paints, printing ink, boot polish etc.

ii) Methane is used as a source of hydrogen gas.

iii) Methane is used in preparation of a organic compounds like
e.g. CH_3Cl, CH_3OH (methyl alcohol), HCHO(formaldehyde), C_2H_2 (acetylene)

iv) Propane is used as refrigerent i.e. cooling agent.

v) n-Butane and iso-Butane are liquified under high pressure under the name L.P.G. (liquified petroleum gas). It is used as domestic fuel.

vi) Petrol, is a mixture of liquid alkanes (iso- octane). It is used as fuel for internal combustion engines.

Q.42.Give the structural formulae and IUPAC names of isomers of a) hexane & b) heptane

Ans : a) Isomers of hexane

Hexane (C_6H_{14}) has five chain isomers

Structure **IUPAC name**

i) $CH_3CH_2CH_2CH_2CH_2CH_3$ Hexane
(Common name : n-Hexane)

ii) $CH_3CH(CH_3)CH_2CH_2CH_3$ 2-Methylpentane
(Common name : Isohexane)

iii) $CH_3CH_2CH(CH_3)CH_2CH_3$ 3-Methylpentane

iv) $CH_3CH(CH_3)CH(CH_3)CH_3$ 2,3-Dimethylbutane

v) $CH_3C(CH_3)_2CH_2CH_3$ 2,2-Dimethylbutane
(Common name : Neohexane)

b) Isomers of heptane

Heptane (C_7H_{16}) has nine chain isomers

i) $CH_3CH_2CH_2CH_2CH_2CH_2CH_3$ Heptane
(Common name : n- heptane)

ii) $CH_3CH(CH_3)CH_2CH_2CH_3$
2-Methylhexane
(Common name : Isoheptane)

iii) $CH_3CH_2CH(CH_3)CH_2CH_2CH_3$ 3-Methylhexane

iv) $CH_3CH_2CH_2C(CH_3)_2CH_3$ 2,2-Dimethylpentane
(Common name : Neoheptane)

v) $CH_3CH_2C(CH_3)_2CH_2CH_3$ 3,3-Dimethylpentane

vi) $CH_3CH_2CH(CH_3)CH(CH_3)CH_3$ 2,3-Dimethylpentane

vii) $CH_3CH(CH_3)CH_2CH(CH_3)CH_3$ 2,4-Dimethylpentane

viii) $CH_3C(CH_3)_2CH(CH_3)CH_3$ 2,2,3-Trimethylbutane

ix) $CH_3CH_2CH(C_2H_5)CH_2CH_3$ 3-Ethylpentane