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7.1 Introduction

From the ancient times, the minerals, plants and animals constitute the major important sources of naturally occurring substances. The compounds obtained from minerals i.e. from nonliving sources are called inorganic compounds. The compounds obtained from animals and plants i.e. from living sources are called organic compounds. Organic compounds are essential (vital) for sustaining the life on earth. During the ancient time it was believed that there was some vital force within the living beings which was needed for the formation of organic compound. In 1828, Friedrich Wohler a German scientist prepared organic compound urea from inorganic compound ammonium cyanate. So the ancient belief was rejected. Now 95% organic substances are synthesised by human beings.

gain four electrons. To achieve this, a very large amount of energy (ionisation enthalpy $\Delta_i H$ and electron gain enthalpy $\Delta_{eg} H$) is required. Consequently it cannot form C^{4+} or C^{4-} ion. However, the carbon atom shares four electrons with some elements and forms four covalent bonds.

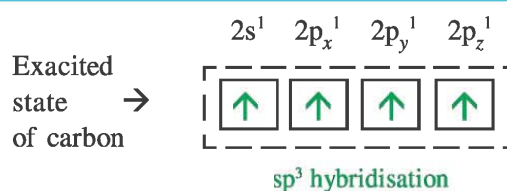
So generally the characteristic of carbon to form four covalent bonds is called tetravalency of carbon. To explain tetravalency of carbon, in its electronic configuration having two electrons in 2s orbital, one of its electron from 2s orbital gets excited and enters in empty $2p_z$ orbital. Hence, the electronic configuration of carbon in excited state is $1s^2, 2s^1, 2p_x^1, 2p_y^1, 2p_z^1$. In the excited state electronic configuration of carbon outermost orbit has all four electrons unpaired. These four electrons are in two different types of orbitals like s and p orbitals. If these unpaired electrons are to form four covalent bonds then four bonds which are formed cannot be considered equivalent. However, it has been experimentally established that the four bonds formed by carbon in the molecules like methane and carbon tetrachloride are equivalent. The equivalent character of these four bonds can be explained by the hybridisation of orbitals of these four unpaired electrons.

7.3 Hybridisation and Hybrid Orbitals

When in an atom there are different types of orbitals having very less energy difference, then such type of two or more than two orbitals combine and form same number of orbitals having similar shapes and energies which are known as hybrid orbitals and the process is known as hybridisation.

7.4 Hybridisation in Carbon Atom and

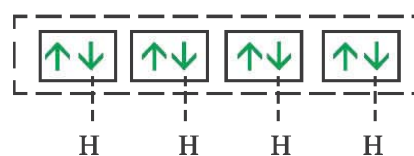
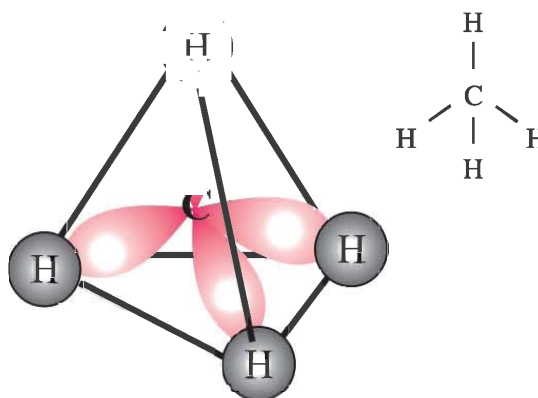
σ bond : As there is C–C single bond in compounds of alkane series, the sp^3 hybridisation taking place in them can be explained as follows: In the excited state of carbon having electronic arrangement in outermost orbital from which one 2s type and three 2p type of orbitals containing unpaired electrons combine and form four hybrid orbitals having equal energies and similar shape, it is known as sp^3 hybridisation.



The four hybrid orbitals having unpaired electrons of equal energy are arranged in tetrahedral shape having bond angle $109^\circ 28'$

7.4.1.1 Shape of methane molecule :

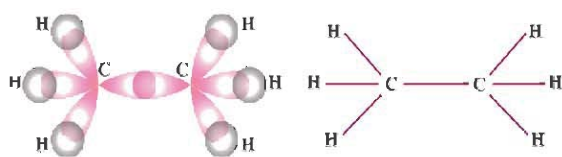
In methane (CH_4) molecule the carbon atom having four unpaired equivalent orbitals, obtained by sp^3 hybridisation are arranged in a tetrahedral shape. Here, the angle between any two adjacent hybrid orbital is $109^\circ 28'$. The four orbitals formed by sp^3 hybridisation of carbon atom which axially overlap with each of the four 1s orbital of four hydrogen atoms containing unpaired electrons with opposite spin to form four covalent bonds of equal energy strength. Thus, an axially overlapping bond formation by sharing of the electrons of two valence orbitals containing unpaired electrons with opposite spin is called σ bond. Hence, the shape of methane molecule is tetrahedral and the four C-H σ bonds have equal energy, the four C-H bonds have equal bond length of 112 pm and H - C - H bond angle is $109^\circ 28'$



7.4.1.2 Shape of ethane molecule :

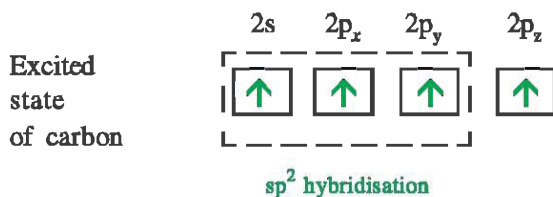
The molecular formula of ethane is C_2H_6 and its molecular structure is CH_3-CH_3 . One of the sp^3 hybrid orbital on each of two carbon

atoms overlap each other axially by sharing of the unpaired electrons to form σ bond. Remaining three sp^3 hybrid orbitals of both the carbon overlap with each of the three 1s orbital of three hydrogen atoms having unpaired electrons with opposite spin which results in total six C-H σ bonds. In ethane molecule the C-C and C - H bond lengths are 154 pm and 112 pm respectively and the bond angle is $109^\circ 28'$.



7.4.2 Shape of sp^2 hybrid orbitals and π bond :

The compounds of alkene series contain carbon-carbon double bond $>C=C<$ involving sp^2 hybridisation which can be explained as follows : The carbon atom in excited state electronic configuration of outermost, orbitals from which one orbital is of 2s type and two orbitals of 2p type i.e. total three orbitals combine and three orbitals having same shape and equal energy formed is known as sp^2 hybridisation. The unpaired electrons in three sp^2 hybrid orbitals have same energy but the $2p_z$ orbital having unpaired electron of carbon atom which has not participated in the formation of sp^2 hybridisation, whose energy is not same as those of the unpaired electrons of the sp^2 hybrid orbitals.

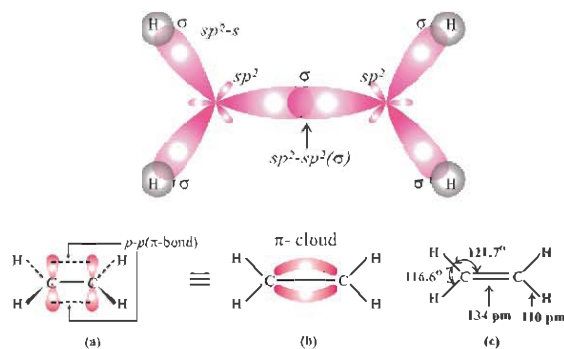


Three orbitals formed due to sp^2 hybridisation are arranged in a planar triangular shape. The angle between any two adjacent orbitals is 120° .

7.4.2.1 Shape of ethene molecule : The molecular formula of ethene is C_2H_4 and its molecular structure is $CH_2=CH_2$. In each carbon atom one orbital which is obtained by sp^2 hybridisation having unpaired electron with opposite spin overlap each other axially and form σ bond between two carbon atoms. Now, both the carbons have remaining two sp^2 hybrid orbitals on each carbon atom which overlap with each

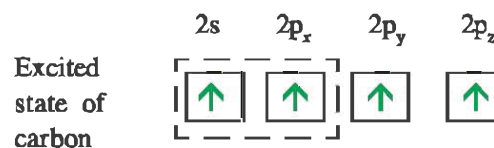
of the two 1s orbital of two hydrogen atoms having unpaired electron with opposite spin result in formation of total four C - H σ bond having equal energy. The four C - H bonds have equal bond length of 110 pm.

Further, both the carbon atoms have $2p_z$ orbital containing unpaired electron which had not participated in hybridisation. Now, due to sharing of these electrons with opposite spin a π bond is formed. Thus, in ethene molecule between two carbon atoms, one σ bond and another π bond i.e double bond is formed. In ethene molecule C = C bond length is 134 pm which is less than C-C bond length in ethane. The shape of ethene molecule is planar triangular and bond angle H-C-H is 116.6° and C-C-H is 121.7° .



7.4.3 Shape of sp -hybrid orbitals and π bond :

The compound of alkyne series contains carbon-carbon triple bond $-C\equiv C-$ involving sp hybridisation which can be explained as follows : A carbon atom in an excited state electronic configuration of outer most orbitals from which one orbital is of s type and one orbital is of 2p type. Hence, total two orbitals combine and form two orbitals having same shape and equal energy, these are known as sp hybrid orbitals and this phenomenon is known as sp hybridisation. The unpaired electrons in these two hybrid orbitals have same energy. Now, remaining $2p_y$ and $2p_z$ orbitals of carbon atom which have not participated in formation of sp hybridisation containing unpaired electrons whose energies are not the same as those of the unpaired electrons of the sp hybrid orbitals.

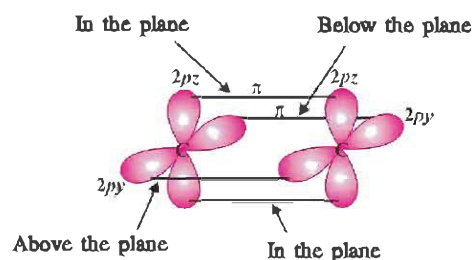
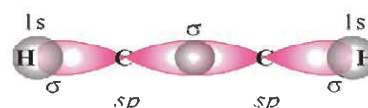


The two orbitals formed due to sp hybridisation are arranged linearly and bond angle between them is 180° .

7.4.3.1 Shape of ethyne molecule :

The molecular formula of ethyne molecule is C_2H_2 and its molecular structure is $HC\equiv CH$. In each carbon atom orbital which is obtained by sp hybridisation having unpaired electron overlap axially with opposite spin and form σ bond between two carbon atoms. Now both the carbon atoms have remaining one sp hybrid orbital on each carbon atom overlap with $1s$ orbital of hydrogen atom having unpaired electron with opposite spins result in formation of two C-H σ bond having equal energy and equal bond length.

Further, both the carbon atoms have $2p_y$ and $2p_z$ orbitals containing unpaired electron which have not participated in hybridisation. These unpaired electron orbitals when spin becomes opposite to each other sharing of electrons results in two π bond formation. Thus in ethyne molecule between two carbon atoms one σ bond and two π bonds i.e triple bond is formed having bond length 120 pm which is less than $>C=C<$ bond length in ethene. The shape of ethyne molecule is linear and bond angle is 180° .



Shape of ethyne molecule

7.5 Functional Groups

An atom or group of atoms that determines the characteristic reaction of an organic compound is known as functional group. In alkane hydrocarbons due to their saturation they do not contain functional group for their characteristic reaction. The different compounds have the same functional group under similar reactions. Some of the functional groups responsible for their chemical reactions are given in table 7.1.

Table 7.1 Classification of some functional groups

Class of compound	Functional group	IUPAC group prefix/suffix	Structural Formula	IUPAC Name
Alkane	R-H	-/ane	$CH_3 - CH_3$ $CH_3 - CH_2 - CH_3$ $CH_3 - CH_2 - CH_2 - CH_3$	Ethane Propane Butane
Alkene	$\begin{array}{c} \diagup \\ C=C \\ \diagdown \end{array}$	-/ene	$CH_2 = CH_2$ $CH_3 - CH = CH_2$ $CH_3 - CH_2 - CH = CH_2$ $CH_3 - CH = CH - CH_3$	Ethene Propene But-1-ene But-2-ene
Alkyne	$-C \equiv C-$	-/yne	$HC \equiv CH$ $CH_3 - C \equiv CH$ $CH_3 - CH_2 - C \equiv CH$ $CH_3 - C \equiv C - CH_3$	Ethyne Propyne But-1-yne But-2-yne
Halide	-X (-F, -Cl, -Br, -I)	halo/-	$CH_3 - CH_2 - CH_2 - Cl$ $CH_3 - \underset{\substack{ \\ Cl}}{CH} - CH_3$ $CH_3 - \underset{\substack{ \\ Cl}}{CH} - CH_2 - CH_2 - CH_3$	1-Chloropropane 2-Chloropropane 1-Chloropentane

Alcohol	-OH	-/ ol	CH ₃ OH CH ₃ CH ₂ OH CH ₃ CH ₂ CH ₂ OH CH ₃ CHCH ₃ OH	Methanol Ethanol Propan-1-ol Propan-2-ol
Ether	-O-	alkoxy / -	CH ₃ -O- CH ₃ CH ₃ -O- CH ₂ CH ₃ CH ₃ - CH ₂ -O-CH ₂ -CH ₃	Methoxy methane Methoxy ethane Ethoxy ethane
Aldehyde	-CHO	-/ al	HCHO CH ₃ CHO CH ₃ CH ₂ CHO	Methanal Ethanal Propanal
Ketone	-CO-	-/ one	CH ₃ COCH ₃ CH ₃ COCH ₂ CH ₃ CH ₃ CH ₂ COCH ₂ CH ₃	Propanone Butan-2-one Pentan-3-one
Carboxylic acid	-COOH	-/ oic Acid	HCOOH CH ₃ COOH CH ₃ CH ₂ COOH	Methanoic acid Ethanoic acid Propanoic acid
Ester	-COOR	-/ oate	HCOOCH ₃ CH ₃ COOCH ₃ CH ₃ COOCH ₂ CH ₃	Methyl methanoate Methyl ethanoate Ethyl ethanoate
Amide	-CONH ₂	-/ amide	CH ₃ CONH ₂ CH ₃ CH ₂ CONH ₂	Ethanamide Propanamide
Amine	-NH ₂	(1 ^o)-/ amine (Primary)	CH ₃ NH ₂ CH ₃ CH ₂ NH ₂ CH ₃ CH ₂ CH ₂ NH ₂ CH ₃ CH CH ₃ NH ₂	Methanamine Ethanamine Propan-1-amine Propan-2-amine
	-NH-	(2 ^o)-/ amine (Secondary)	CH ₃ NHCH ₃ CH ₃ CH ₂ NHCH ₃	N-methyl methanamine N-methyl ethanamine

	$\overset{ }{-N-}$	(3 ^o)-/ amine (Tertiary)	$\begin{array}{c} \text{CH}_3 \\ \\ \text{CH}_3 - \text{N} - \text{CH}_2 \text{CH}_2 \text{CH}_3 \end{array}$	N-N dimethyl ethanamine
			$\begin{array}{c} \text{CH}_3 \\ \\ \text{CH}_3\text{NCH}_3 \end{array}$	N-N dimethyl methanamine
Nitro	NO ₂	nitro/-	CH ₃ CH ₂ NO ₂	Nitroethane
			CH ₃ CH ₂ CH ₂ NO ₂	1-Nitropropane
			$\begin{array}{c} \text{CH}_3\text{CHCH}_3 \\ \\ \text{NO}_2 \end{array}$	2-Nitropropane
Cynide OR Nitrile	-C≡N	-/ nitrile	CH ₃ CN	Ethane nitrile
			CH ₃ CH ₂ CN	Propane nitrile
			CH ₃ CH ₂ CH ₂ CN	Butane nitrile

7.6 Homologous Series

A series of organic compounds having same functional group in which two successive members differ from each other by fixed number of carbon and hydrogen (CH₂). Such series of organic compounds is known as homologous series. Almost all types of organic compounds form homologous series and they have similar chemical characteristics e.g. CH₄, C₂H₆, C₃H₈ etc.

7.6.1 Characteristics of Homologous series :

- The elements and functional group present in compound of a homologous series are same.
- Each member of the series can be expressed by common molecular formula. For example, each member of alkane series can be indicated by a common formula C_nH_{2n+2}.
- The difference between the molecular formula of two successive members of the series will be of CH₂.
- The difference between the molecular weights of two successive members of a series will be of 14 amu (u).
- The name of each member of a series begins either with a common prefix or suffix.
- The chemical reactions of each member of series are same if the functional group present in them is same and their methods of preparation are also the same.
- As the number of carbon and hydrogen atoms increase with member of a given series the molecular mass of the members increases. Hence there will be gradual change in the properties of the members which depend upon their molecular mass which include

boiling point, melting point, density, solubility etc. The characteristics of homologous series of alkane compounds are given in table 7.2.

Table 7.2 Characteristics of homologous series of alkanes

Name of Alkane	Molecular formula	Molecular mass gram mol ⁻¹	Melting point K	Boiling point K	State
Methane	CH ₄	16	91	109	gas
Ethane	C ₂ H ₆	30	87	184	gas
Propane	C ₃ H ₈	44	83	231	gas
Butane	C ₄ H ₁₀	58	135	272.5	gas
Pentane	C ₅ H ₁₂	72	143	309	gas, liquid

7.7 Isomerism

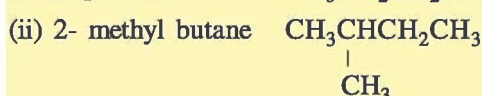
The organic compounds having the same molecular formula but different structural formula are called isomers. This phenomenon is called isomerism. The isomerism has been classified mainly in two types depending upon their differences in structural aspects :

- structural isomerism
- stereo isomerism.

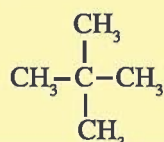
7.7.1 Structural Isomerism : Structural isomerism is a result of different arrangements of atoms or groups of atoms in molecules of organic compounds having same molecular formula. Hence, the organic compounds having same molecular formula but different structures are called structural isomers and the phenomenon is structural isomerism. There are five different types of structural isomerism :

(1) Skeletal or chain isomerism (2) Position isomerism (3) Functional group isomerism (4) Metamerism (5) Tautomerism.

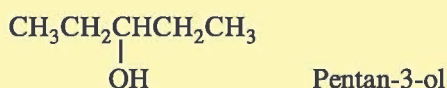
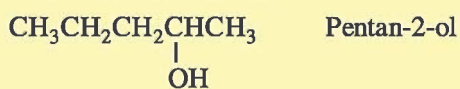
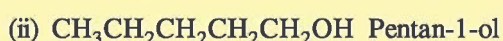
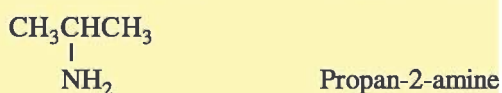
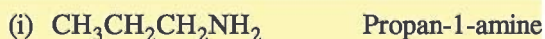
(1) Skeletal or chain isomerism : The organic compounds having same molecular formula but arrangement of carbon atoms in a linear or branch are different; such type of isomerism is called chain isomerism. Methane, ethane and propane do not exhibit chain isomerism but butane has two isomers. Pentane has three isomers, hexane has five isomers. For example three isomers of pentane are given below.



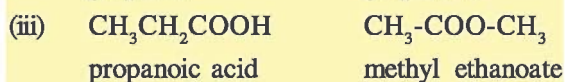
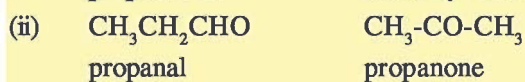
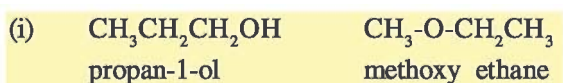
(iii) 2,2-dimethyl propane



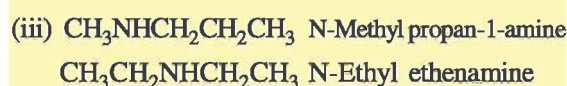
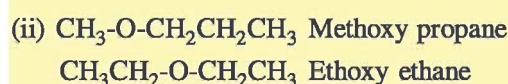
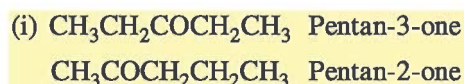
(2) Position isomerism : Organic compounds have same molecular formula and similar carbon chain but differ in the position of functional group. This type of isomerism is called position isomerism. For example



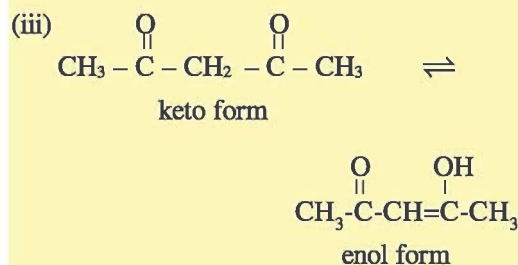
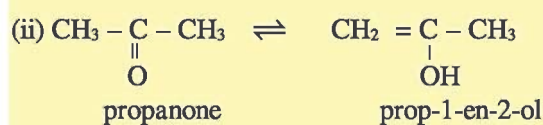
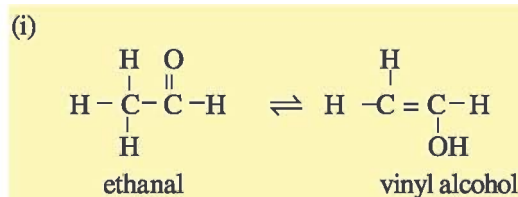
(3) Functional group isomerism : The organic compounds having the same molecular formula but different functional groups are called functional group isomers and this phenomenon is called functional group isomerism; for example.



(4) Metamerism : The organic compounds having same molecular formula and same functional group but different number of carbon in alkyl group on either side of the functional group are called metamers and such isomerism is called metamerism. This type of isomerism is shown by ethers, ketones and amines. For example.



(5) Tautomerism : The organic compounds having same molecular formula but isomers differ in the arrangement of atoms and are in dynamic equilibrium with each other are called tautomers and this phenomenon is called tautomerism. For example



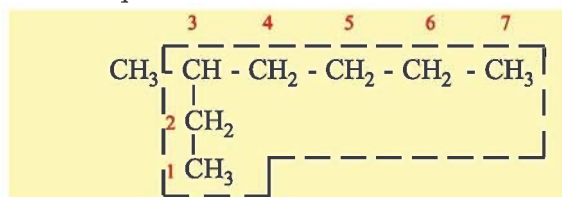
In structure of organic compounds having keto form and enol form in dynamic equilibrium with each other is known as keto-enol tautomerism.

7.8 Nomenclature of Organic Compounds

About a century ago a few number of organic compounds were known. At that time the naming of compounds was done as per their properties, structures or their origin. During the first half of the 20th century many types of

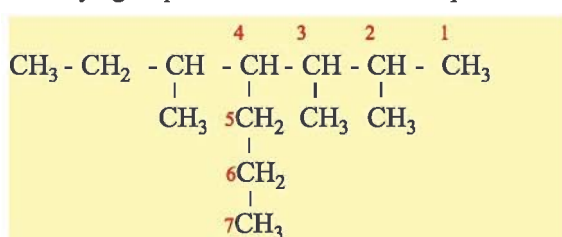
organic compounds were synthesised, hence, the nomenclature by old pattern became impossible. Besides that the nomenclature of an organic compound should be such that the structure of a newly synthesised compound can be understood by all the chemists. So, in 1889, a committee was formed by International Chemical Congress for laying down definite rules for nomenclature. The report of this committee submitted, in 1892, at Geneva was inadequate. So based on that, in 1930, International Union of Pure and Applied Chemistry presented a more meaningful account. After the naming of organic compounds was over, a committee formed in 1947, recommended various types of rules. The nomenclature done by these rules is known today as IUPAC (International Union of Pure and Applied Chemistry) system. The changes in rules take place from time to time. The IUPAC nomenclature rules in order are given below :

(1) To determine the longest carbon chain. Select the longest continuous chain of carbon atoms in given structure of organic compound. For example.

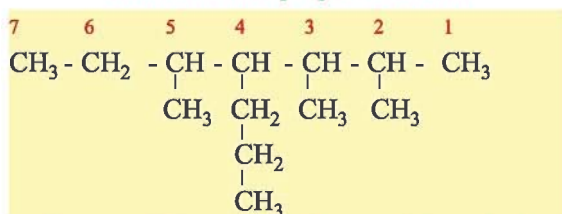


In this structure, the longest chain of carbons is seven and so original hydrocarbon will be heptane.

If in a given organic compound, the two different chains but of equal length are possible, the chain with maximum number of side branch or alkyl groups is selected. For example



Longest chain at 7-carbon total branch - 3
So this is not proper selection

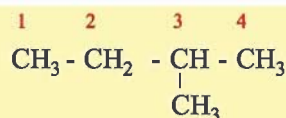


longest chain at 7 carbon total branch 4
so this is proper selection.

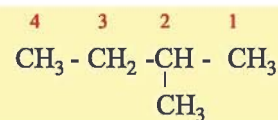
(2) To determine the position of substituted group :

(i) Position of mono substituted group :

The carbon atoms of longest chain, the number given from the end which gives lower number to the carbon atoms carrying the substituent i.e. branch starts as early as possible. For example

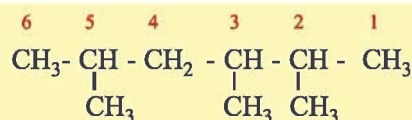


If carbon numbering of chain starts from left side end then branched carbon gets 3 number
(incorrect method)

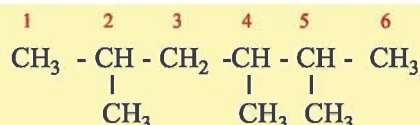


If numbering at carbon chain starts from right side end then branched carbon gets 2 number (correct method)

(ii) Lowest set of locants : When two or more substituents are present in a given carbon chain, then number is given to the chain in such a way so that substituent gets the lowest set of locants which is known as the lowest set of locants. For example

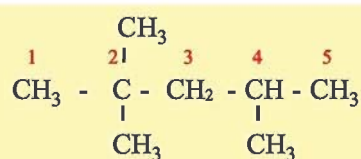


sets of locant 2,3,5 (correct method)

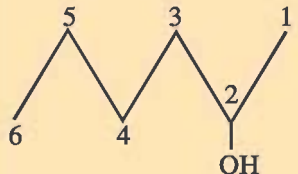

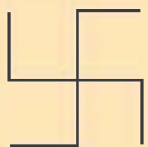
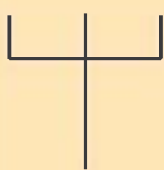
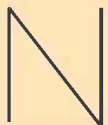

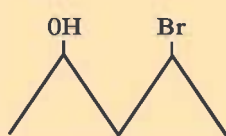


sets of locant 2,4,5 (incorrect method)

Here, the first locant number is 2-2 in both; hence comparing second locant 3-4, 3 is lower number of locant so the the first structure having locant 2, 3, 5, is the correct method of numbering while 2, 4, 5 numbering is incorrect method.



(set of locant 2,2,4) (correct method)

Bond-line structure	Complete structural formula
	$\overset{6}{\text{CH}_3} - \overset{5}{\text{CH}_2} - \overset{4}{\text{CH}_2} - \overset{3}{\text{CH}_2} - \overset{2}{\underset{\text{OH}}{\text{CH}}} - \overset{1}{\text{CH}_3}$ Hexan-2-ol
	$\overset{8}{\text{CH}_3} \overset{7}{\text{CH}_2} \overset{6}{\text{CH}_2} - \overset{5}{\text{CH}_2} - \overset{4}{\text{CH}} = \overset{3}{\text{CH}} - \overset{2}{\underset{\text{Br}}{\text{CH}}} - \overset{1}{\text{CH}_3}$ 2-bromo oct-3-ene
	$\overset{1}{\text{CH}_3} - \overset{2}{\text{CH}_2} - \overset{3}{\underset{\text{CH}_2\text{-CH}_3}{\overset{\text{CH}_2\text{-CH}_3}{\text{C}}} - \overset{4}{\text{CH}_2} - \overset{5}{\text{CH}_3}$ 3,3-diethyl pentane
	$\overset{1}{\text{CH}_3} - \overset{2}{\text{CH}_2} - \overset{3}{\underset{\text{CH}_3}{\overset{\text{CH}_3}{\text{C}}} - \overset{4}{\text{CH}_2} - \overset{5}{\text{CH}_3}$ 3,3-dimethyl pentane
	$\text{CH}_3 \text{ CH}_2 \text{ CH}_2 - \text{CH}_3$ Butane
	$\overset{1}{\text{CH}_3} - \overset{2}{\underset{\text{CH}_3}{\text{CH}}} - \overset{3}{\text{CH}_2} - \overset{4}{\underset{\text{CH}_3}{\text{CH}}} - \overset{5}{\text{CH}_3}$ 2,4-dimethyl pentane
	$\overset{1}{\text{CH}_3} - \overset{2}{\underset{\text{OH}}{\text{CH}}} - \overset{3}{\text{CH}_2} - \overset{4}{\underset{\text{Br}}{\text{CH}}} - \overset{5}{\text{CH}_3}$ 4-bromopentan-2-ol

IUPAC names of some structural formula

Structural formula	IUPAC Name
$\text{CH}_3 - \underset{\text{CH}_3}{\text{CH}} - \underset{\text{CH}_3}{\text{CH}} - \text{CH}_2 - \text{CHO}$	3,4-dimethyl pentanal
$\text{CH}_2 = \text{CHCH}_2 \underset{\text{CH}_3}{\text{CH}} - \text{CH}_3$	4-methyl pent-1-ene
$\text{CH}_2 = \text{CHCH}_2 \underset{\text{NH}_2}{\text{CH}} \text{CH}_3$	pent-4-en-2-amine

$\begin{array}{c} \text{CH}_3 \\ \\ \text{CH} \equiv \text{CCHCH}_2\text{C}(\text{O})\text{CH}_3 \end{array}$	4- methyl hex-5-yn-2-one
$\begin{array}{c} \text{CH}_3-\text{CH}-\text{CH}-\text{CHCH}_2\text{COOH} \\ \quad \quad \\ \text{Br} \quad \text{Br} \quad \text{CH}_2\text{CH}_3 \end{array}$	4,5-dibromo-3-ethyl hexanoic acid
	5- bromo-1-nitrononan-2-one

7.9 Common and IUPAC Nomenclature of Organic Compounds

The common and IUPAC nomenclature of organic compounds based on functional groups are given in table 7.3.

Table 7.3 Common and IUPAC names based on functional group

Type of compound	Functional group	Structure	Common name	IUPAC name
Alkene	$\begin{array}{c} \quad \\ -\text{C} = \text{C}- \end{array}$	$\text{CH}_2 = \text{CH}_2$	ethylene	ethene
		$\text{CH}_3\text{CH} = \text{CH}_2$	propylene	propene
		$\text{CH}_3\text{CH}_2\text{CH} = \text{CH}_2$	Butylene	but-1-ene
		$\text{CH}_3\text{CH} = \text{CHCH}_3$	2-butylene	but -2-ene
Halide	-X	$\text{CH}_3\text{CH}_2\text{Cl}$	ethyl chloride	chloro ethane
		$\text{CH}_3\text{CH}_2\text{CH}_2\text{Cl}$	propyl chloride	1-chloro propane
Alcohol	-OH	$\text{CH}_3\text{CH}_2\text{OH}$	ethyl alcohol	ethanol
		$\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$	propyl alcohol	propan-1-ol
Ether	-O-	$\text{CH}_3\text{-O-CH}_3$	dimethyl ether	methoxy methane
		$\text{CH}_3\text{-O-CH}_2\text{-CH}_3$	ethyl methyl ether	methoxy ethane
		$\text{CH}_3\text{CH}_2\text{-O-CH}_2\text{-CH}_3$	diethyl ether	ethoxy ethane
Aldehyde	-CHO	HCHO	formaldehyde	methanal
		CH_3CHO	acetaldehyde	ethanal
Ketone	$\begin{array}{c} -\text{CO} \\ \end{array}$	CH_3COCH_3	acetone or dimethyl ketone	propanone
		$\text{CH}_3\text{COCH}_2\text{CH}_3$	ethyl methyl ketone	butan -2-one
Carboxylic acid	-COOH	HCOOH	formic acid	methanoic acid
		CH_3COOH	acetic acid	ethanoic acid

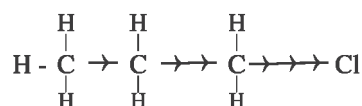
Amide	-CONH ₂	HCONH ₂ CH ₃ CONH ₂	formamide acetamide	methanamide ethanamide
Amine	-NH ₂ (1°)	CH ₃ NH ₂ CH ₃ CH ₂ NH ₂ CH ₃ CH ₂ -CH-CH ₃ NH ₂	methyl amine ethyl amine 2-butyl amine	methanamine ethanamine butan -2- amine
	-NH- (2°)	CH ₃ NH CH ₃ CH ₃ NH CH ₂ CH ₃	dimethyl amine ethyl methyl amine	N-methyl methanamine N-methyl ethanamine
	$\begin{array}{c} \\ -N- \\ \\ (3^\circ) \end{array}$	(CH ₃) ₃ N (CH ₃) ₂ NCH ₂ CH ₃ $\begin{array}{c} \text{CH}_2\text{CH}_3 \\ \\ \text{CH}_3 - \text{N} - \text{CH}_2\text{CH}_3 \end{array}$	trimethylamine ethyl dimethyl amine diethyl methyl amine	N, N-dimethyl methamine N, N-dimethyl ethanamine N- methyl-N- ethyl ethanamine
Nitro	-NO ₂	CH ₃ NO ₂ CH ₃ CH ₂ NO ₂ CH ₃ CH ₂ CH ₂ NO ₂ $\begin{array}{c} \text{CH}_3 \quad \text{CH} \quad \text{CH}_3 \\ \\ \text{NO}_2 \end{array}$	nitromethane nitroethane nitropropane 2- nitropropane	nitromethane nitroethane 1- nitropropane 2- nitropropane
Cynide/ Nitrile	-CN	CH ₃ CN CH ₃ CH ₂ CN CH ₃ CH ₂ CH ₂ CN	methyl cynide ethyl cynide propyl cyanide	ethane nitrile propane nitrile butane nitrile
Ester	-COOR	HCOOCH ₃ CH ₃ COOCH ₃ CH ₃ COOCH ₂ CH ₃	methyl formate methyl acetate ethyl acetate	methyl methanoate methyl ethanoate ethyl ethanoate
Acid anhydride	$\begin{array}{c} \diagup \\ \text{C}=\text{O} \\ \\ \text{O} \\ \\ \text{C}=\text{O} \\ \diagdown \end{array}$	$\begin{array}{c} \text{O} \quad \text{O} \\ \quad \\ \text{CH}_3 - \text{C} - \text{O} - \text{C} - \text{CH}_3 \end{array}$ $\begin{array}{c} \text{O} \quad \text{O} \\ \quad \\ \text{H} - \text{C} - \text{O} - \text{C} - \text{H} \end{array}$	acetic anhydride formic anyhydride	ethanoic anhydride methanoic anhydride

7.10 Electronic Displacement (Substitution) in Covalent Bond

Organic compounds contain mostly covalent bond. Hence the substitution of hydrogen atom or of functional group with or without electron pair takes place in different ways. Four types of electronic displacement are generally noticed in the mechanism of organic reactions.

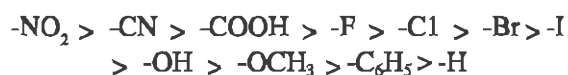
7.10.1 (1) Inductive effect : In organic compound if a carbon atom is covalently bonded to an atom of higher electronegativity (like halogen)

the bond becomes polar due to large difference in electronegativities and the polar effect of this spreads over the carbon atoms arranged in the chain. This effect is called an inductive effect (I- effect). It is shown by \rightarrow sign. For example, in propyl chloride (1-chloropropane) this effect is shown as under : Inductive effect is the permanent effect.



We know that chlorine is more electronegative than carbon. Due to large electronegativity of chlorine atom the electron pair which is shared between C-Cl, is displaced towards chlorine atom. As a result of this, chlorine atom acquires a partial negative charge (δ^-) and carbon atom acquires a partial positive charge (δ^+). This displacement is however not limited to C-Cl bond but is transmitted to other carbon atom along the chain. This effect goes on decreasing on moving from near carbon to farther carbon from chlorine atom generally after three carbon. From fourth carbon this effect becomes negligible. For comparing the relative effect hydrogen atom is taken as a standard and the atoms or groups can be classified into two categories.

(i) Negative I effect (-I effect) : Atoms or group of atoms having electron attraction capacity more than that of hydrogen are referred to as (electron attracting) atoms or electron negative (-I) effect For example :



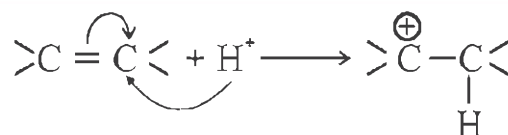
(ii) Positive I effect (+I effect) : Atoms or group of atoms having less electron attracting power than that of hydrogen are referred to as a (electron repelling) atom or positive I effect (+I effect). For example



7.10.2 Electromeric effect : An electron pair bonded between two atoms with more than one bond shifts to a more electronegative atom in presence of a reagent depending upon its characteristics. This effect is termed as electromeric (E-effect) effect. For example, electron pair of double bond between carbon group >C=O present in aldehydes and ketone shift to the original atom which is more electronegative when comes in contact with a reagent having higher electronegative charge. This effect is termed as an electromeric effect. This effect is due to the presence of reagent so it is a temporary effect.

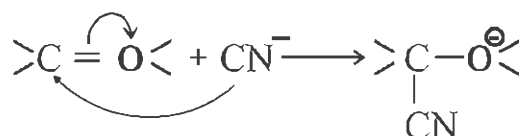
Electromeric effect can be classified into two categories :

(i) Positive electromeric effect (+E effect) : When the transfer of electrons takes place towards the attacking reagent, it is called positive electromeric effect. For example,



(ii) Negative electromeric effect (-E effect) :

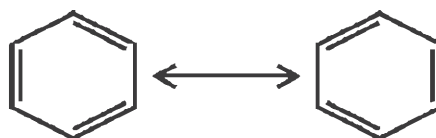
When the transfer of electron takes place away from the attacking reagent, it is called negative electromeric effect (-E effect). For example



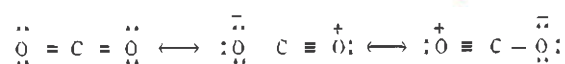
7.10.3 Resonance or Mesomeric effect :

A molecule of some organic compound can be represented by two or more electronic structures, however, all of its properties cannot be explained by a single structure. The actual structure is represented by an intermediate stage between two or among more electronic structures. These structures are called resonance or mesomeric structures and the resulting characteristic is known as resonance or mesomeric effect. Resonance effect is shown by a symbol \leftrightarrow . For example

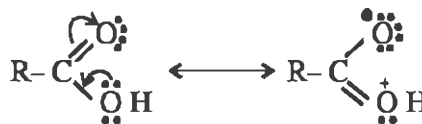
Two resonance structures of benzene :



Three resonance structures of CO_2 :

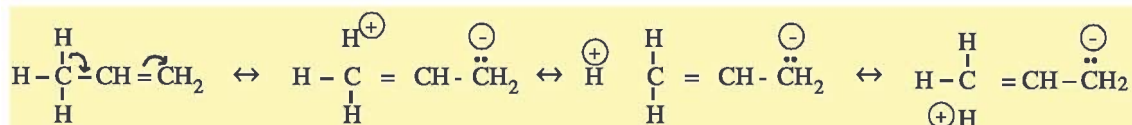


Two resonance structures of carboxylic acid :



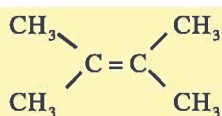
7.10.4 Hyperconjugation : In some organic compounds when a C-C single bond is aligned with C=C double bond or attached to a benzene ring, the electron pair of the σ bond between C-H single bond is attracted towards the double bond. This effect is termed as hyperconjugation. If an alkyl group carrying at least one hydrogen atom is attached to an unsaturated carbon atom, it releases electrons of carbon hydrogen single bond (σ bond) toward the double bond. For example, hyperconjugation in propene is shown below :

Hyperconjugation in propene



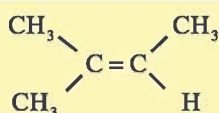
The hyperconjugation is very useful in explaining stabilities of some organic molecules. For example

(i) The order of stability for $-\text{CH}_3$ substituted alkene as given below :



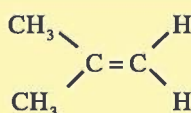
2,3-dimethyl but-2-ene

Structure - I



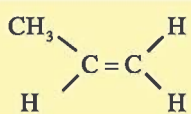
2-methyl but-2-ene

Structure - II



2-methyl propene

Structure - III



Propene

Structure - IV

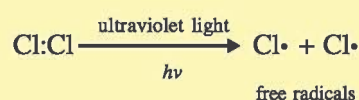
Hence, the structure I has 12 hyperconjugation C-H bond in structure II 9 C-H σ bond and hence structure I has more C-H σ bond so the hyperconjugation effect being more which makes it more stable. Same way structure III has 6 C-H σ bond and structure IV has only 3 C-H σ bonds, hence the descending order of stability can be explained.

- (ii) The stability of carbocation and free radicals can be explained by hyperconjugation.
- (iii) Shortening of carbon-carbon single bond adjacent to carbon having $\text{C}=\text{C}$ double bond or $-\text{C}\equiv\text{C}-$ triple bond is also explained by hyperconjugation.

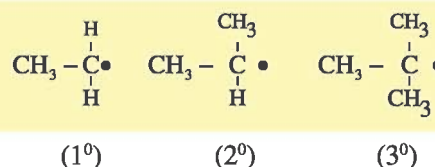
7.11 Fission of Covalent Bond

The fission of covalent bond can occur in two ways.

(1) **Homolytic fission** : A covalent bond is formed by sharing of two electrons between same two electronegative atoms then during fission of that covalent bond both atoms separated by gaining one-one electron each is called homolytic fission. The atoms separated in this way possessing unpaired electron are called free radicals. These free radicals have unpaired electrons so they have strong tendency to pair the electrons. Hence, they are very reactive and have a very short life.

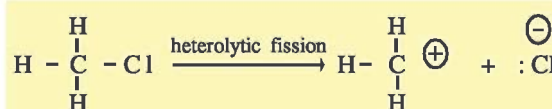


Alkyl free radicals are classified into three categories : primary (1°) secondary (2°) and tertiary (3°). For example



The order of stability for free radical is CH_3 , $1^\circ < 2^\circ < 3^\circ$ which can be explained by hyperconjugation

(2) **Heterolytic fission** : A covalent bond is formed by sharing of two electrons between two different electronegative atoms then during fission of that covalent bond more electronegative atom acquires shared electrons paired and less electronegative atom has shortage of electron and such fission is known as heterolytic fission. The atoms get two electrons resulting into negative (-ve) ion and atoms having shortage of electron results into positive (+ve) ion; so heterolytic fission results into +ve and -ve ions. For example,



Hence, the breaking of C-Cl covalent bond in which chlorine atom is more electronegative compared to carbon atom results into shared electron pair with chlorine atom as (Cl⁻) ion while carbon atom has shortage of electron which results into CH₃⁺ positive ion.

7.12 Electrophile, Nucleophile, Carbocation or Carbonium Ion, Carbanion

Electrophile : The part of positive charge (positive ion) obtained during a heterolytic fission or some neutral molecules having capacity to accept pair of electrons are called electrophiles. Electrophiles are also called Lewis acid. For example

+ve ions : ⁺NO₂, Cl⁺, ⁺SO₃H, ⁺CH₃, CH₃⁺CO, H⁺, H₃O⁺ etc.

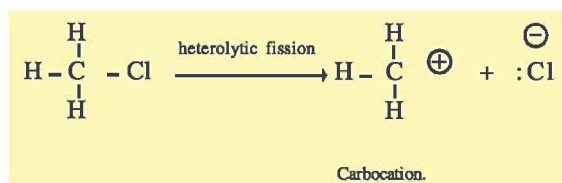
Neutral molecules : AlCl₃, BF₃, SO₃ etc.

Nucleophile : The part of negative charge (negative ions) obtained during heterolytic fission or some neutral molecules having capacity to donate electron pair are called nucleophiles. Nucleophiles are also called Lewis base. For example

-ve ions : ⁻X, ⁻OH, ⁻CN, ⁻NH₂ etc.

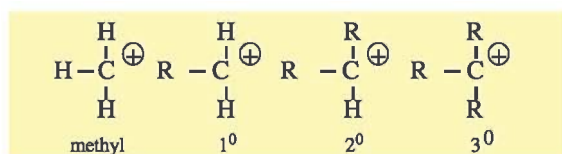
Neutral molecules : NH₃, H₂O, ROH, R-O-R, R₃N, R₂NH etc.

Carbocation or carbonium ion : A group having several atoms in which a carbon atom has six electrons and consequently has positive charge is called a carbocation or carbonium ion. It is highly reactive and is very short lived. For example.



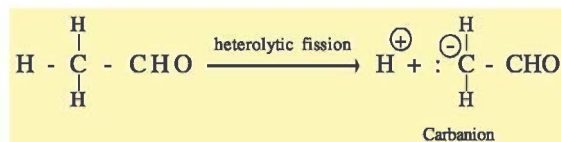
Carbocations are classified into three categories: primary (1^o), secondary (2^o) tertiary (3^o)

When a positively charged carbon atom is directly attached to one, two or three carbons such carbocation is called Primary (1^o), Secondary (2^o) and Tertiary (3^o) respectively for example,



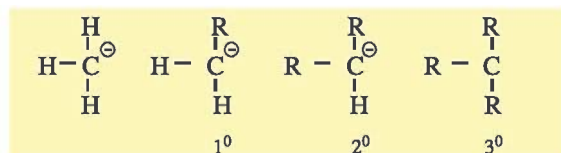
Now methyl (alkyl) group has (+I-effect) positive inductive effect. So alkyl group attached to positively charged carbon atom tends to release electrons towards carbon. As a result it decreases the +ve charge on the carbon atom but itself becomes positively charged so the positive charge on carbon atom gets dispersed. Therefore, more the number of alkyl groups, the greater will be the dispersion of charges decreasing the positive charge of carbon and stability of carbon (carbocation) increases. Thus the order of stability for carbocation is ⁺CH₃ < 1^o < 2^o < 3^o.

Carbanion : A group of atoms in which a carbon atom has eight electrons and hence has a negative charge, such a group is called carbanion. It is highly active and is very short lived. For example



Carbanions are classified into three categories as primary (1^o), secondary (2^o) and tertiary (3^o)

When a negatively charged carbon atom is directly attached to one, two or three alkyl groups are called primary (1^o), secondary (2^o) and tertiary (3^o) respectively. For example

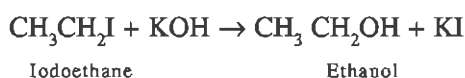
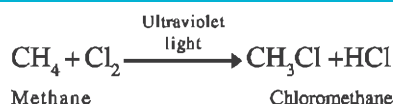


Now alkyl group has positive inductive effect (+I effect); alkyl group has electron releasing tendency, and therefore, increases the electron density on the negatively charged carbon atom and hence stability decreases; more the number of alkyl groups attached to the negatively charged carbon atom greater will be the electron density on the carbon atom and lower will be its stability. So the order of stability for carbanion is ⁻CH₃ > 1^o > 2^o > 3^o.

7.13 Main Types of Organic Reactions

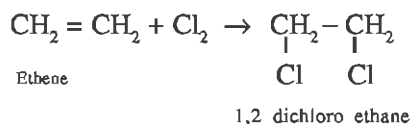
There are four main types of organic reactions :

(1) Substitution reaction : An atom or group of atom in an organic compound is substituted by different atoms or group of atoms in a reaction is called substitution reaction. For example,



In the above reactions the H of methane is substituted by -Cl and -I of iodoethane is substituted by -OH functional group.

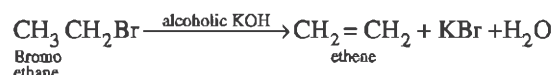
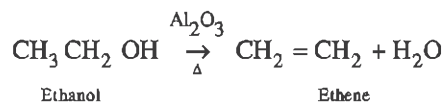
(2) Addition reaction : During a chemical reaction with a molecule containing a double bond or a triple bond, if the π bond of the double or a triple bond breaks and a new organic compound is formed by addition of another molecule, the reaction is called addition reaction. In this type of reaction two molecules are reacted to form a product having single molecule. For example



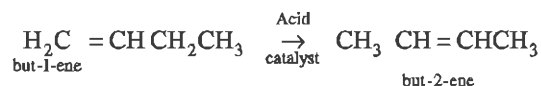
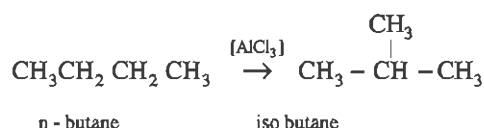
Here, the π bond breaks and chlorine molecule is added and the product formed is 1,2 dichloro ethane.

(3) Elimination reaction : In an organic reaction, atom or group of atoms is removed from adjacent carbon atom resulting in the

formation of additional new bond between two carbon atoms, the reaction is called elimination reaction. This reaction is also known as β -elimination reaction. For example.



(4) Rearrangement reaction : In a molecule of organic compound the migration of atom or group of atoms to another position takes place within the same molecule under suitable conditions, the reaction is called rearrangement reaction. For example,




SUMMARY

Organic chemistry is in fact the science of hydrocarbons formed by carbon and hydrogen. The compounds of several types are obtained by the substitution of hydrogen in them. It also gives the information of tetravalency of carbon and structures of organic molecules.

The information about the shapes of molecules of alkane, alkene and alkyne formed by sp^3 , sp^2 and sp hybridisation in carbon can be obtained. It also gives information about σ and π bonds. Homologous series and the study of its characteristics are useful in understanding the properties of compounds. IUPAC nomenclature can be carried out by the study of isomerism and detailed information about its types and obtaining their complete structural formulas and also the information about the nomenclature of compounds or information about structure from nomenclature suggested by IUPAC. The inductive effect, electromeric effect, mesomeric effect and hyperconjugation are useful for the study of stability of certain organic molecules and ions as well as the study of chemical reactions. The free radicals produced during homolytic and heterolytic fission of organic compounds containing covalent bond provides explanation of electrophilic and nucleophilic reagents. There are four main types of organic reactions which can be understood by many reactions.

EXERCISE

1. Select the proper choice from the given multiple choices :

- (1) But-1-ene molecule carbon has which type of hybridisation ?
 (A) sp^3 (B) sp^2
 (C) sp^3 and sp^2 (D) sp
- (2) Pent-2-yne has how many σ and π bonds ?
 (A) 10 σ , 2 π (B) 12 σ , 2 π
 (C) 15 σ , 2 π (D) 13 σ , 3 π
- (3) Which molecule has longest carbon chain ?
 (A) Neopentane (B) Isopentene
 (C) Neohexane (D) N-pentane
- (4) The IUPAC nomenclature of  is
 (A) 2,3-dimethyl 7-bromo octane (B) 2-bromo-5,6-dimethyl octane
 (C) 2-bromo 6,7-dimethyl octane (D) 1-bromo-5,6-dimethyl heptane
- (5) How many structural isomers of hexane are there ?
 (A) 6 (B) 5
 (C) 4 (D) 9
- (6) Which type of product is obtained by heterolytic fission?
 (A) Electrophile (B) Nucleophile
 (C) Carbonium ion (D) All
- (7) Which of the following is a nucleophile ?
 (A) ROH (B) CH_3CN
 (C) CH_3NH_2 (D) all
- (8) Which free radical is the most stable ?
 (A) $RCH_2\cdot$ (B) $R_2CH\cdot$
 (C) $R_3C\cdot$ (D) $CH_3\cdot$
- (9) Which molecule has the least C-C distance ?
 (A) C_2H_6 (B) C_2H_4
 (C) C_2H_2 (D) C_4H_8
- (10) In which molecule all the carbon atoms have same type of hybridisation ?
 (A) ethyne (B) propene
 (C) prop-1-yne (D) but-2-ene
- (11) During the addition reaction of ethene which type of change in hybridisation of carbon atom takes place ?
 (A) sp^2 to sp^3 (B) sp^3 to sp^2
 (C) sp to sp^3 (D) sp^3 to sp
- (12) $CH_3CONH_2 \xrightarrow{P_2O_5} CH_3CN$; during this reaction which type of change occurs in hybridisation of carbonyl carbon ?
 (A) sp^3 to sp^2 (B) sp^2 to sp^3
 (C) sp^2 to sp (D) sp to sp^2

- (13) Ethanal and vinyl alcohol are examples of which isomerism ?
(A) Metamerism (B) Tautomerism
(C) Position isomerism (D) Functional group isomerism
- (14) In which type of reaction a new π bond is added between two carbon atoms ?
(A) Substitution (B) Addition
(C) Elimination (D) Rearrangement

2. Write the answers of the following questions in short :

- (1) What is hybridisation ?
- (2) Mention bond angle and shape of methane molecule.
- (3) Mention bond length and hybridisation of ethane molecule.
- (4) Write examples of functional group isomerism.
- (5) Draw structures for isomers of butane.
- (6) Draw isomers of compound having formula C_3H_6O .
- (7) Draw isomers of compound having formula $C_4H_{10}O$
- (8) Write two examples having -I effect.
- (9) Draw resonance structure of CO_2 .
- (10) What is free radical ?

3. Write answers of the following questions :

- (1) Which belief was rejected by Wohler ? Give example.
- (2) What is an inductive effect ? Explain.
- (3) What is an electromeric effect ? Explain.
- (4) Explain hyperconjugation in propene.
- (5) What is homolytic fission ? Explain.
- (6) Explain carbonium ion and carbanion.

4. Write the answers of the following questions :

- (1) Explain with proper example shapes of sp^2 hybridised orbitals and π -bonds.
- (2) What is homologous series ? Mention its characteristics.
- (3) Mention the types of structural isomerism and explain in brief.
- (4) Explain the methods of fission of electron in covalent bonds.
- (5) Explain types of organic reactions.
- (6) Write IUPAC names :
 - (1) $CH_3CH_2CH_2CONH_2$
 - (2) $CH_3CH_2OCH_2CH_3$
 - (3) $CH_3CH_2CH_2COOCH_3$
 - (4) $CH_3CH_2CH_2CH_2CN$
 - (5) $CH_3CH=CH-C\equiv C-CH_2OH$

APPENDIX -1

Atomic Number and Molar Mass of Elements

Element	Symbol	Atomic Number	Molar mass(g mol ⁻¹)
Actinium	Ac	89	227.03
Aluminium	Al	13	26.98
Americium	Am	95	(243)
Antimony	Sb	51	121.75
Argon	Ar	18	39.95
Arsenic	As	33	74.92
Astatine	At	85	210
Barium	Ba	56	137.34
Berkelium	Bk	97	(247)
Beryllium	Be	4	9.01
Bismuth	Bi	83	208.98
Bohrium	Bh	107	(264)
Boron	B	5	10.81
Bromine	Br	35	79.91
Cadmium	Cd	48	112.40
Caesium	Cs	55	132.91
Calcium	Ca	20	40.08
Californium	Cf	98	251.08
Carbon	C	6	12.01
Cerium	Ce	58	140.12
Chlorine	Cl	17	35.45
Chromium	Cr	24	52.00
Cobalt	Co	27	58.93
Copper	Cu	29	63.54
Curium	Cm	96	247.07
Dubnium	Db	105	(263)
Dysprosium	Dy	66	162.50

Element	Symbol	Atomic Number	Molar mass(g mol ⁻¹)
Einsteinium	Es	99	(252)
Erbium	Er	68	167.26
Europium	Eu	63	151.96
Fermium	Fm	100	(257.10)
Fluorine	F	9	19.00
Francium	Fr	87	(223)
Gadolinium	Gd	64	157.25
Gallium	Ga	31	69.72
Germanium	Ge	32	72.61
Gold	Au	79	196.97
Hafnium	Hf	72	178.49
Hassium	Hs	108	(269)
Helium	He	2	4.00
Holmium	Ho	67	164.93
Hydrogen	H	1	1.0079
Indium	In	49	114.82
Iodine	I	53	126.90
Iridium	Ir	77	192.2
Iron	Fe	26	55.85
Krypton	Kr	36	83.80
Lanthanum	La	57	138.91
Lawrencium	Lr	103	(262.1)
Lead	Pb	82	207.19
Lithium	Li	3	6.94
Lutetium	Lu	71	174.96
Magnesium	Mg	12	24.31
Manganese	Mn	25	54.94

Element	Symbol	Atomic Number	Molar mass(g mol ⁻¹)	Element	Symbol	Atomic Number	Molar mass(g mol ⁻¹)
Meitneium	Mt	109	(268)	Samarium	Sm	62	150.35
Mendelevium	Md	101	258.10	Scandium	Sc	21	44.96
Mercury	Hg	80	200.59	Seaborgium	Sg	106	(266)
Molybdenum	Mo	42	95.94	Selenium	Se	34	78.96
Neodymium	Nd	60	144.24	Silicon	Si	14	28.08
Neon	Ne	10	20.18	Silver	Ag	47	107.87
Neptunium	Np	93	(237.05)	Sodium	Na	11	22.99
Nickel	Ni	28	58.71	Strontium	Sr	38	87.62
Niobium	Nb	41	92.91	Sulphur	S	16	32.06
Nitrogen	N	7	14.0067	Tantalum	Ta	73	180.95
Nobelium	No	102	(259)	Technetium	Tc	43	(98.91)
Osmium	Os	76	190.2	Tellurium	Te	52	127.60
Oxygen	O	8	16.00	Terbium	Tb	65	158.92
Palladium	Pd	46	106.4	Thallium	Tl	81	204.37
Phosphorus	P	15	30.97	Thorium	Th	90	232.04
Platinum	Pt	78	195.09	Thulium	Tm	69	168.93
Plutonium	Pu	94	(244)	Tin	Sn	50	118.69
Polonium	Po	84	210	Titanium	Ti	22	47.88
Potassium	K	19	39.10	Tungsten	W	74	183.85
Praseodymium	Pr	59	140.91	Ununbium	Uub	112	(277)
Promethium	Pm	61	(145)	Ununnilium	Uun	110	(269)
Protactinium	Pa	91	231.04	Unununium	Uuu	111	(272)
Radium	Ra	88	(226)	Uranium	U	92	238.03
Radon	Rn	86	(222)	Vanadium	V	23	50.94
Rhenium	Re	75	186.2	Xenon	Xe	54	131.30
Rhodium	Rh	45	102.91	Ytterbium	Yb	70	173.04
Rubidium	Rb	37	85.47	Yttrium	Y	39	88.91
Ruthenium	Ru	44	101.07	Zinc	Zn	30	65.37
Rutherfordium	Rf	104	(261)	Zirconium	Zr	40	91.22

The value given in parenthesis is the molar mass of the isotope of highest known half life

APPENDIX -2

Electronic Configuration of Elements

Element	Atomic Number	Electronic Configuration
H	1	1s ¹
He	2	1s ²
Li	3	[He] 2s ¹
Be	4	[He] 2s ²
B	5	[He] 2s ² 2p ¹
C	6	[He] 2s ² 2p ²
N	7	[He] 2s ² 2p ³
O	8	[He] 2s ² 2p ⁴
F	9	[He] 2s ² 2p ⁵
Ne	10	[He] 2s ² 2p ⁶
Na	11	[Ne] 3s ¹
Mg	12	[Ne] 3s ²
Al	13	[Ne] 3s ² 3p ¹
Si	14	[Ne] 3s ² 3p ²
P	15	[Ne] 3s ² 3p ³
S	16	[Ne] 3s ² 3p ⁴
Cl	17	[Ne] 3s ² 3p ⁵
Ar	18	[Ne] 3s ² 3p ⁶
K	19	[Ar] 4s ¹
Ca	20	[Ar] 4s ²
Sc	21	[Ar] 3d ¹ 4s ²
Ti	22	[Ar] 3d ² 4s ²
V	23	[Ar] 3d ³ 4s ²
*Cr	24	[Ar] 3d ⁵ 4s ¹
Mn	25	[Ar] 3d ⁵ 4s ²
Fe	26	[Ar] 3d ⁶ 4s ²

Element	Atomic Number	Electronic Configuration
Co	27	[Ar] 3d ⁷ 4s ²
Ni	28	[Ar] 3d ⁸ 4s ²
*Cu	29	[Ar] 3d ¹⁰ 4s ¹
Zn	30	[Ar] 3d ¹⁰ 4s ²
Ga	31	[Ar] 3d ¹⁰ 4s ² 4p ¹
Ge	32	[Ar] 3d ¹⁰ 4s ² 4p ²
As	33	[Ar] 3d ¹⁰ 4s ² 4p ³
Se	34	[Ar] 3d ¹⁰ 4s ² 4p ⁴
Br	35	[Ar] 3d ¹⁰ 4s ² 4p ⁵
Kr	36	[Ar] 3d ¹⁰ 4s ² 4p ⁶
Rb	37	[Kr] 5s ¹
Sr	38	[Kr] 5s ²
Y	39	[Kr] 4d ¹ 5s ²
Zr	40	[Kr] 4d ² 5s ²
Nb	41	[Kr] 4d ³ 5s ²
*Mo	42	[Kr] 4d ⁵ 5s ¹
Tc	43	[Kr] 4d ⁵ 5s ²
Ru	44	[Kr] 4d ⁶ 5s ²
Rh	45	[Kr] 4d ⁷ 5s ²
Pd	46	[Kr] 4d ⁸ 5s ²
*Ag	47	[Kr] 4d ¹⁰ 5s ¹
Cd	48	[Kr] 4d ¹⁰ 5s ²
In	49	[Kr] 4d ¹⁰ 5s ² 5p ¹
Sn	50	[Kr] 4d ¹⁰ 5s ² 5p ²
Sb	51	[Kr] 4d ¹⁰ 5s ² 5p ³
Te	52	[Kr] 4d ¹⁰ 5s ² 5p ⁴

Element	Atomic Number	Electronic Configuration
I	53	[Kr] 4d ¹⁰ 5s ² 5p ⁵
Xe	54	[Kr] 4d ¹⁰ 5s ² 5p ⁶
Cs	55	[Xe] 6s ¹
Ba	56	[Xe] 6s ²
*La	57	[Xe] 5d ¹ 6s ²
*Ce	58	[Xe] 4f ² 6s ²
Pr	59	[Xe] 4f ³ 6s ²
Nd	60	[Xe] 4f ⁴ 6s ²
Pm	61	[Xe] 4f ⁵ 6s ²
Sm	62	[Xe] 4f ⁶ 6s ²
Eu	63	[Xe] 4f ⁷ 6s ²
*Gd	64	[Xe] 4f ⁷ 5d ¹ 6s ²
Tb	65	[Xe] 4f ⁹ 6s ²
Dy	66	[Xe] 4f ¹⁰ 6s ²
Ho	67	[Xe] 4f ¹¹ 6s ²
Er	68	[Xe] 4f ¹² 6s ²
Tm	69	[Xe] 4f ¹³ 6s ²
Yb	70	[Xe] 4f ¹⁴ 6s ²
Lu	71	[Xe] 4f ¹⁴ 5d ¹ 6s ²
Hf	72	[Xe] 4f ¹⁴ 5d ² 6s ²
Ta	73	[Xe] 4f ¹⁴ 5d ³ 6s ²
*W	74	[Xe] 4f ¹⁴ 5d ⁵ 6s ¹
Re	75	[Xe] 4f ¹⁴ 5d ⁵ 6s ²
Os	76	[Xe] 4f ¹⁴ 5d ⁶ 6s ²
Ir	77	[Xe] 4f ¹⁴ 5d ⁷ 6s ²
*Pt	78	[Xe] 4f ¹⁴ 5d ⁹ 6s ¹
*Au	79	[Xe] 4f ¹⁴ 5d ¹⁰ 6s ¹
Hg	80	[Xe] 4f ¹⁴ 5d ¹⁰ 6s ²
Tl	81	[Xe] 4f ¹⁴ 5d ¹⁰ 6s ² 6p ¹

Element	Atomic Number	Electronic Configuration
Pb	82	[Xe] 4f ¹⁴ 5d ¹⁰ 6s ² 6p ²
Bi	83	[Xe] 4f ¹⁴ 5d ¹⁰ 6s ² 6p ³
Po	84	[Xe] 4f ¹⁴ 5d ¹⁰ 6s ² 6p ⁴
At	85	[Xe] 4f ¹⁴ 5d ¹⁰ 6s ² 6p ⁵
Rn	86	[Xe] 4f ¹⁴ 5d ¹⁰ 6s ² 6p ⁶
Fr	87	[Rn] 7s ¹
Ra	88	[Rn] 7s ²
Ac	89	[Rn] 6d ¹ 7s ²
Th	90	[Rn] 6d ² 7s ²
Pa	91	[Rn] 5f ² 6d ¹ 7s ²
U	92	[Rn] 5f ³ 6d ¹ 7s ²
Np	93	[Rn] 5f ⁴ 6d ¹ 7s ²
Pu	94	[Rn] 5f ⁶ 7s ²
Am	95	[Rn] 5f ⁷ 7s ²
Cm	96	[Rn] 5f ⁷ 6d ¹ 7s ²
Bk	97	[Rn] 5f ⁸ 6d ¹ 7s ²
Cf	98	[Rn] 5f ¹⁰ 7s ²
Es	99	[Rn] 5f ¹¹ 7s ²
Fm	100	[Rn] 5f ¹² 7s ²
Md	101	[Rn] 5f ¹³ 7s ²
No	102	[Rn] 5f ¹⁴ 7s ²
Lr	103	[Rn] 5f ¹⁴ 6d ¹ 7s ²
Rf	104	[Rn] 5f ¹⁴ 6d ² 7s ²
Db	105	[Rn] 5f ¹⁴ 6d ³ 7s ²
Sg	106	[Rn] 5f ¹⁴ 6d ⁴ 7s ²
Bh	107	[Rn] 5f ¹⁴ 6d ⁵ 7s ²
Hs	108	[Rn] 5f ¹⁴ 6d ⁶ 7s ²
Mt	109	[Rn] 5f ¹⁴ 6d ⁷ 7s ²

* Elements having exceptional electronic configuration

APPENDIX -3

Physical Constants

Quantity	Symbol	Traditional Units	SI Units
Acceleration of gravity	g	980.6 cm s ⁻¹	9.806 m s ⁻¹
Atomic mass unit (1/12 th of the mass of ¹² C atom)	amu or u	1.6606 × 10 ⁻²⁴ g	1.6606 × 10 ⁻²⁷ kg
Avogadro constant	N _A	6.022 × 10 ²³ particles mol ⁻¹	6.022 × 10 ²³ particles mol ⁻¹
Bohr radius	a ₀	0.52918 Å	5.2918 × 10 ⁻¹¹ m 5.2918 × 10 ⁻⁹ cm
Boltzmann constant	k	1.3807 × 10 ⁻¹⁶ erg K ⁻¹	1.3807 × 10 ⁻²³ J K ⁻¹
Charge-to-mass ratio of electron	e / m	1.7588 × 10 ⁸ coulomb g ⁻¹	1.7588 × 10 ¹¹ C kg ⁻¹
Electronic charge	e	1.60219 × 10 ⁻¹⁹ coulomb 4.8033 × 10 ⁻¹⁹ esu	1.60219 × 10 ⁻¹⁹ C
Electron rest mass	m _e	9.10952 × 10 ⁻²⁸ g 0.00054859 u	9.10952 × 10 ⁻³¹ kg
Faraday constant	F	36,487 coulombs eq ⁻¹ 23.06 kcalvolt ⁻¹ eq ⁻¹	96,487 C (mol e ⁻) ⁻¹ 36,487 J V ⁻¹ .(mol e ⁻) ⁻¹
Gas constant	R	0.8206 Latmmol ⁻¹ K ⁻¹ 1.987 calmol ⁻¹ K ⁻¹	8.3145 kPa dm ³ mol ⁻¹ K ⁻¹ 8.3145 J mol ⁻¹ K ⁻¹
Molar volume (STP)	V _m	22.710981 L mol ⁻¹	22.710981 × 10 ⁻³ m ³ mol ⁻¹ 22.710981 dm ³ mol ⁻¹
Neutron rest mass	m _n	1.67495 × 10 ⁻²⁴ g 1.008665 u	1.67495 × 10 ⁻²⁷ kg
Planck constant	h	6.6262 × 10 ⁻²⁷ ergs	6.6262 × 10 ⁻³⁴ J s
Proton rest mass	m _p	1.6726 × 10 ⁻²⁴ g 1.007277 u	1.6726 × 10 ⁻²⁷ kg
Rydberg constant	R	3.089 × 10 ¹⁵ cycles s ⁻¹ 2.1799 × 10 ⁻¹¹ erg	1.0974 × 10 ⁷ m ⁻¹ 2.1799 × 10 ⁻¹⁸ J
Speed of light (in vacuum)	c	2.9979 × 10 ¹⁰ cm s ⁻¹ (186,281 mile second ⁻¹)	2.9979 × 10 ⁸ m s ⁻¹

$$\pi = 3.1416 \quad 2.303 R = 4.576 \text{ cal mol}^{-1} \quad K = 19.15 \text{ J mol}^{-1} \text{ K}^{-1}$$

$$e = 2.71828 \quad 2.303 RT \text{ (at } 25^{\circ}\text{C)} - 1364 \text{ cal mol}^{-1} = 5709 \text{ J mol}^{-1}$$

$$\ln X = 2.303 \log X$$

APPENDIX - 4

Some Useful Conversion Factors

Common Units of Mass and Weight

- 1 pound = 453.59 grams**
 1 pound = 453.59 grams = 0.45359 kilogram
 1 kilogram = 1000 grams = 2.205 pounds
 1 gram = 10 decigrams = 100 centigrams
 = 1000 milligrams
 1 gram = 6.022×10^{23} atomic mass units or u
 1 atomic mass units = 1.6606×10^{-24} gram
 1 metric ton = 1000 kilograms
 = 2205 pounds

Common Unit of Volume

- 1 quart = 0.9463 litre**
1 litre = 1.056 quarts

 1 litre = 1 cubic decimetre = 1000 cubic centimetres = 0.001 cubic metre
 1 millilitre = 1 cubic centimetre = 0.001 litre
 = 1.056×10^{-3} quart
 1 cubic foot = 28.316 litres = 29.902 quarts
 = 7.475 gallons

Common Units of Energy

- 1 joule = 1×10^7 ergs**
 1 thermochemical calorie
 = 4.184 joules
 = 4.184×10^7 ergs
 = 4.129×10^{-2} litre-atmosphere
 = 2.612×10^{-19} electron volts
 1 erg = 1×10^{-7} joule = 2.3901×10^{-8} calorie
 1 electron volt = 1.6022×10^{-19} joule
 = 1.6022×10^{-12} erg
 = 96.487 kJ/mol

- 1 litre-atmosphere = 24.217 calories
 = 101.32 joules
 = 1.0132×10^9 ergs
 1 British Thermal Unit = 1055.06 joules
 = 1.05506×10^{10} ergs
 = 252.2 calories

Common Units of Length

- 1 inch = 2.54 centimetres (exactly)**
 1 mile = 5280 feet = 1.609 kilometres
 1 yard = 36 inches = 0.9144 metre
 1 metre = 100 centimetres = 39.37 inches
 = 3.281 feet
 = 1.094 yards
 1 kilometre = 1000 metres = 1094 yards
 = 0.6215 mile
 1 angstrom = 1.0×10^{-8} centimetre
 = 0.10 nanometre
 = 1.0×10^{-10} metre
 = 3.937×10^{-9} inch

Common Units of Force* and Pressure

- 1 atmosphere = 760 millimetres of mercury
 = 1.013×10^5 pascal
 = 14.70 pounds per square inch
 1 bar = 10^5 pascals
 1 torr = 1 millimetre of mercury
 1 pascal = $1 \text{ kg/ms}^2 = 1 \text{ N/m}^2$

Temperature SI Base Unit: Kelvin (K)

- K = -273.15°C
 K = $^\circ\text{C} + 273.15$
 $^\circ\text{F} = 1.8(^\circ\text{C}) + 32$

APPENDIX - 5

Nobel Prize Winners of 21st century (chemistry)

Year	Scientist	Birth place (Birth date)	Place of work	Research work
2001	K. Barry Sharpless	USA (28-04-1941)	USA	Study on chirality Catalysed hydrohination reactions
	Ryoji Noyori	Japan (03-09-1938)	Japan	
	William S. Knowles	USA (01-06-1917)	USA	
2002	John B. Fenn	USA (15-6-1917)	USA	Development of Nuclear Magnetic Resonance spectroscopy for determining the three-dimensional structure of biological macromolecules in solution
	Koichi Tanaka	Japan (3-8-1959)	Japan	
	Kurt Wuthrich	Switzerland (4-10-1938)	USA	
2003	Peter Agre	USA (30-1-1949)	USA	Discovery of Water channels (transport of water and ions from cell membrane)
	Roderick Mackinnon	USA (19-2-1956)		
2004	Aaron Ciechanover	Israel (1-10-1947)	Israel	Discovery of degradation of Ubiquitin Mediated protein
	Avram Hershko	Hungary (31-12-1937)	Israel	
	Irwin Rose	USA (16-7-1926)	USA	
2005	Yves Chauvin	France (10-10-1930)	France	Development of the metathesis method in organic synthesis
	Robert H. Grubbs	USA (27-2-1942)	USA	
	Richard R. Schrock	USA (4-1-1945)	USA	
2006	Roger D. Kornberg	USA (26-4-1947)	USA	Studies of mechanism and control of the eukaryotic transcription
2007	Gerhard Ertl	Germany (10-10-1936)	Germany	Studies of the chemical processes on solid surfaces
2008	Osamu Shimomura	Japan (1928)	USA	Discovery and development of the Green Fluorescent Protein
	Martin Chalfie	USA (1947)	USA	
	Roger Y. Tsien	USA (1-2-1952)	USA	
2009	Venkatraman Rama krishnan	India(Tamilnadu)(1952)	UK	Studies of the Structure and Function of the Ribosome
	Thomas A. Steitz	USA (23-8-1940)	USA	
	Ada E. Yonath	Isreal (22-6-1939)	Israel	

